Universitat de Girona
Escola Politècnica Superior

Treball final de grau

Estudi: Grau en Enginyeria Mecànica

Títol: Actualització i millora d’un banc d’assaigs de motors tèrmics.

Document: 1. Memòria i annexos

Alumne: Adrià Pérez Muriel

Tutor: Martí Comamala Laguna
Departament: Enginyeria mecànica i de la construcció industrial
Àrea: Màquines i motors tèrmics

Convocatòria (mes/any): Juny 2024

ÍNDEX

1. INTRODUCCIÓ

1.1 Antecedents

1.1.1 Peticionari

La petició del projecte es realitza a càrrec del grup de recerca GREFEMA (Grup de Recerca en Energia, Fluids i Medi Ambient), a través del professor Martí Comamala Laguna, situat al carrer de la Universitat de Girona, 4 del Campus Montilivi a la ciutat de Girona (17003).

1.1.2 Estat actual

Al laboratori de Motors Tèrmics de l’Escola Politècnica Superior de Girona fa anys que s’hi realitzen pràctiques i també investigació en un banc de proves de motor tèrmic. El banc de proves no està suficientment instrumentat ni automatitzat per realitzar una investigació moderna d’acord a les exigències de prestacions i emissions contaminants que actualment es demanen als motors de combustió interna alternatius (MCIA).

El banc de proves actual consisteix en un banc d’assaig amb fre dinamomètric instrumentat amb un sistema de control i d’adquisició de dades del model SP4 de la marca SportDevices, sensors termoparell de tipus K, una cèl·lula de càrrega, un sensor d’efecte Hall per mesurar les revolucions del motor i una tovera per mesurar el flux d’aire que entra al motor. Es disposa també de diferents sensors amb connexió directa a la centraleta electrònica del motor, tals com el sensor de posició de cigonyal, de posició de l’arbre de lleves, sensor de pressió d’aire absoluta, una sonda lambda amb controlador, un sensor de posició de l’accelerador i una estació meteorològica amb connexió USB a ordinador. Per altra banda, hi ha instal·lat un petit servomotor que permet modificar la càrrega de l’accelerador a partir d’una palanca manual. Es disposa també per a l’adquisició de dades del software informàtic *SportDyno v4.0*.

L’estat de la sala de proves amb caràcter previ a la realització del projecte es mostra a continuació a la *Figura 1.*

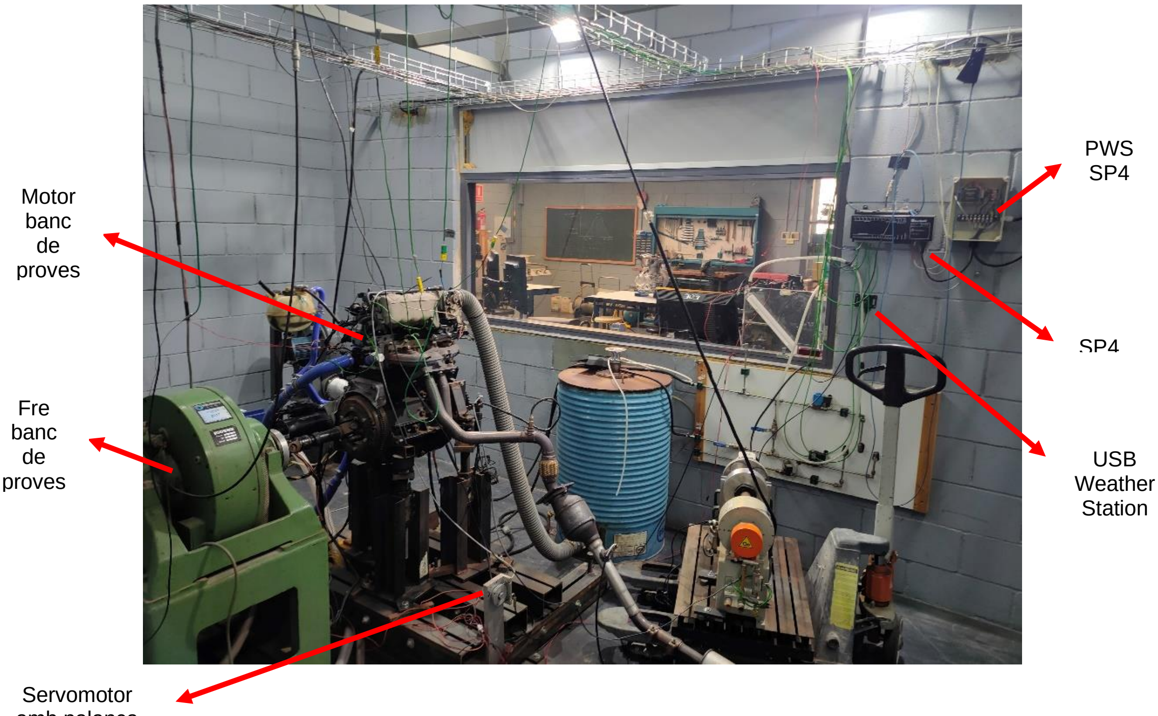


Figura 1. Estat actual de la sala de proves.

1.2 Objecte del projecte

L'objecte del projecte és l'actualització i millora del banc de proves existent per tal de rendibilitzar al màxim les tasques de docència dels diferents estudis que ofereix l'Escola Politècnica Superior de la Universitat de Girona i les tasques d'investigació del grup de recerca GREFEMA.

Els objectius de millora i actualització del banc d'assaigs es centren en els aspectes següents:

- Instal·lació d'un nou sistema de control del banc de proves i d'adquisició de senyals.
- Implementació de cicles de prova tipus WLTP o cicles específics *"on demand"*.
- Adquisició de dades d'elements específics del motor.
- Integració en l'adquisició de dades de paràmetres del motors fins ara independents.

- Implementació d’un nou software de control del banc de proves i d’adquisició de dades.

- Compatibilitat del sistema de control i adquisició nou amb el sistema existent.

1.3 Especificacions i abast

1.3.1 Especificacions

Els requeriments que han de satisfer l’execució del present projecte i de mutu acord entre peticionari i projectista es detallen a continuació a la *Taula 1*:

Tema	Descripció
Sistema de control i adquisició de dades	Instal·lació d'un nou sistema de control del banc de proves i d'adquisició de senyals.
Software	Implementació d'un software a l'ordinador per al control del banc de proves i visualització de les dades recollides.
Sensors	Implementació d'una sonda lambda per a la mesura de la relació aire-combustible.
Sensors	Implementació d'un sensor de massa d'aire aspirada.
Sensors	Instal·lació d'un sensor de contingut d'etanol per a la mesura de la composició del combustible.
Actuador	Implementació d'un servomotor per a la realització de cicles de prova.
Instrumentació	Implementació d'un oscil·loscopi amb connexió a ordinador.
Compatibilitat	El nou sistema ha de ser compatible amb el sistema existent. Cal garantir que els sensors i l'actuador instal·lats es puguin connectar i desconnectar d’ambdós sistemes àgilment.
Connexions	Els cables de la xarxa elèctrica han d'estar separats dels sensors per evitar l'adquisició de senyals errònies.

Taula 1. Requeriments del projecte.

1.3.2 Abast del projecte

Per tal de complir amb els objectius del projecte, aquest comprendrà tant la fase d'elecció dels components de millora del banc de proves, així com la seva instal·lació, calibratge i la posterior posada en marxa del nou sistema per a la realització de proves experimentals.

2. ENTORN DE PROVES EXISTENT

2.1. Motor experimental

El motor del qual es disposa al laboratori de motors tèrmics per a tasques d'investigació i docència, el qual es pot observar a la *Figura 2*, és un motor de cicle Otto de 4 temps, concretament del model SEAT AFT 1,6 litres comercialitzat a la dècada dels 90 i utilitzat en varis models de la marca SEAT i VOLKSWAGEN.

El motor ofereix una potència màxima de 74 kW (101 CV) a 5800 rpm i un parell màxim de 140 Nm a 3800 rpm. Té una cilindrada de 1593 cm^3, disposa de quatre cilindres i utilitza com a combustible gasolina E5 o E10.

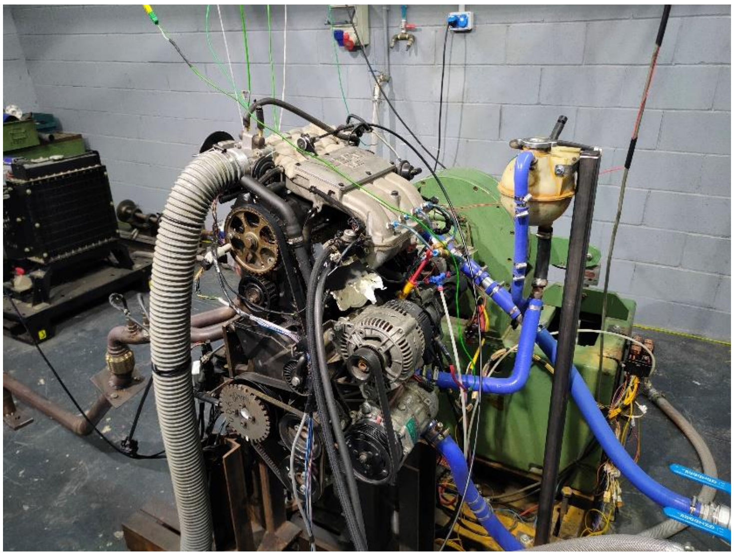


Figura 2. Motor del banc de proves.

2.2. Fre dinamomètric

Un MCIA (motor de combustió interna alternatiu) converteix energia en forma de calor a partir de la combustió d'un combustible, generalment fòssil, en energia mecànica disponible en un eix. A major grau de càrrega, el motor gira més ràpidament, per tant és necessari un element que freni o reguli el règim de gir del motor. La regulació consisteix en controlar, per qualsevol grau de càrrega, el règim de gir del motor.

El banc de proves disposa d'un fre dinamomètric de corrents de Foucault de la marca SCHENCK i model W130 fabricat l'any 1978. Aquest model té una potència màxima de càrrega de 130 KW. El parell nominal és de 400 Nm i la velocitat màxima és de 10000 rpm.

El fre s'utilitza per avaluar diferents paràmetres dels motors com són el règim de gir (rpm) i el parell efectiu (Nm) amb la finalitat d'obtenir dades característiques del motor a assajar com poden ser la potència efectiva, la pressió mitja efectiva o dades de consum.

Quan el motor es troba regulat i en estat estacionari es procedeix al registre i adquisició de les dades desitjades. La mesura del règim del motor (rpm) s'aconsegueix per mitjà d'un tacòmetre magnètic i una roda dentada unida a l'eix del fre, acoblat a l'eix del motor mitjançant una junta Cardan.

La mesura del parell efectiu s'obté per mitjà d'una cèl·lula de càrrega unida per un dels seus extrems al fre del motor. El fre dinamomètric existent al banc de proves s'observa a la *Figura 3*.

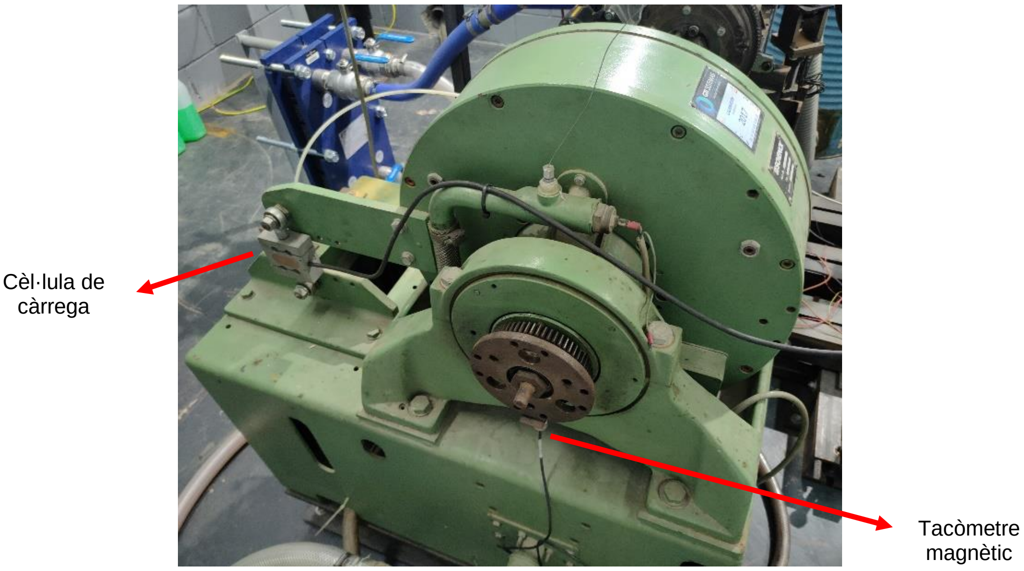


Figura 3. Fre dinamomètric SCHENCK W130.

2.3. Unitat d'adquisició de dades SP4

Per a l'obtenció de dades del banc de proves es disposa d'un mòdul d'adquisició de dades de la marca SportDevices, model SP4.

Aquest mòdul disposa de diverses entrades i sortides per a l'adquisició de dades del motor i per al control del fre i altres components del banc de proves, tal i com s'observa a la *Figura 4* i a la *Taula 2*.

En primer lloc, disposa de 7 entrades analògiques per a sensors que proporcionen senyals de 0 a 5 V. Prèviament a la realització d'aquest projecte no es disposa de cap sensor preparat per a l'adquisició de senyal a partir del mòdul esmentat.

A continuació, el mòdul disposa de dues sortides preparades per al control de servomotors de radio control d'alt parell (high torque RC servo) que s'utilitzen per al maneig de l'accelerador. Aquesta possibilitat que ofereix l'SP4 tampoc s'utilitza ja que l'accelerador es controla mitjançant una palanca manual situada a l'exterior de la sala de proves.

A més a més, disposa de 4 terminals amb connexió directe amb la cèl·lula de càrrega situada al fre. Aquests terminals corresponen a les senyals positives i negatives d'entrada i sortida.

També ofereix la possibilitat de controlar el fre a partir d'una senyal PWM (pulse width modulation). Modificant l'amplada d'impuls de la senyal, aquesta opció permet regular la potència del fre.

Per altra banda, disposa una entrada anomenada *Roller input*. Aquesta entrada serveix per a poder llegir la velocitat del fre i per tant la velocitat a la qual està girant el motor.

El mòdul també incorpora una entrada que és sensible a petits polsos de corrent. Mitjançant unes pinces inductives permet obtenir la velocitat de gir del motor.

La unitat SP4 també permet la lectura de temperatures mitjançant 8 entrades per a sensors de temperatura termoparell de tipus K i la connexió de 7 relés amb alimentació de 12 V. Aquestes sortides poden ser utilitzades per al control de ventiladors de refrigeració.

Finalment, disposa 2 connectors RS485 que permeten la realització dels assajos amb una consola. El mòdul d'adquisició de dades s'alimenta a 230 V i a una freqüència de 50/60 Hz.

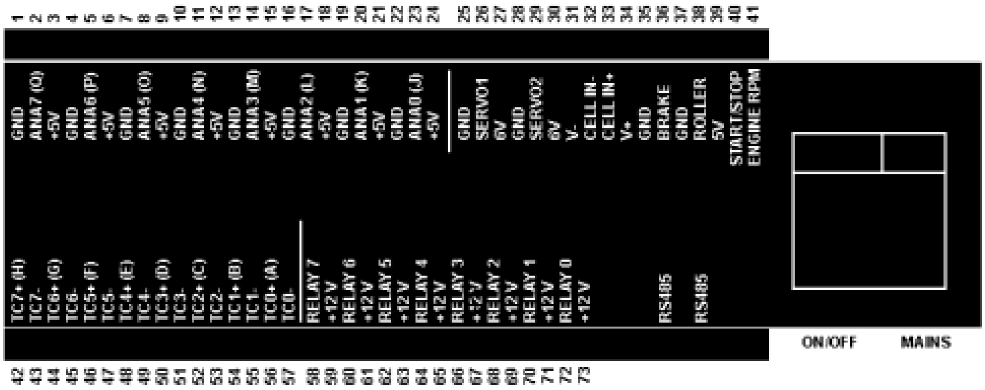


Figura 4. Panell frontal SP4.

Entrades i sortides mòdul SP4					
1	GND	26	Servo 1 (Throttle)	51	TC3 -
2	Analog input 7 (key Q)	27	6 Volt (3 Amp)	52	TC2 + (key C)
3	5 Volt	28	GND	53	TC2 -
4	GND	29	Servo 2	54	TC1 + (key B)
5	Analog input 6 (key P)	30	6 Volt (3 Amp)	55	TC1 -
6	5 Volt	31	V- (gnd)	56	TC0 + (key A)
7	GND	32	Cell IN -	57	TC0 -
8	Analog input 5 (key O)	33	Cell IN +	58	Relay 7
9	5 Volt	34	V+ (5 Volt, regulated)	59	12 Volt
10	GND	35	GND	60	Relay 6
11	Analog input 4 (key N)	36	Brake Output	61	12 Volt
12	5 Volt	37	GND	62	Relay 5
13	GND	38	RPM in (active HIGH)	63	12 Volt
14	Analog input 3 (key M)	39	5 Volt	64	Relay 4
15	5 Volt	40	Start/Stop (active LOW)	65	12 Volt
16	GND	41	Engine RPM (current pulses)	66	Relay 3 (fan 2)
17	Analog input 2 (key L)	42	TC7 + (key H)	67	12 Volt
18	5 Volt	43	TC7 -	68	Relay 2 (fan 1)
19	GND	44	TC6 + (key G)	69	12 Volt
20	Analog input 1 (key K)	45	TC6 -	70	Relay 1 (starter)
21	5 Volt	46	TC5 + (key F)	71	12 Volt
22	GND	47	TC5 -	72	Relay 0 (ignition)
23	Analog input 0 (key J)	48	TC4 + (key E)	73	12 Volt
24	5 Volt	49	TC4 -		
25	GND	50	TC3 + (key D)		

Taula 2. Entrades i sortides SP4.

2.4. Sensors existents

2.4.1. Sensor de posició del cigonyal

El sensor de posició del cigonyal o CKP (*Crankshaft Position Sensor)* identifica la posició i la velocitat de gir del cigonyal del motor. La posició del cigonyal es determina identificant la posició del primer pistó del motor quan aquest es troba en el seu punt mort superior.

La funció d'aquest sensor és important ja que, sabent la posició del primer pistó del motor, el mòdul de control (ECU) pot activar les bobines, injectors i més actuadors que regulen el funcionament del motor.

Els objectius del sensor CKP són ajudar al sistema d'encesa del motor, el qual produeix les guspires a través de les bugies, i al sistema d'injecció, indicant-li el moment exacte (juntament amb l'ajuda d'altres sensors) en el qual pot injectar el combustible.

Existeixen principalment dos tipus de sensors de posició del cigonyal, els d'inducció magnètica i els d'efecte Hall. Al laboratori de motors tèrmics, tal i com s'observa a la *Figura 5*, es disposa d'un sensor CKP d'inducció.

Aquest sensor d'inducció treballa conjuntament amb una roda fònica de 40 dents. Normalment, aquesta roda fònica disposa d'alguna o vàries dents de diferent mida o d'algun espai entre dents lliure. Quan aquestes determinades posicions s'alineen amb el sensor CKP, el voltatge canvia (generalment baixa) i la senyal és enviada a la computadora.

Tot i que aquest sensor és capaç de proporcionar una lectura sobre les revolucions del motor i identificar la posició del primer pistó, en el motor del laboratori només s'encarrega de mesurar la velocitat de gir. Al treballar conjuntament amb el sensor de posició de l'arbre de lleves (CMP), aquest ja s'encarrega d'identificar la posició del pistó.

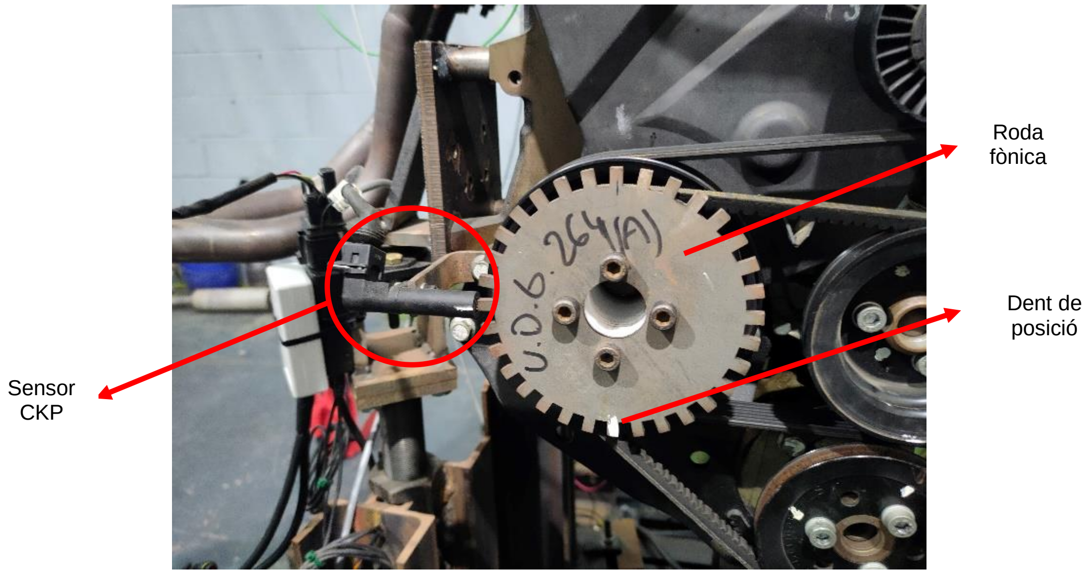


Figura 5. Sensor de posició del cigonyal.

2.4.2. Sensor de posició de l'arbre de lleves

El sensor de posició de l'arbre de lleves o CMP (*Camshaft Position Sensor)* determina amb exactitud la posició del primer pistó del motor, treballant conjuntament amb el sensor de posició del cigonyal o CKP. Concretament, emet una senyal a la ECU instants abans que el pistó arribi al punt mort superior, donant temps suficient a la centraleta a que interpreti la senyal i doni l'ordre en el moment precís i la seqüència adequada als injectors de combustible.

Al motor amb el qual es realitzen els assajos es disposa d'un sensor CMP de tipus Hall, ubicat a la politja de l'arbre de lleves, com es pot observar a la *Figura 6*.

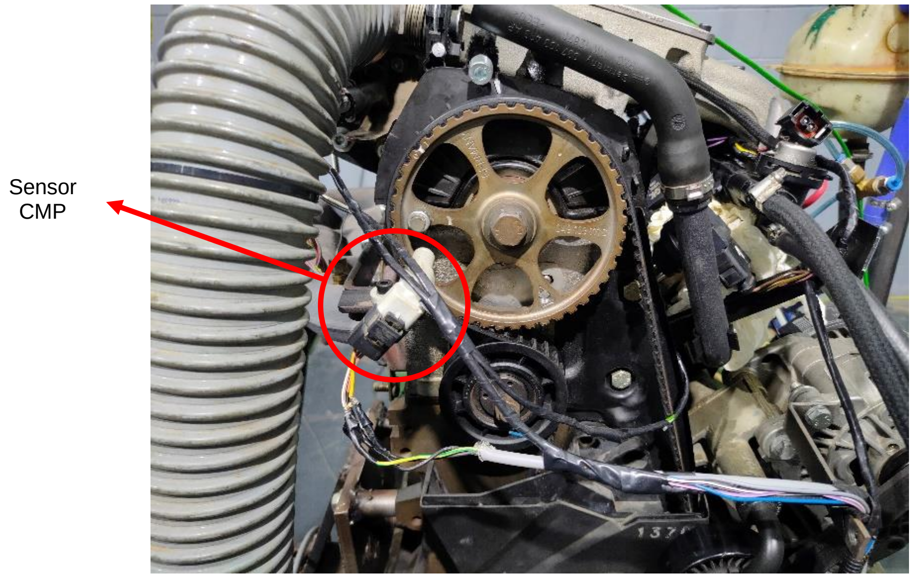


Figura 6. Sensor de posició de l'arbre de lleves.

2.4.3. Sensor de posició de l'accelerador

El sensor de posició de l'accelerador o TPS (*Throttle Position Sensor*) té la funció de determinar quina és la posició de la papallona d'admissió. En altres paraules, indica a la centraleta la càrrega que aplica el conductor del vehicle sobre el pedal d'acceleració. El sensor TPS és un potenciòmetre de resistència variable que emet una senyal en funció de la posició de la vàlvula de papallona.

Aquesta senyal, normalment de 0 a 5 V, s'envia al mòdul de control electrònic que s'encarrega de regular la injecció de combustible a les cambres de combustió. A més a més, aquesta senyal captada mitjançant el TPS és utilitzada per la ECU com a factor de càlcul per a determinar les revolucions del motor.

Quan el motor es troba en posició de ralentí, el sensor envia una senyal elèctrica que correspon a un angle de 0º, és a dir, la vàlvula d'admissió del motor es troba tancada. De la mateixa manera, quan l'acceleració és màxima i la papallona es troba en posició horitzontal, permetent el pas de la mescla d'aire-combustible, s'envia una senyal que correspon a un angle de 100º.

El sensor TPS, tal i com s'observa a la *Figura 7*, es troba a la part inferior del cos de la vàlvula d'admissió.

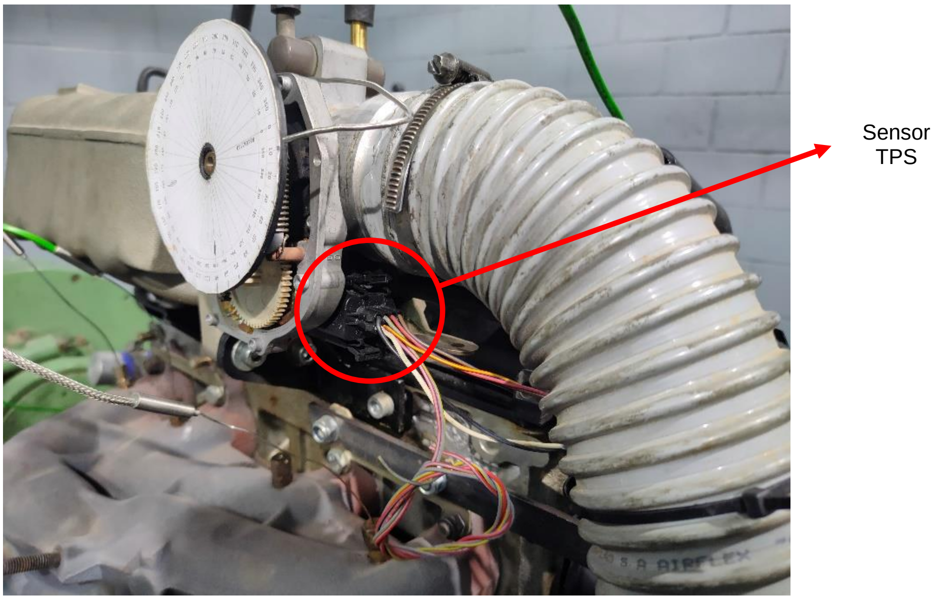


Figura 7. Sensor de posició de l'accelerador.

2.4.4. Sensor de pressió absoluta del col·lector

El sensor de pressió absoluta del múltiple d’admissió o MAP (*Manifold Absolute Pressure)* s’encarrega de mesurar la pressió d’aire en el col·lector d’admissió. S’envia una senyal a la centraleta del motor que aquesta és capaç d’interpretar per calcular el volum d’aire que ha entrat al motor, juntament amb les dades que proporcionen altres sensors com el TPS, CKP o MAF. D’aquesta manera la ECU és capaç de determinar i controlar la quantitat de combustible que és necessari injectar per fer una mescla aire-combustible adequada i eficient.

La lectura del sensor MAP s’aconsegueix mitjançant la conducció a la centraleta d’un tub comú que es ramifica en quatre tubs connectats a cada un dels conductes del col·lector d’admissió del motor.

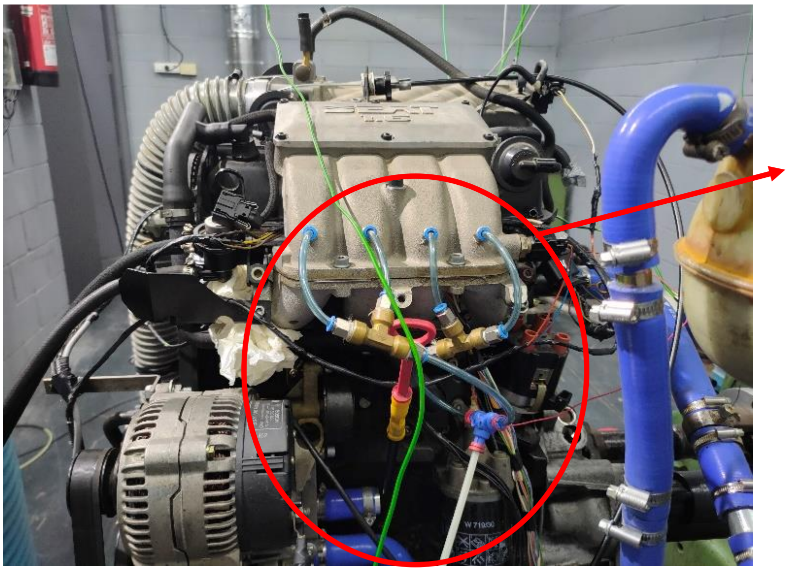


Figura 8. Tubs de conducció d'aire pel sensor MAP.

2.4.5. Sonda lambda LC-1

La sonda lambda o sensor d'oxigen té com a objectiu mesurar la concentració d'oxigen dels gasos d'escapament del motor. La senyal proporcionada pel sensor és enviada a la centraleta electrònica. La ECU s'encarrega, a partir de la senyal rebuda, d'ajustar la mescla aire-combustible garantint en tot moment que la combustió interna del motor és la correcta, reduint el consum i com a conseqüència les emissions contaminants.

Al laboratori de motors tèrmics es disposa d'un sensor d'oxigen de la marca Bosch 0 258 003 139 (LSU 4.2) instal·lada abans del catalitzador amb un controlador extern de banda ample de la firma Innovate Motorsports, tal i com es pot veure a la *Figura 9*, que converteix les senyals de la sonda lambda en senyal analògica lineal de 0-5V interpretable per la ECU.

Prèviament a la realització del projecte, aquesta sonda lambda només disposa de connexió directa amb la ECU. Durant el projecte es realitza la connexió amb el nou mòdul d'adquisició de dades i s'acaba descartant degut a que les dades proporcionades pel sensor no són fiables.

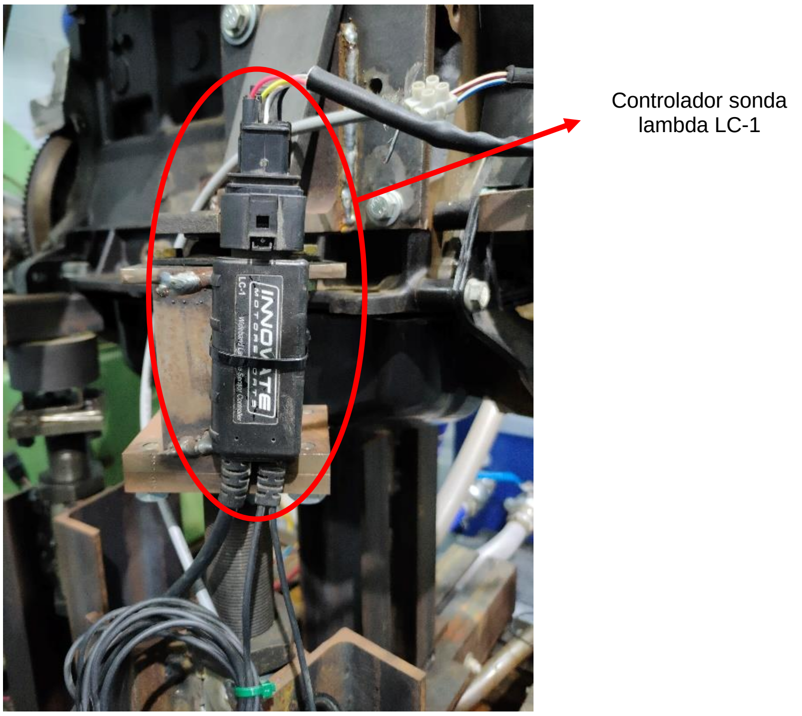


Figura 9. Sonda lambda amb controlador LC-1.

2.4.6. Sondes de temperatura

Per tal d'analitzar el funcionament del motor i observar possibles anomalies, es disposa de 6 sondes termoparell de tipus K instal·lades al motor amb connexió a l'SP4.

En primer lloc, es disposa de 3 sondes de temperatura instal·lades als cilindres 1, 3 i 4 del motor, com es pot observar en la *Figura 10*. D'aquesta manera es pot controlar la combustió dels cilindres del motor per separat. També són útils per trobar el punt de màxima eficiència del motor. En el moment en el que es produeix el parell màxim, apareix un instant de temps on aquest no augmenta ni decreix, però sí ho fa la temperatura.

Per altra banda, hi ha instal·lades 2 sondes de temperatura que permeten controlar la temperatura d'entrada del motor i de sortida.

Finalment, es disposa d'una última sonda destinada a avaluar la temperatura del fre.

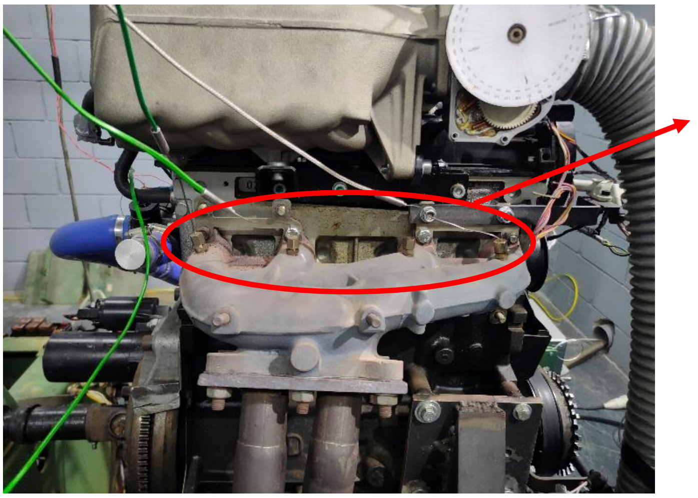


Figura 10. Sondes de temperatura als cilindres.

2.5. ECU

La unitat de control electrònic del motor o ECU s'encarrega de gestionar diversitat d'aspectes relacionats amb la combustió interna del motor del vehicle. Disposa de connexió amb diferents sensors i la senyal proporcionada per aquests li permet realitzar càlculs i executar comandes, a través de la lògica del seu propi software, sobre actuadors com poden ser els injectors de combustible o les bobines d'encesa.

Al laboratori de motors tèrmics de la universitat es disposa d'una centraleta Megasquirt MS3 de competició, com s'observa en la *Figura 11*.

Aquesta centraleta electrònica ja disposa de connexió amb els sensors CKP, CMP, sonda lambda LC-1 i MAP. A més a més, ofereix la possibilitat de connectar-hi un sensor flex fuel, pensat per a obtenir una lectura percentual del contingut d'etanol del combustible emprat. També possibilita la connexió d'un sensor MAF, per obtenir el cabal d'aire que entra al motor.

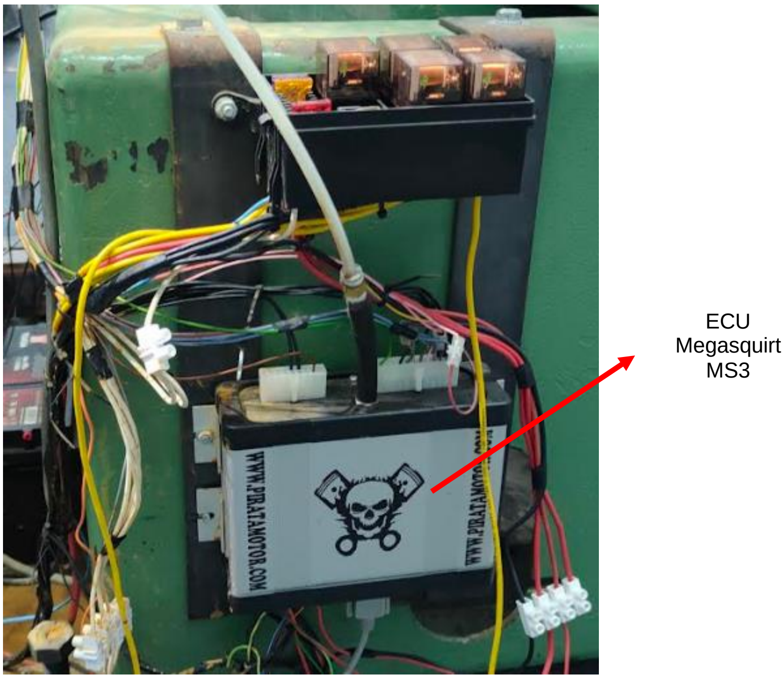


Figura 11. ECU Megasquirt MS3.

2.6. Estació meteorològica

A la sala de proves es disposa també d’una estació meteorològica amb connexió USB per a ordinador de la marca *SportDevices (Figura 12)*. L’estació meteorològica s’utilitza per determinar les condicions ambientals de la sala d’assaigs enviant al software d’adquisició de dades una mostra cada segon.

Figura 12. Estació meteorològica amb USB SportDevices.
(https://sportdevices.com/product/usb-weather-station/)

L'instrument disposa internament d'un sensor de temperatura, capaç de mesurar en un rang de -40 ºC a 85 ºC, un sensor de pressió, hàbil per un rang de 300 a 1100 mbar, i un sensor d'humitat. A la *Figura 13* s'observa la connexió de l'estació meteorològica i els components que l'integren.

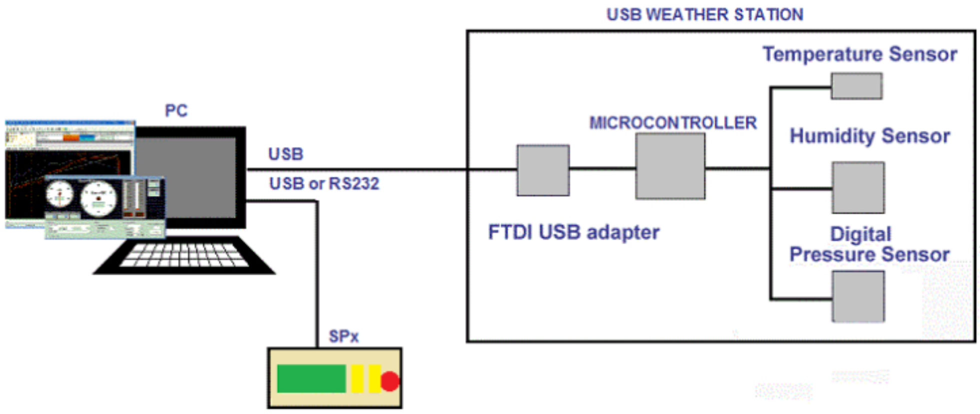


Figura 13. Esquema de connexions estació meteorològica.
(https://sportdevices.com/product/usb-weather-station/)

El programari d'adquisició de dades permet la compensació de les dades obtingudes mitjançant fórmules de correcció de normes reconegudes com són la ISO 1585, SAE J1349 o DIN 70020. Els factors de correcció poden ser prescindibles ja que l'estació inclou sensors de temperatura i pressió de bona qualitat de la marca Bosch, però permet obtenir dades més acurades per al posterior càlcul de paràmetres importants del motor.

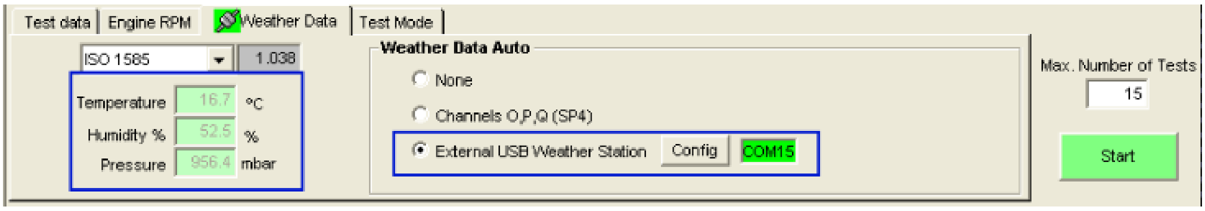


Figura 14. Dades i normes de correcció estació meteorològica.
(https://sportdevices.com/product/usb-weather-station/

3. MILLORA DEL BANC DE PROVES

Per tal de millorar i actualitzar el banc de proves del laboratori de motors tèrmics de l'Escola Politècnica Superior de la Universitat de Girona s'opta per la instal·lació d'una nou mòdul d'adquisició de dades i control conjuntament amb la implementació de nous sensors i actuadors al banc de proves per tal de treure el màxim rendiment a les tasques de docència i investigació.

Tota la instrumentació implementada està pensada per ser compatible amb l'entorn de proves existent amb caràcter previ a la realització del projecte.

3.1. Sensors

En aquest apartat es detallen els nous sensors escollits per implementar al banc de proves per a l'adquisició de dades específiques del motor, conjuntament amb la connexió al mòdul d'adquisició de dades.

3.1.1. Sensor de massa d'aire aspirada

El present projecte contempla la instal·lació d'un sensor capaç d'obtenir la quantitat d'aire que entra al motor. Aquest sensor és de gran importància ja que s'encarrega de mesurar la quantitat d'aire que entra al motor per tal que la centraleta electrònica calculi la quantitat de combustible que cal injectar i els temps d'encesa.

Existeixen principalment dos conceptes de mesuradors de cabal d'aire en motors: els sensors de massa d'aire de fil calent amb cabalímetre i els sensors de massa d'aire de paleta o de tipus potenciòmetre.

Els sensors de massa d'aire de fil calent (*Hot wire Mass Air Flow sensors)* consten d'un venturi amb dos fils de platí: un fil calent i un altre de compensació, que mesura la temperatura de l'aire que entra al motor. El venturi es troba dins del conducte principal del sensor. Un circuit electrònic incorporat al sensor, escalfa el fil calent a una temperatura constant, normalment de 100 ºC, per sobre de l'aire d'admissió. Quan l'aire travessa el sensor provoca el refredament del fil calent. El circuit electrònic compensa aquesta disminució de temperatura, augmentant la corrent que circula pel fil calent, amb l'objectiu de mantenir la diferència de temperatures inicial. Aquesta variació de corrent produïda és una mesura de la massa d'aire a l'admissió. Aquest tipus de sensors habitualment van acoblats a un cabalímetre per on circula l'aire que entra al motor, de tal manera que el fil calent s'hi troba en contacte directe. A la *Figura 15* es mostra de manera esquemàtica un sensor MAF de fil calent amb cabalímetre.

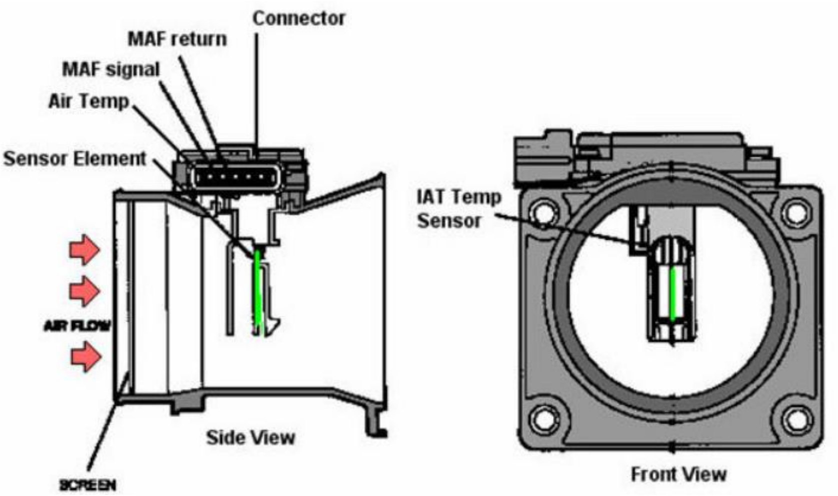


Figura 15. Sensor MAF de fil calent amb cabalímetre.
(https://www.ingenieriaymecanicaautomotriz.com/que-es-el-sensor-maf-y-como-funciona-en-el-vehiculo/)

Els sensors de massa d'aire de paleta o de tipus potenciòmetre (*Vane Air Flow sensor)* disposen d'una paleta carregada amb un ressort que pivota sobre un eix quan s'obre i es tanca en resposta al volum d'aire que entra. Un potenciòmetre està connectat a la paleta en el seu punt de pivot, provocant una variació de la tensió de sortida quan l'aire canvia l'angle de la paleta.

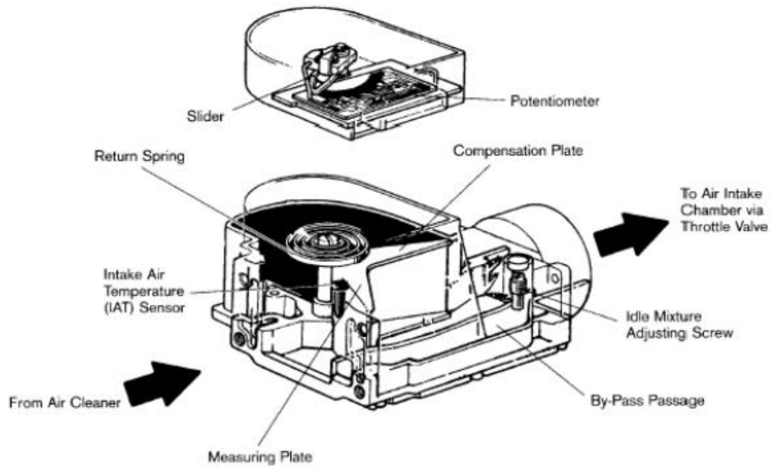


Figura 16. Sensor de paleta amb potenciòmetre. (Font: Centro Internacional de Instrucción Técnica Automotriz)

S'opta per la implementació d'un sensor MAF de fil calent amb cabalímetre, àmpliament utilitzat en automoció i amb bona fiabilitat. La incorporació d'un cabalímetre en facilita la instal·lació.

S'escull un sensor analògic de la marca Bosch, model F 00C 2G2 027 amb un cabalímetre, també de la mateixa marca, model 0 280 217 003 el qual es decideix instal·lar al dipòsit d'alimentació d'aire del motor mitjançant un acoblament realitzat amb dues abraçadores metàl·liques i un maneguet de silicona, habitualment utilitzat en automoció.

La connexió amb el mòdul d'adquisició de dades s'efectua a partir d'un connector de 4 pins extret d'un Audi A6 de l'any 1998 i un connector estanc d'automoció de 4 vies que facilitarà la connexió amb el mòdul. El muntatge del sensor es mostra a la Figura 16.

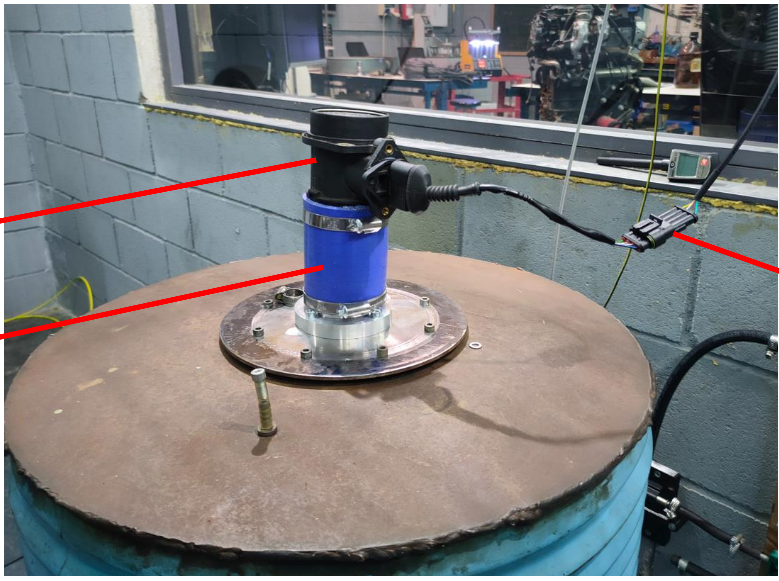


Figura 17. Muntatge del sensor MAF.

A continuació, a la *Taula 3*, es detalla l'assignació de pins corresponents al sensor MAF, així com la connexió al mòdul d'adquisició de dades.

Connector MAF			Connector estanc 4 vies		
Pin	Descripció	Color cablejat	Pin	Color cablejat	Connexió DAQ
1	Senyal de sortida sensor de temperatura (no s'utilitza)	-	-	-	-
2	Senyal d'entrada 12 V	Blau i negre	1	Verd	12 V (CNT)
3	Terra (GND)	Marró i blanc	2	Marró	GND (AIN3)
4	Senyal d'entrada 5 V de referència	Lila i blanc	3	Blanc	5 V (ANALOG)
5	Senyal de sortida (0-5V)	Verd i marró	4	Groc	AIN 3

Taula 3. Assignació de pins sensor MAF.

3.1.2. Sonda lambda

Per tal de monitoritzar la relació aire-combustible (AFR) s'opta per la implementació d'un sensor d'oxigen o sonda lambda. Aquesta instal·lació es realitza amb l'objectiu d'adaptar la mescla a partir de les dades obtingudes per tal d'aconseguir una millor combustió interna del motor, tot augmentant l'eficiència i, per tant, reduint les emissions contaminants.

Els sensors d'oxigen es localitzen a la línia d'escapament del motor. Els gasos d'escapament, en condicions d'alta temperatura i pressió, són expulsats del motor durant la fase d'escapament i entren en contacte amb el sensor d'oxigen col·locat abans del convertidor catalític.

A l'extrem frontal del sensor, hi ha un protector metàl·lic amb forats que encapsula un element sensible de diòxid de zirconi. Els gasos d'escapament circulen a través dels forats i entren en contacte directe amb l'element sensible o cel·la de Nernst. A l'altre extrem del sensor, l'aire de l'exterior entra al sensor a través dels espais entre els cables de connexió. Aquest aire exterior és escalfat capacitant als ions a produir voltatge. La diferència de concentració d'oxigen entre l'aire exterior i els gasos d'escapament genera un moviment dels ions d'oxigen produint una diferència de potencial. El funcionament i les parts principals d'un sensor d'oxigen es mostren a la *Figura 18*.

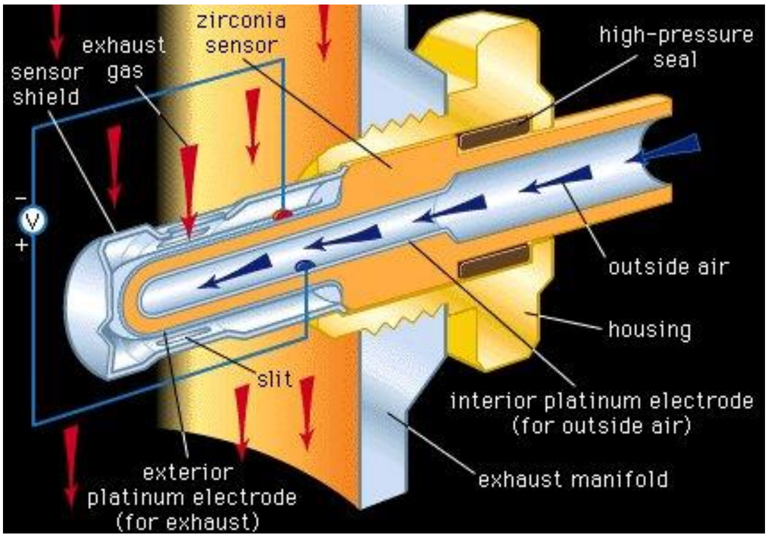


Figura 18. Funcionament i parts d'un sensor d'oxigen. (https://www.hydrogen-generators-usa.com/auto_oxygen_sensors.html)

Existeixen dos tipus de sonda lambda: els sensors d’oxigen de banda estreta i els sensors d’oxigen de banda ample.

Els sensors d’oxigen de banda estreta, com indica el seu nom, només són capaços de mesurar una finestra molt estreta de mescles aire-combustible: al voltant de 0,99 a 1.01 λ o de 14,6 a 14,8 AFR. Aquest tipus de sonda lambda només és capaç d’indicar si el motor està treballant amb una mescla ideal (14,7 parts d’oxigen per 1 part de combustible) o no. Si el motor funciona amb una mescla molt rica (excés de combustible) o massa pobre (dèficit de combustible), el sensor no és capaç de proporcionar una mesura.

Els sensors de banda ample, a diferència dels de banda estreta, permeten un marge més ampli de mesura de la relació aire combustible. En concret, el sensor d’oxigen de banda ample permet mesures d’entre 0.68 fins 1.36 λ o d’entre 10:1 fins a 20:1 AFR. Aquest fet possibilita la monitorització en tot moment de la relació aire-combustible real i la comparació amb la relació desitjada o estequiomètrica (14.7 parts d’aire en pes per 1 part de combustible en pes), convertint-los en una millor opció en front als sensors d’oxigen de banda estreta.

No obstant, la complexitat dels sensors de banda ample fa que hagin d’anar acompanyats d’un controlador electrònic que s’encarrega de tractar i filtrar la senyal, convertint-la en una senyal lineal de 0 a 5 V interpretable per la centraleta electrònica i les unitats d’adquisició de dades. El sensor d’oxigen implementat és de la marca Bosch, model LSU 4.2 i incorpora un controlador de la marca SportDevices, fent-lo compatible amb el mòdul d’adquisició de dades escollit i permetent una lectura en un rang de 10:1 fins a 18:1 AFR.

Per a la instal·lació de la sonda lambda és necessari mecanitzar una rosca M18 x 1,5 en el tub d’escapament del motor, aigües amunt del catalitzador, tal i com s’observa a la *Figura 19*.

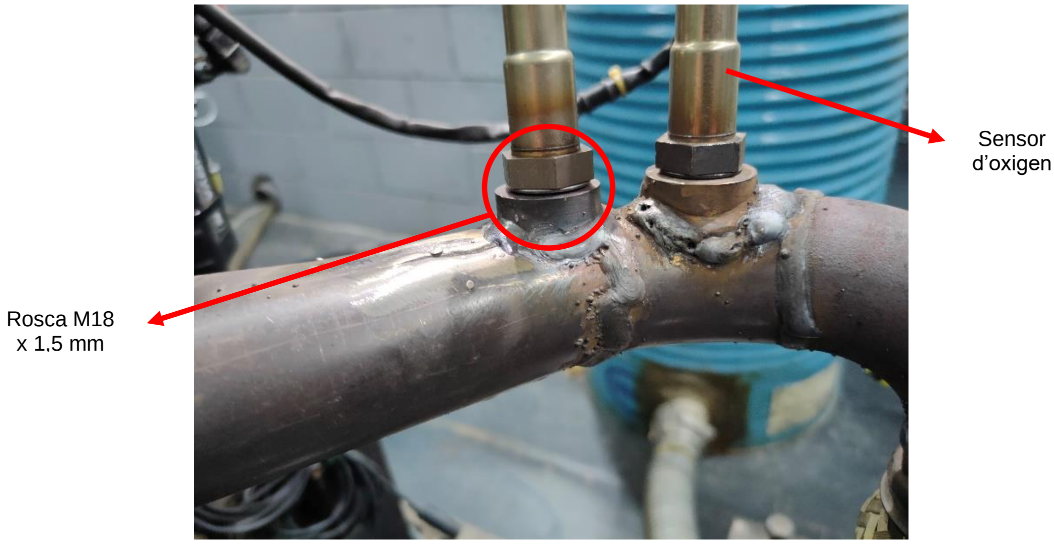


Figura 19. Muntatge del sensor d'oxigen al tub d'escapament.

També s'opta per al disseny i fabricació d'un suport per tal de mantenir el controlador de la sonda lambda a una certa distància del tub d'escapament evitant l'exposició a altes temperatures, tal i com es mostra a la *Figura 20*.

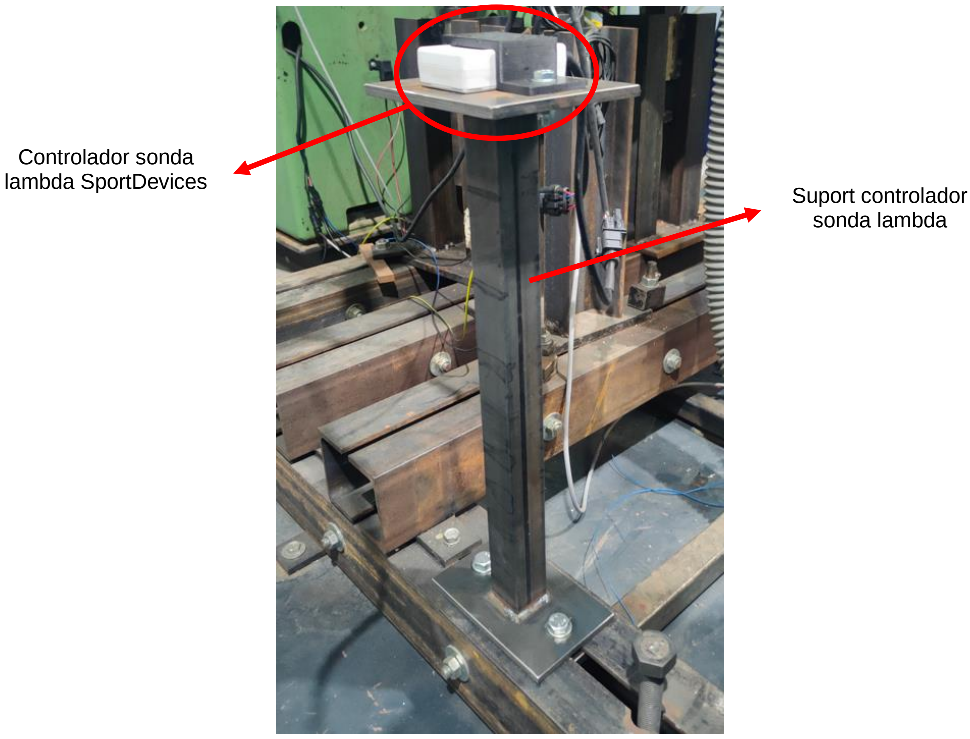


Figura 20. Suport controlador sonda lambda.

Per a la instal·lació del sensor d'oxigen s'utilitza un connector estanc d'automoció de 4 vies, permetent la distribució del cablejat cap a la bateria, centraleta del motor i unitat d'adquisició de dades. A més a més, s'opta per instal·lar un fusible de protecció amb un porta fusibles estanc d'automoció. Tot seguit, a la *Taula 4*, es detalla l'assignació de pins del sensor i del connector, conjuntament amb la connexió al mòdul d'adquisició de dades, ECU i a la bateria del motor.

Pinout controlador			Connector estanc 4 vies		
Pin	Descripció	Color cablejat	Pin	Color cablejat	Connexió
1	Senyal de sortida analògica (0-5V)	Vermell	1	Blanc	AIN 2 / Pin 13 del connector 1 de 20 pins ECU
2	Terra senyal	Blau	2	Marró	GND (AIN 2)
3	Terra alimentació	Negre	3	Blau i negre	V - bateria
4	Alimentació 12 V	Vermell	4	Vermell i negre	V + bateria

Taula 4. Assignació de pins sonda lambda.

3.1.3. Sensor flex fuel d'etanol

El sensor de contingut d'etanol o sensor flex fuel, tal i com el seu nom indica, s'encarrega de proporcionar una lectura del percentatge d'etanol del combustible utilitzat. Aquesta mesura és de gran importància ja que permet a la centraleta electrònica del motor ajustar amb precisió la correcta quantitat de combustible a partir d'una barreja específica de gasolina i etanol.

L'etanol és un compost químic obtingut a partir de diferents plantes amb riquesa de cel·lulosa, com la canya de sucre, la remolatxa o alguns cereals com el blat. També es pot obtenir a partir de restes de la silvicultura o residus agrícoles. S'utilitza com a combustible, sol, o bé, barrejat en quantitats variades amb la gasolina. Algunes de les barreges més comuns que podem trobar a les estacions de servei són combustibles E5 (5% etanol i 95% gasolina) o E10 (10% etanol i 90% gasolina).

No obstant, com major és el contingut d'etanol, majors són els beneficis en quant a rendiment del motor es refereix. En primer lloc, un combustible amb alt percentatge d'etanol, com per exemple un E85 (85% etanol i 15% gasolina), comporta un augment de l'índex d'octà de manera que el motor pot utilitzar de manera segura una major pressió de sobrealimentació, fet que es tradueix en una major potència efectiva del motor. Un augment de l'índex d'octà també permet al motor portar a terme una sincronització d'encesa amb un menor risc de detonació.

Per altra banda, l'etanol ofereix un punt d'ignició significativament més baix. És per aquest motiu que la combustió d'un combustible amb alt percentatge d'etanol es produeix a temperatures més baixes, permetent un ambient més segur en motors d'alt rendiment on s'executen pressions de sobrealimentació i sincronització d'enceses altes.

Altres beneficis de l'etanol com a combustible poden ser la reducció d'emissions contaminants, la reducció de la dependència dels combustibles fòssils i de les importacions i un preu menor respecte altres combustibles.

El sensor d'etanol disposa d'una cel·la de mesura on dos elèctrodes en contacte amb el combustible mesuren la permitivitat, la conductivitat i la temperatura. La permitivitat de la gasolina és diferent de la de l'etanol, degut a la diferència en les composicions moleculars. També existeix una notable diferència entre la conductivitat dels dos fluids. El contingut d'etanol proporcionat pel sensor és una funció de la permitivitat i la conductivitat, segons la temperatura del combustible. En la *Figura 21* es pot observar un esquema de la cel·la de mesura del sensor i la funció del contingut d'etanol a partir de la constant dielèctrica i la temperatura del combustible.

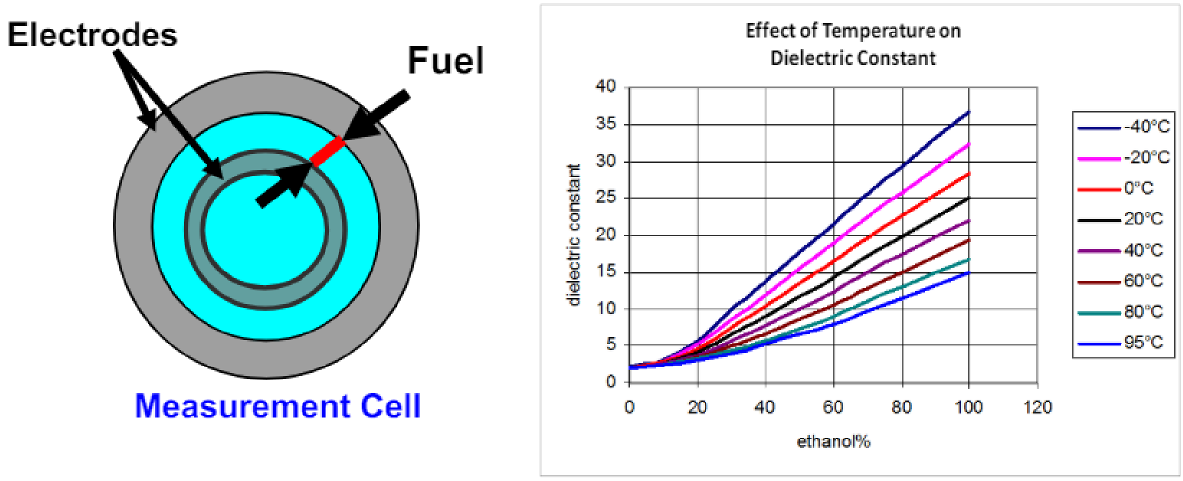


Figura 21. Cel·la de mesura i funció del contingut d'etanol. (Font: Continental AG).

Per tal d'estudiar les propietats que ofereix l'etanol com a combustible i els seus beneficis, s'instal·la un sensor de contingut d'etanol del model SE1004S de la marca Continental, una marca referència en automoció. Aquest sensor s'ubicarà a la línia de retorn del combustible, on la pressió del combustible és menor i ideal pel funcionament del sensor, seguint l'esquema de la *Figura 22*.

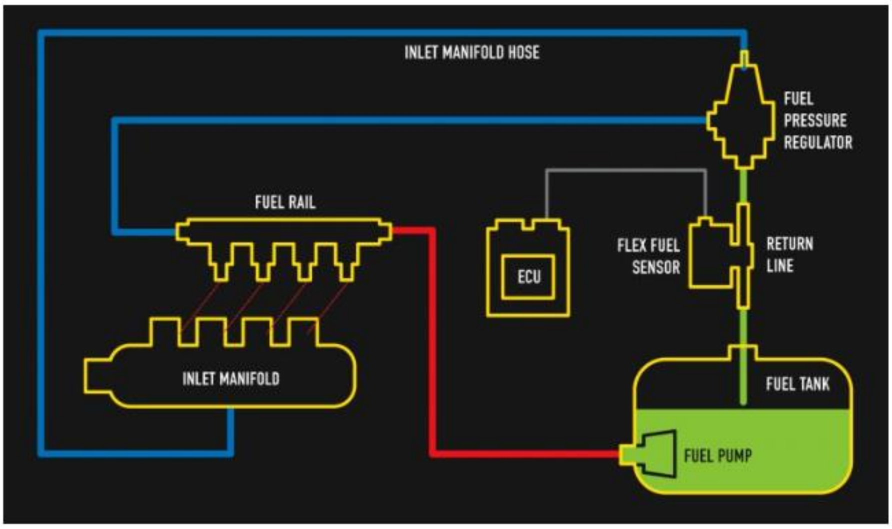


Figura 22. Esquema de posicionament del sensor dins el circuit d'alimentació de combustible. (https://www.haltech.com/news-events/how-flex-fuel-control-works/)

Per a la instal·lació del sensor es dissenya un suport mitjançant impressió 3D. La conducció del combustible a través del sensor es realitza per mitjà de tub flexible de combustible de cautxú de nitril (NBR), tal i com es mostra en la *Figura 23*.

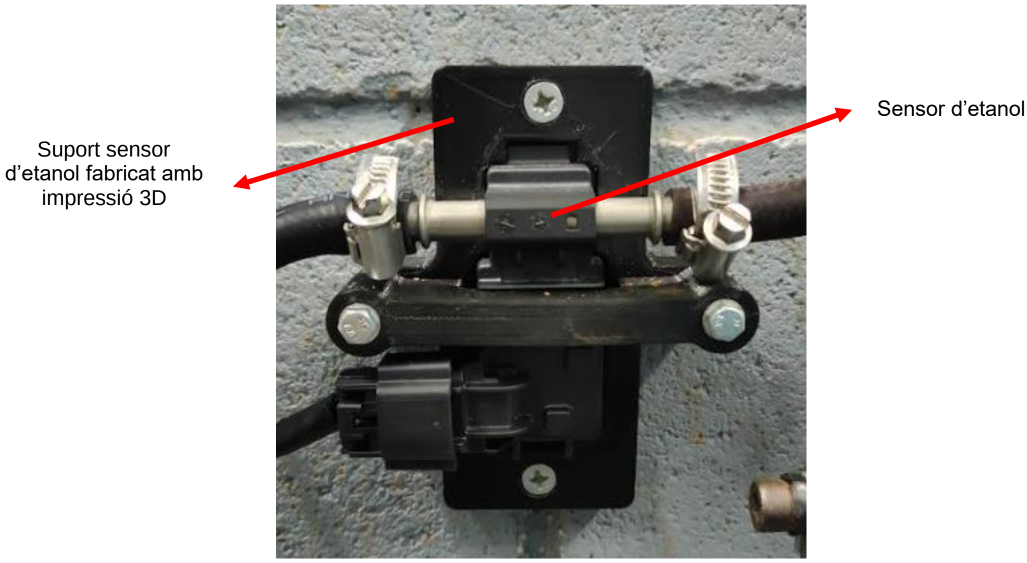


Figura 23. Suport sensor etanol.

La senyal de sortida que proporciona el sensor d'etanol és una senyal digital de baixa freqüència (50 – 150 Hz). Per a realitzar la connexió amb el mòdul d'adquisició de dades s'utilitzarà un connector estanc d'automoció i un connector GX16 femella de 3 pins com els de la *Figura 24*.

Figura 24. Connector estanc d'automoció (esquerra) i connector GX16 femella (dreta).

A la *Taula 5* es mostra l'assignació de pins corresponents als connectors utilitzats en la instal·lació del sensor d'etanol, juntament amb la connexió final al mòdul d'adquisició de dades.

Connector estanc 3 vies			
Pin	Descripció	Color cablejat	Connexió
1	Alimentació 12 V	Negre i groc	12 V (relay)
		Connector GX16 femella	
2	Terra (GND)	Marró	Pin 1 connector GX16 femella 3 pins (entrada RPM DAQ SP6)
3	Senyal de sortida digital (50 - 150 Hz)	Blanc	Pin 2 connector GX16 femella 3 pins (entrada RPM DAQ SP6)

Taula 5. Assignació de pins sensor d'etanol.

3.2. Actuadors

3.2.1. Servomotor d'alt parell

Per tal de manejar el cable de l'accelerador s'instal·la un servomotor de radio control d'alt parell amb l'electrònica dissenyada per la marca SportDevices. El servomotor, de la marca 9IMOD, és capaç de donar un parell de 130 kg*cm a 12V.

Es tracta d'un servomotor de tipus digital amb moviment polar, format per un motor sense escombretes de corrent continua capaç de girar un rang total de 180º. També disposa d'un potenciòmetre unit a l'eix del motor mitjançant una caixa reductora d'engranatges de manera que el sensor és capaç de determinar en tot moment la posició en que es troba l'eix.

Quan s'engega el motor, el mòdul d'adquisició de dades envia una senyal PPM (Pulse Position Modulation) per indicar al servomotor que es posi en la posició de 0º. De la mateixa manera, a través del programa informàtic i el mòdul d'adquisició de dades s'envia una senyal PPM per indicar l'angle de gir del servomotor, que es tradueix en el percentatge de càrrega de l'accelerador desitjable.

A continuació, a la *Figura 25,* s'observa el servomotor d'alt parell conjuntament amb l'electrònica dissenyada per SportDevices.

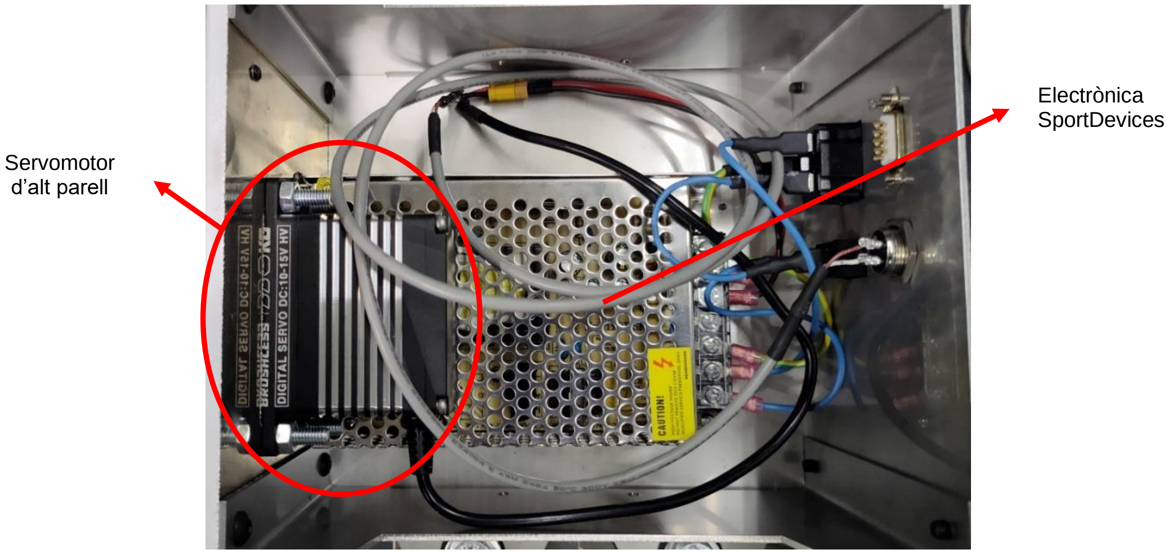


Figura 25. Servomotor d'alt parell amb electrònica SportDevices.

Per tal de garantir el correcte funcionament del servomotor, cal configurar el mòdul d'adquisició de dades internament ja que per defecte la configuració de la senyal de sortida cap al servomotor és de PWM (Pulse Width Modulation). Cal canviar la posició dels ponts o *jumpers* J5 i J6. El pont J5 cal posicionar-lo a la posició "B" mentre que el pont J6 es configura a la posició "A", com es mostra a la *Figura 26*. D'aquesta manera la senyal que s'envia al servomotor queda configurada com a senyal PPM o RC pulse.

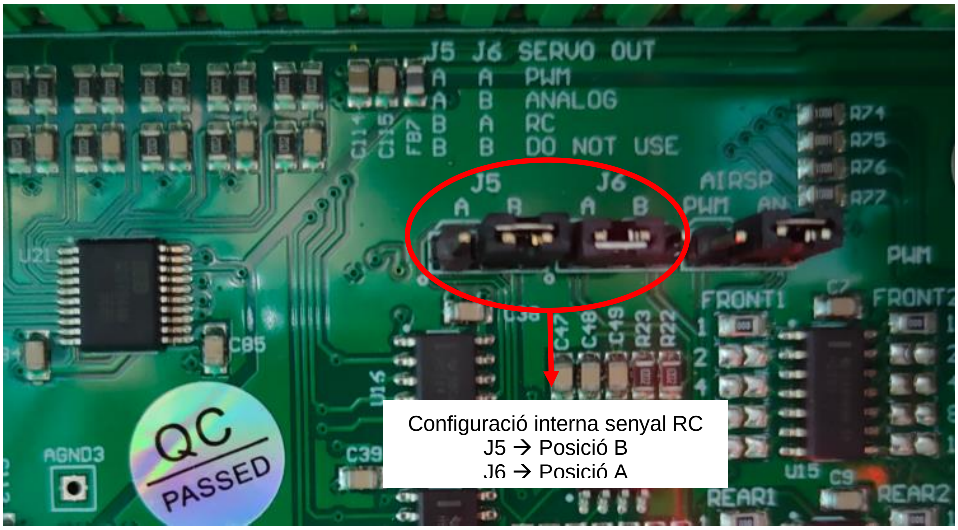


Figura 26. Configuració interna de senyal RC per al control del servomotor.

La connexió entre el servomotor i el mòdul de control i adquisició de dades es realitza mitjançant un connector GX16 de 4 pins instal·lat a la caixa del servomotor. D'aquest connector esmentat s'utilitzen 2 pins per al cablejat de senyal PPM o RC pulse i massa. L'assignació de pins i la connexió al mòdul es detalla a la *Taula 6*, tot seguit:

Connector GX16 4 pins			
Pin	Descripció	Color cablejat	Connexió
1	Senyal PPM servo	Blanc	Servo OUT (SP6)
2	-	-	-
3	-	-	-
4	Terra (GND)	Marró	Servo GND (SP6)

Taula 6. Assignació de pins servomotor.

Per a la instal·lació del servomotor s'opta per el disseny i fabricació d'un suport per tal de posicionar l'actuador a una distància adequada del motor i elevar-lo una certa altura, facilitant la unió amb el cable de l'accelerador. El muntatge del suport amb el servomotor es mostra a la *Figura 27*, a continuació:

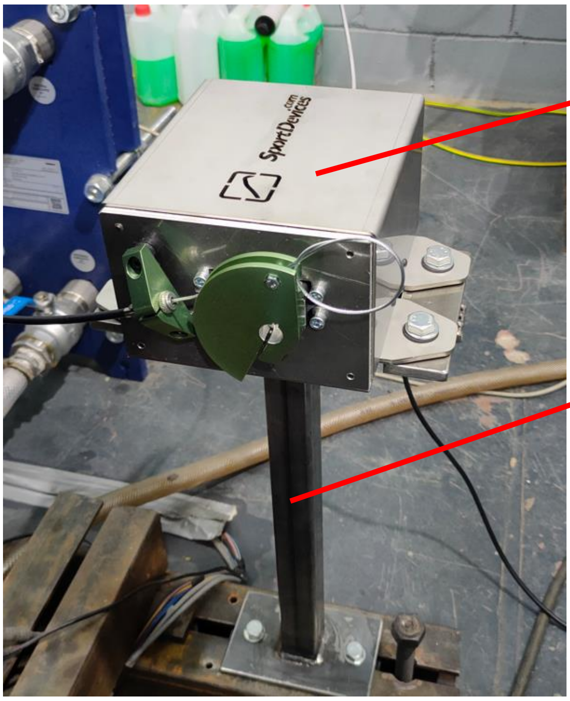


Figura 27. Conjunt suport i servomotor d'alt parell.

3.3. Adquisició de dades i control

3.3.1. Mòdul d'adquisició de dades SP6

Per al control i adquisició de dades del banc de proves s'instal·la el mòdul d'adquisició de dades SP6 de la marca SportDevices.

El mòdul d'adquisició de dades disposa de diverses entrades i sortides per a l'adquisició de dades del motor a assajar i per al control del fre i altres parts de la instal·lació.

A la part frontal, el mòdul SP6 disposa de 9 connectors GX16 circulars mascles. D'aquests connectors, 4 són de 4 pins i estan destinats a la connexió de 4 cèl·lules de càrrega en el cas de que es disposés d'un banc d'assaig amb 4 frens destinats a la realització de proves de vehicles amb tracció a les 4 rodes. De la mateixa manera, per a l'adquisició i control de la velocitat dels frens existeixen 4 connectors de 5 pins. Finalment, es destina un últim connector de 3 pins per a l'adquisició de la velocitat de gir del motor mitjançant unes pinces inductives.

Al laboratori de motors tèrmics, es disposa d'un banc de proves de tipus estacionari, amb el motor a assajar connectat directament al fre dinamomètric. És per aquesta raó que només s'utilitzen un connector circular de 4 pins amb connexió a la cèl·lula de càrrega instal·lada al fre i un altre connector circular de 5 pins amb connexió al sensor d'efecte Hall situat al fre per al coneixement i control de la velocitat del motor.

El mòdul també disposa de connectors per a ordinador i una consola de control remot. A més disposa de connexió a internet i un sistema CAN bus. L'alimentació del mòdul es realitza a 230 VAC. La part frontal de l'SP6 amb totes les connexions descrites disponibles es mostra a la *Figura 28.*

Figura 28. Part frontal SP6. (https://sportdevices.com/)

A la part posterior, el mòdul inclou 8 sortides per al control i accionament de diferents relés, com poden ser ventiladors, per a la refrigeració del motor i de la sala de proves, o un sistema d'encesa del motor amb un botó *Start / Stop.*

També disposa d'un interruptor normalment obert destinat a un possible polsador d'emergència. Si s'activés aquest polsador d'emergència, el mòdul aplicaria un parell de frenada fins que el motor s'aturés.

Per altra banda, a la part posterior es repliquen 4 sortides de senyal PWM per facilitar la instal·lació del mòdul SP6 i la seva corresponent font d'alimentació.

A continuació, s'inclouen una entrada destinada a un comptador de baixa freqüència (típicament utilitzada per a comptar les detonacions que es produeixen durant la combustió), una sortida per al control d'un servomotor ajustable internament per a emetre senyals PPM, PWM o analògica.

Finalment, l'SP6 inclou una sortida "*Air speed*", 8 entrades analògiques destinades a la instal·lació de sensors i 8 entrades per a sensors de temperatura termoparell de tipus K.

La part posterior, amb les diferents entrades i sortides descrites, es mostra a la *Figura 29.*

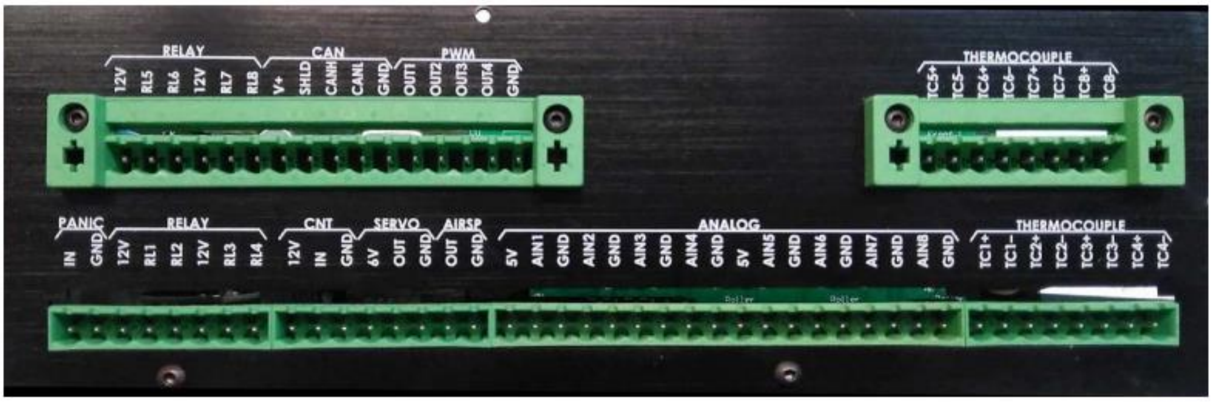


Figura 29. Part posterior SP6. (https://sportdevices.com/)

A continuació, a la *Taula 7*, es mostren els terminals utilitzats per a la connexió del sensor de massa d'aire aspirada, sonda lambda, sensors de temperatura termoparell de tipus K, servomotor d'alt parell i sensor de contingut d'etanol.

Entrades i sortides mòdul SP6					
1	IN (Panic Button)	23	OUT 4 (PWM signal)	45	AIN 6
2	GND (Panic Button)	24	GND (PWM signal)	46	GND
3	12 V	25	12 V (Low speed counter)	47	AIN 7
4	RL1 (IGN / Ignition)	26	IN (Low speed counter)	48	GND
5	RL2 (Starter relay)	27	GND (Low speed counter)	49	AIN 8
6	12 V	28	6 V (Servo)	50	GND
7	RL3 (Ventilador 1)	29	OUT (Servo)	51	TC1 +
8	RL4 (Ventilador 2)	30	GND (Servo)	52	TC1 -

9	12 V	31	OUT (Airspeed output)	53	TC2 +
10	RL5	32	GND (Airspeed output)	54	TC2 -
11	RL6 (Elevador)	33	5 V	55	TC3 +
12	12 V	34	AIN 1	56	TC3 -
13	RL7	35	GND	57	TC4 +
14	RL8	36	AIN 2	58	TC4 -
15	V + (CANBUS)	37	GND	59	TC5+
16	SHLD (CANBUS)	38	AIN 3	60	TC5 -
17	CAN H (CANBUS)	39	GND	61	TC6 +
18	CAN L (CANBUS)	40	AIN 4	62	TC6 -
19	GND (CANBUS)	41	GND	63	TC7 +
20	OUT 1 (PWM signal)	42	5 V	64	TC7 -
21	OUT 2 (PWM signal)	43	AIN 5	65	TC8 +
22	OUT 3 (PWM signal)	44	GND	66	TC8 -

	Sensor MAF
	Sensor contingut etanol
	Servomotor d'alt parell
	Sonda lambda LC-1
	Sonda lambda SPd
	Sondes temperatura

Taula 7. Terminals i connexions part posterior SP6.

3.3.2. Software de control i adquisició de dades SportDyno v4.1

Per a l'adquisició i control del banc de proves, visualització de les dades, obtenció de gràfics característics del motor i realització d'assajos, la marca SportDevices ofereix el seu propi programari que es troba en continu desenvolupament. Actualment es troba a la versió 4.1, amb un gran ventall de configuracions i possibilitats. A continuació es mostren algunes de les característiques més importants del programari.

La pantalla principal del programa es divideix en vàries zones. A la part superior de la finestra es mostra el menú principal tal i com es mostra a la *Figura 30*. Dintre del menú principal apareixen els menús d'arxiu, d'assaig, d'opcions, connexions, canals d'adquisició i ajuda. A sota del menú principal es troba una barra d'icones amb opcions típiques, com ara l'acció de guardar, ampliar o reduir l'àrea de gràfics, impressió o obrir la configuració de canals, entre d'altres.

Figura 30. Menu principal i barra d'icones SportDyno v4.1.

A la part esquerra de la finestra principal del programa existeix una zona on s'ofereix la possibilitat de seleccionar els canals que es volen visualitzar a l'àrea de gràfics, com la potència calculada, les revolucions a les quals gira el motor, o el factor lambda, entre altres opcions. També hi ha l'opció d'activar la visualització de dades a temps real i el control de relés com poden ser ventiladors per a la sala de proves o un polsador d'arrancada del motor.

A la zona central de la interfície principal es mostra l'àrea de gràfics on es visualitzen les corbes a partir de les dades obtingudes dels diferents canals del mòdul SP6 ja sigui a temps real o a partir d'assajos emmagatzemats a la memòria del programa.

A continuació, a la *Figura 31*, es mostra la finestra principal del programa on es pot observar a la part esquerra, els canals disponibles per a la representació de gràfics i el control de relés. A la part dreta, es mostra l'àrea de gràfics.

Figura 31. Interfície principal SportDyno v4.1.

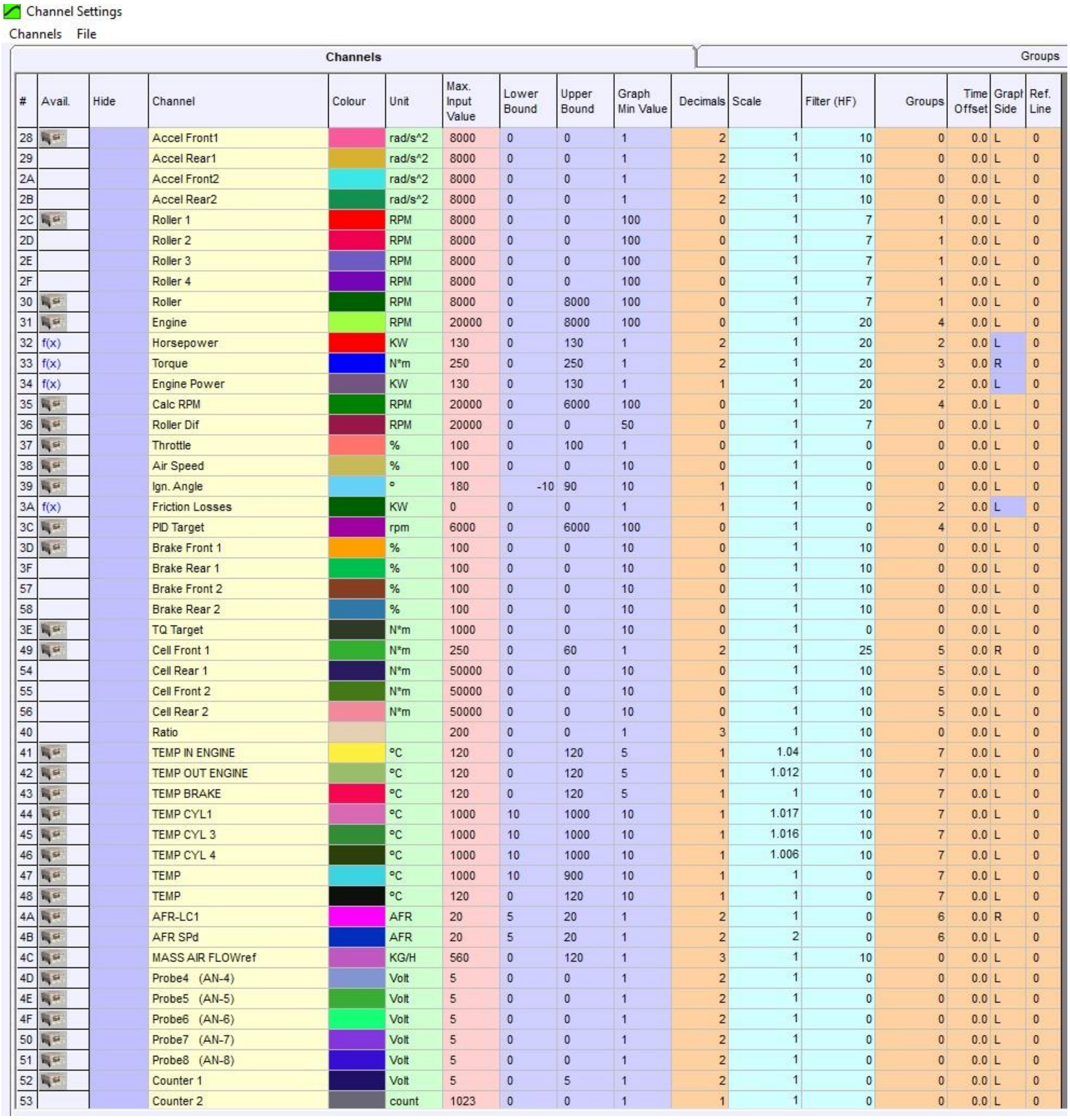
Polsant a la icona d'inici, s'accedeix a una segona finestra on es visualitzen els mesuradors. Es permet la visualització de les dades que l'usuari desitgi a través de rellotges, termòmetres o caixes numèriques, tal i com es mostra a la *Figura 32*.

Dins la mateixa pantalla dels mesuradors, a la part inferior, s'ubica una finestra que s'utilitza per a configurar les dades dels assajos a realitzar, permet visualitzar les dades enviades per l'estació meteorològica, configurar el tipus d'assaig a realitzar (inercial, estacionari, rampa o mode fre). També ofereix la possibilitat de carregar fitxers per al seqüenciador i el control del servomotor d'alt parell, entre altres opcions.

Figura 32. Pantalla de mesuradors i control del banc de proves.

Accedint a la configuració de canals, mostrada a la *Figura 33,* que es troba al menú principal o a la barra d'eines, es permet visualitzar tots els canals i modificar-los. Es distingeix entre canals interns, canals digitals, canals analògics (0-5V), canals per a sondes de temperatura, canals calculats, canals d'adquisició de les dades de l'estació meteorològica i canals OBDII.

Els canals de tipus digital, interns, estació meteorològica i OBDII no són modificables per l'usuari. No obstant, el programari ofereix la possibilitat de modificar els canals de tipus analògic, permetent a l'usuari realitzar una interpolació o afegir una compensació i ajustar una escala. Les sondes de temperatura es poden ajustar segons el tipus (estat gas o líquid) i les unitats de temperatura (graus Celsius o Fahrenheit). Per altra banda, els canals calculats permeten a l'usuari obtenir dades significatives per a l'estudi del motor mitjançant l'aplicació de fórmules matemàtiques a partir de les dades obtingudes d'altres canals.



#	Avail.	Hide	Channel	Colour	Unit	Max. Input Value	Lower Bound	Upper Bound	Graph Min Value	Decimals	Scale	Filter (HF)	Groups	Time Offset	Graph Side	Ref. Line
28			Accel Front1		rad/s^2	8000	0	0	1	2	1	10	0	0.0	L	0
29			Accel Rear1		rad/s^2	8000	0	0	1	2	1	10	0	0.0	L	0
2A			Accel Front2		rad/s^2	8000	0	0	1	2	1	10	0	0.0	L	0
2B			Accel Rear2		rad/s^2	8000	0	0	1	2	1	10	0	0.0	L	0
2C			Roller 1		RPM	8000	0	0	100	0	1	7	1	0.0	L	0
2D			Roller 2		RPM	8000	0	0	100	0	1	7	1	0.0	L	0
2E			Roller 3		RPM	8000	0	0	100	0	1	7	1	0.0	L	0
2F			Roller 4		RPM	8000	0	0	100	0	1	7	1	0.0	L	0
30			Roller		RPM	8000	0	8000	100	0	1	7	1	0.0	L	0
31			Engine		RPM	20000	0	8000	100	0	1	20	4	0.0	L	0
32	f(x)		Horsepower		KW	130	0	130	1	2	1	20	2	0.0	L	0
33	f(x)		Torque		N*m	250	0	250	1	2	1	20	3	0.0	R	0
34	f(x)		Engine Power		KW	130	0	130	1	1	1	20	2	0.0	L	0
35			Calc RPM		RPM	20000	0	6000	100	0	1	20	4	0.0	L	0
36			Roller Dif		RPM	20000	0	0	50	0	1	7	0	0.0	L	0
37			Throttle		%	100	0	100	1	0	1	0	0	0.0	L	0
38			Air Speed		%	100	0	0	10	0	1	0	0	0.0	L	0
39			Ign. Angle		°	180	-10	90	10	1	1	0	0	0.0	L	0
3A	f(x)		Friction Losses		KW	0	0	0	1	1	1	0	2	0.0	L	0
3C			PID Target		rpm	6000	0	6000	100	0	1	0	4	0.0	L	0
3D			Brake Front 1		%	100	0	0	10	0	1	10	0	0.0	L	0
3F			Brake Rear 1		%	100	0	0	10	0	1	10	0	0.0	L	0
57			Brake Front 2		%	100	0	0	10	0	1	10	0	0.0	L	0
58			Brake Rear 2		%	100	0	0	10	0	1	10	0	0.0	L	0
3E			TQ Target		N*m	1000	0	0	10	0	1	0	0	0.0	L	0
49			Cell Front 1		N*m	250	0	60	1	2	1	25	5	0.0	R	0
54			Cell Rear 1		N*m	50000	0	0	10	0	1	10	5	0.0	L	0
55			Cell Front 2		N*m	50000	0	0	10	0	1	10	5	0.0	L	0
56			Cell Rear 2		N*m	50000	0	0	10	0	1	10	5	0.0	L	0
40			Ratio			200	0	0	1	3	1	10	0	0.0	L	0
41			TEMP IN ENGINE		°C	120	0	120	5	1	1.04	10	7	0.0	L	0
42			TEMP OUT ENGINE		°C	120	0	120	5	1	1.012	10	7	0.0	L	0
43			TEMP BRAKE		°C	120	0	120	5	1	1	10	7	0.0	L	0
44			TEMP CYL1		°C	1000	10	1000	10	1	1.017	10	7	0.0	L	0
45			TEMP CYL 3		°C	1000	10	1000	10	1	1.016	10	7	0.0	L	0
46			TEMP CYL 4		°C	1000	10	1000	10	1	1.006	10	7	0.0	L	0
47			TEMP		°C	1000	10	900	10	1	1	0	7	0.0	L	0
48			TEMP		°C	120	0	120	10	1	1	0	7	0.0	L	0
4A			AFR-LC1		AFR	20	5	20	1	2	1	0	6	0.0	R	0
4B			AFR SPd		AFR	20	5	20	1	2	2	0	6	0.0	L	0
4C			MASS AIR FLOWref		KG/H	560	0	120	1	3	1	10	0	0.0	L	0
4D			Probe4 (AN-4)		Volt	5	0	0	1	2	1	0	0	0.0	L	0
4E			Probe5 (AN-5)		Volt	5	0	0	1	2	1	0	0	0.0	L	0
4F			Probe6 (AN-6)		Volt	5	0	0	1	2	1	0	0	0.0	L	0
50			Probe7 (AN-7)		Volt	5	0	0	1	2	1	0	0	0.0	L	0
51			Probe8 (AN-8)		Volt	5	0	0	1	2	1	0	0	0.0	L	0
52			Counter 1		Volt	5	0	5	1	2	1	0	0	0.0	L	0
53			Counter 2		count	1023	0	0	1	1	1	0	0	0.0	L	0

Figura 33. Configuració de canals SportDyno v4.1.

Una altra finestra important dins del software és la pantalla de configuració del controlador PID, la qual es mostra a la *Figura 34*. Aquesta configuració és de vital importància ja que ajustant els paràmetres propis del controlador (constant proporcional, integral i derivativa) correctament, s'aconsegueix que la velocitat real del motor i la consigna (velocitat objectiu) convergeixin. Es busca assolir la velocitat desitjada el més ràpid possible i amb el mínim d'oscil·lacions possibles.

El controlador es pot ajustar en funció del tipus de senyal d'entrada ja sigui de tipus graó o rampa observant la senyal de sortida al monitor PID i canviant els paràmetres a mode de prova i error fins a trobar els adequats. També es pot ajustar un filtre d'acceleració per reduir l'oscil·lació.

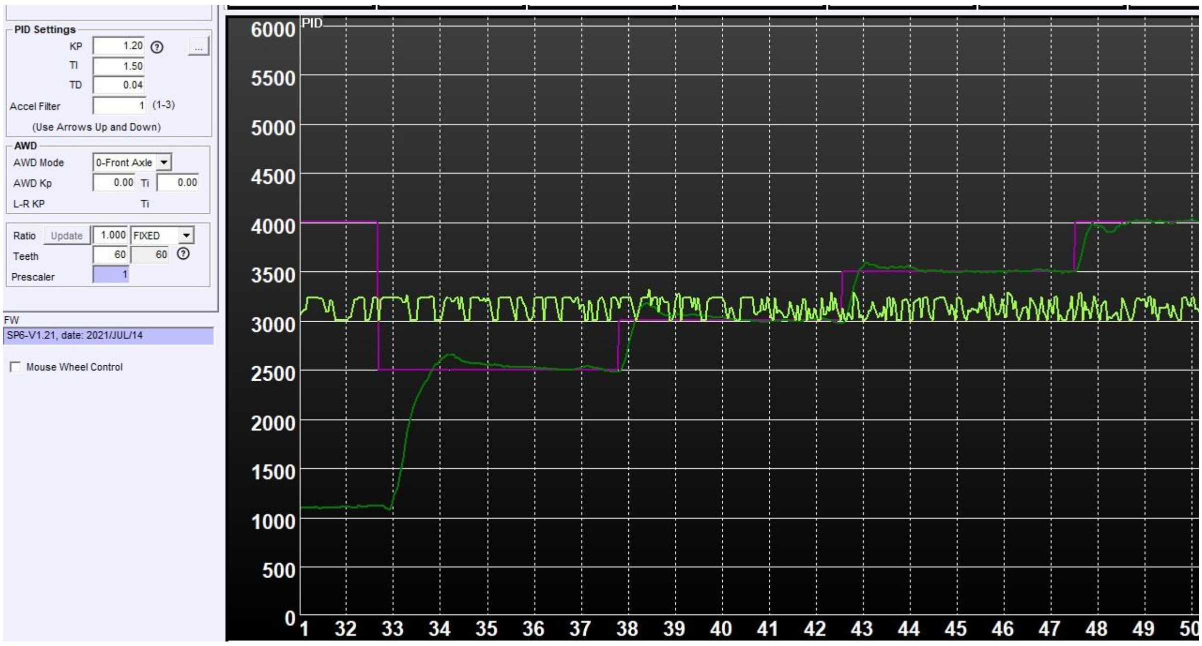


Figura 34. Monitor PID SportDyno v4.1.

El software incorpora l'opció de configuració de l'accelerador governat per el servomotor d'alt parell. Aquesta finestra de configuració inclou una barra lliscant per ajustar el percentatge de càrrega de l'accelerador movent el servomotor. També es permet ajustar la posició mínima i màxima del servomotor, i les velocitats d'obertura i tancament de l'accelerador. La finestra de configuració de l'accelerador es mostra a la *Figura 35*.

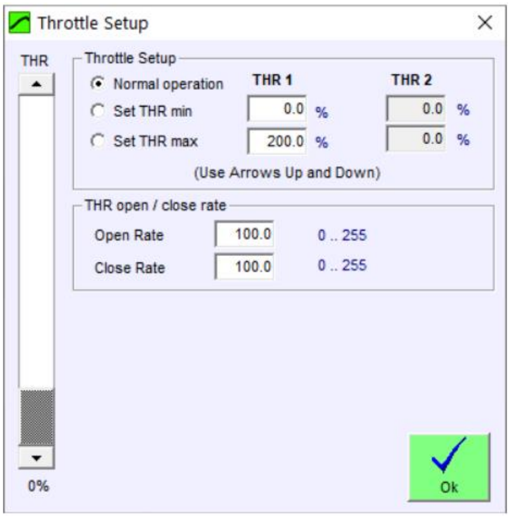


Figura 35. Configuració accelerador SportDyno v4.1.

Finalment cal destacar l’opció del seqüenciador. El seqüenciador permet la realització d’assajos de manera automatitzada. El primer mode del seqüenciador és un mode estàndard. Aquesta finestra és útil per a cicles automatitzats simples. L’usuari pot editar la duració de les diferents etapes (estabilització, acceleració, frenada i buit) i ajustar paràmetres relacionats amb l’acceleració i revolucions del motor inicials i finals, tal i com es mostra a la *Figura 36*.

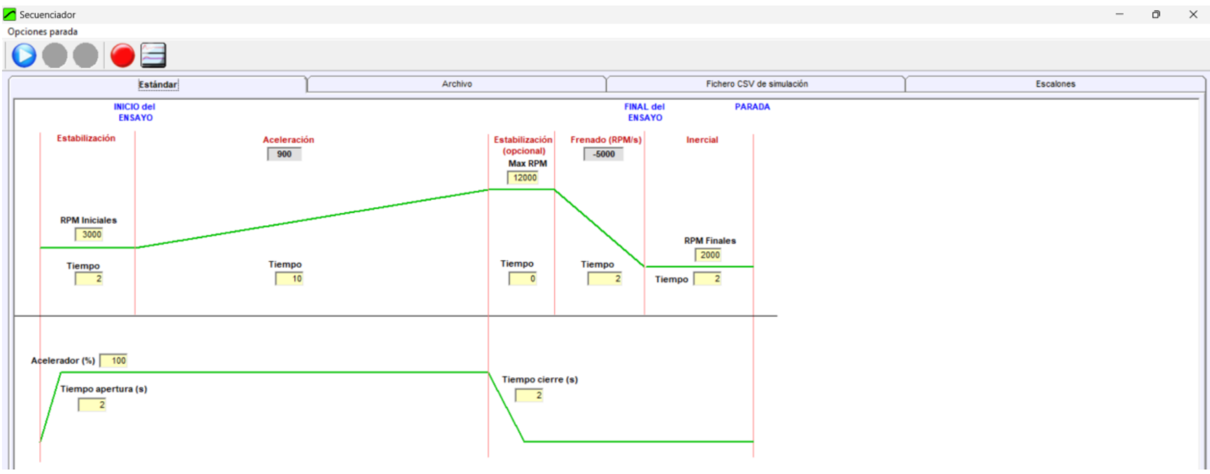


Figura 36. Seqüenciador estàndard SportDyno v4.1.

Si es volen portar a terme assajos més complexos, el programa permet crear seqüències a partir d'un fitxer de text per mitjà d'ordres simples, tal i com s'observa a la *Figura 37*.

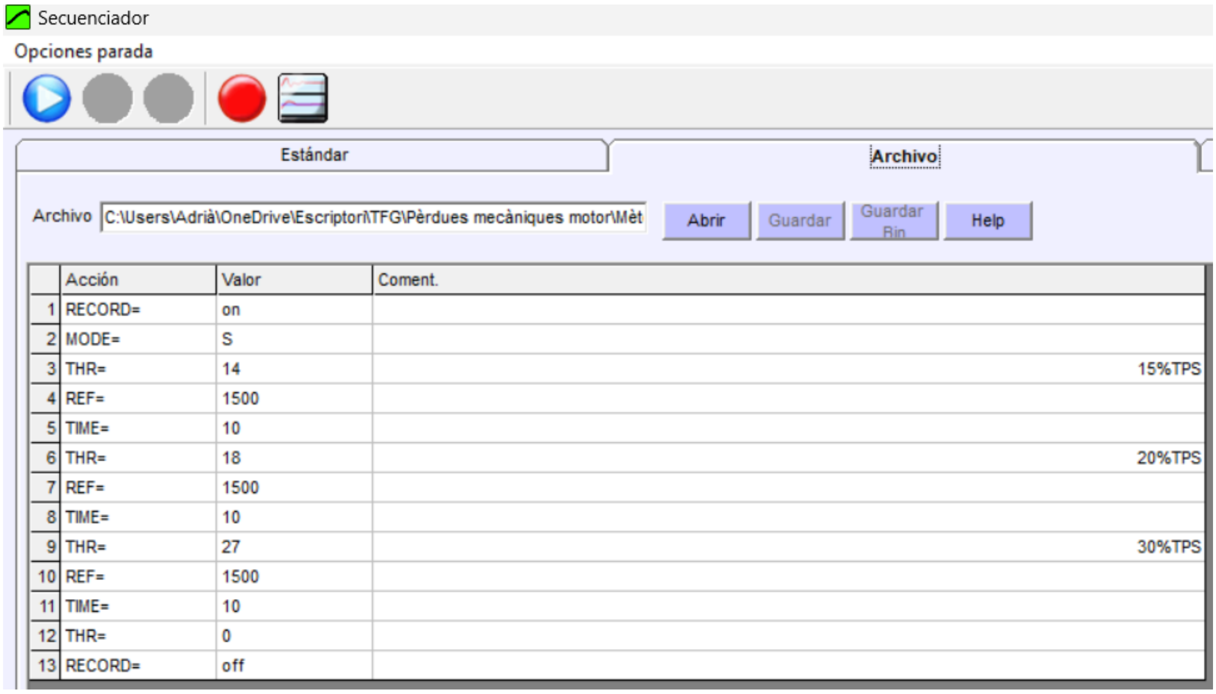


Figura 37. Seqüenciador per edició de fitxers SportDyno v4.1.

3.3.3. Oscil·loscopi per a PC

A automoció, la majoria de senyals elèctriques produïdes en els sistemes de comunicació entre unitats electròniques com el CANBUS, en les bobines dels injectors, en sensors com el CKP, CMP, MAF o sonda lambda són senyals normalment de corrent contínua que varien de voltatge molt ràpidament en el temps. És per aquesta raó que per tasques de diagnosi, investigació i estudi de diferents components elèctrics d'un motor és imprescindible la utilització d'un oscil·loscopi per davant d'un polímetre.

En el present projecte, la implementació d'un oscil·loscopi amb connexió USB a ordinador és de gran utilitat per a la realització de proves experimentals i en el calibratge dels diferents sensors instal·lats.

Les característiques tècniques més importants per escollir un oscil·loscopi adequat per al banc de proves són el nombre de canals, l'amplada de banda, la taxa de mostreig i el màxim voltatge de mesura.

- El nombre de canals de l'oscil·loscopi fa referència al nombre de senyals que l'instrument és capaç d'adquirir simultàniament.

- L'amplada de banda, expressada en Hz, és la rapidesa amb que l'oscil·loscopi pot mesurar una senyal. A més amplada de banda, més ràpides podran ser les senyals que es podran visualitzar a l'oscil·loscopi.

- Taxa de mostreig, mesurada en mostres per segon o *samples per second* (Sa/s), fa referència a les mostres per segon que l'oscil·loscopi és capaç de prendre de la senyal mesurada. Una major taxa de mostreig comporta una major precisió de la senyal adquirida.

- El voltatge màxim d'entrada fa referència al valor màxim en Volts que l'oscil·loscopi és capaç de mesurar.

S'escull un oscil·loscopi digital de la marca RS PRO, model 2205864, el qual es mostra a la *Figura 38*. L'aparell disposa de quatre canals analògics, amb capacitat de mesurar dos senyals simultàniament i una amplada de banda de 70 MHz. Cal destacar que l'oscil·loscopi ofereix una taxa de mostreig de 1 GSa/s (10^9 mostres per segon) i un voltatge màxim d'entrada als canals de 35 V, fet que el fa ideal per aplicacions amb motors d'encesa provocada (MEP) i d'encesa per compressió (MEC).

Figura 38. Oscil·loscopi per a PC RS PRO. (Font: https://es.rs-online.com/web/p/osciloscopios/2205864)

L'oscil·loscopi disposa d'un programari propi per a la interpretació de les senyals. A l'eix vertical es mostra el voltatge de la senyal, mentre que a l'eix horitzontal es representa l'escala de temps, permetent la mesura de paràmetres importants de la senyal com la freqüència, el voltatge màxim i mínim, voltatge pic a pic o el període de la senyal.

A continuació, a la *Figura 39*, es mostra una senyal adquirida amb l'oscil·loscopi d'un injector de combustible del motor del banc de proves. A la dreta de la interfície del programa, es permet ajustar l'escala de voltatge i l'escala de temps, conjuntament amb el tipus de senyal elèctrica (corrent contínua o alterna), l'atenuació i el mode de dispar o *trigger*.

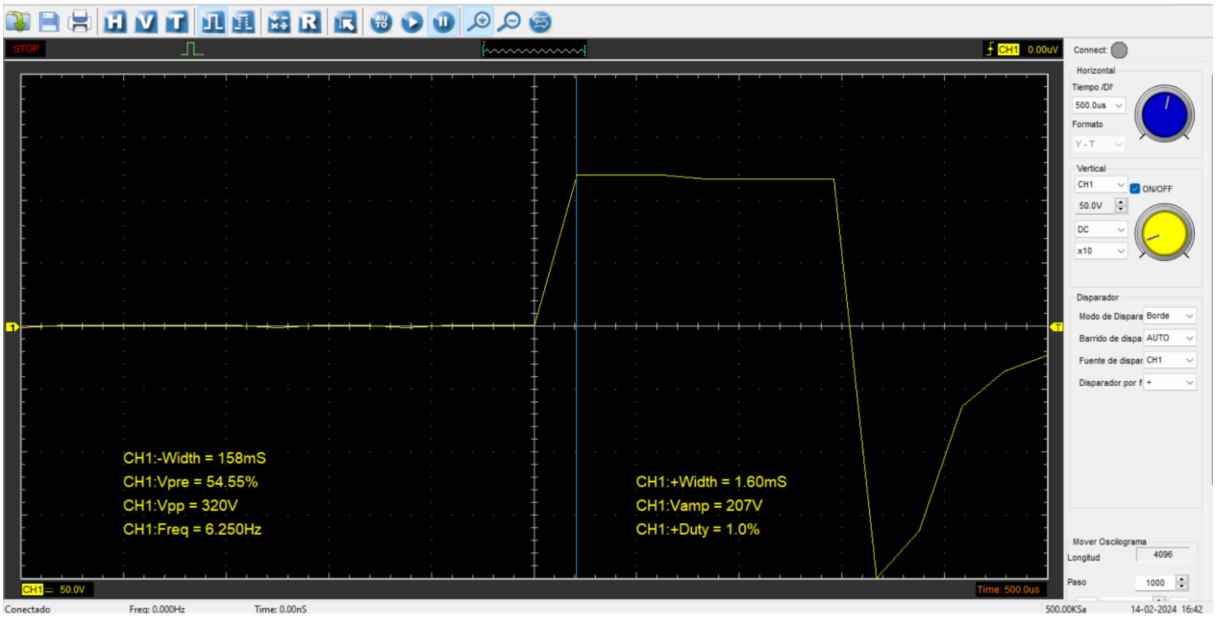


Figura 39. Visualització de senyal amb oscil·loscopi per a PC.

4. CALIBRATGE INSTRUMENTACIÓ

Per tal de garantir el correcte funcionament de la instrumentació instal·lada al banc de proves i comprovar la veracitat i precisió de les dades obtingues es realitza un procés de calibratge dels sensors de massa d'aire aspirada, sonda lambda i sondes de temperatura termoparell de tipus K. Per altra banda, en aquest capítol també es detalla el procés de configuració del control de l'accelerador mitjançant el servomotor i la configuració del controlador PID que utilitza el sistema d'adquisició de dades per a governar el conjunt motor-fre.

4.1. Sensor MAF

El calibratge del sensor MAF es realitza utilitzant el banc de flux del qual es disposa al laboratori de motors tèrmics. L'objectiu és l'obtenció de la corba que relacioni el cabal màssic d'aire que circula a través del cabalímetre (kg/h) i el voltatge de sortida (V) del sensor. Aquesta corba s'introduirà al software d'adquisició de dades per tal de monitoritzar el cabal màssic d'aire a l'admissió del motor.

El procediment de calibratge precisa de la utilització d'un banc de flux per tal de poder ajustar diferents valors de cabals volumètrics d'aire, un multímetre per a llegir els valors de voltatge que proporciona el sensor, dues fonts d'alimentació destinades a l'alimentació de 12 V i de 5 V de referència del sensor, un higròmetre i un baròmetre per a mesurar les condicions ambientals de l'assaig.

El muntatge experimental de la prova de calibratge, és el que es mostra a la *Figura 40*.

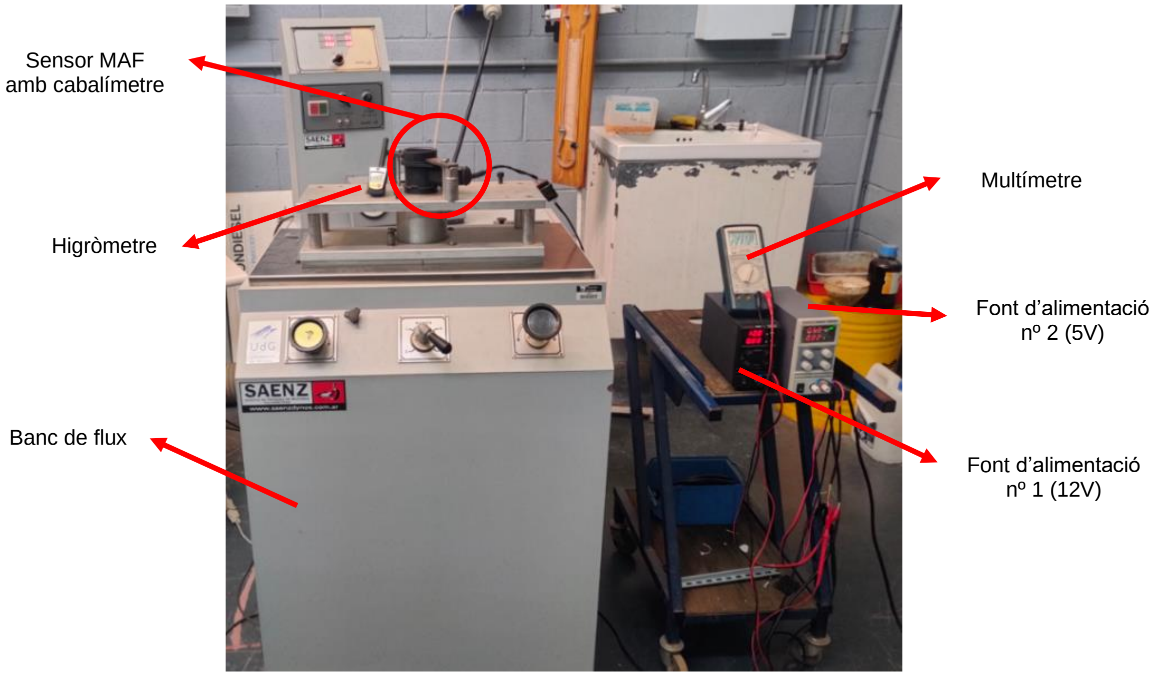


Figura 40. Muntatge del calibratge del sensor MAF.

La connexió efectuada per al procés de calibratge es detalla a la *Taula 8* mostrada a continuació:

Color cablejat	Descripció	Connexió
Verd	12 V alimentació sensor	Font d'alimentació 1
Marró	Terra (GND)	Negatius fonts d'alimentació i multímetre
Blanc	5 V referència sensor	Font d'alimentació 2
Groc	Senyal de sortida (0-5 V)	Positiu multímetre

Taula 8. Connexions calibratge sensor MAF.

Es realitzen dos assajos al banc de flux on s'obtindran per diferents cabals volumètrics (m^3/min) el voltatge de sortida del sensor MAF. Els resultats obtinguts del primer assaig es mostren a la *Taula 9* i els obtinguts del segon assaig a la *Taula 10*:

Assaig 1		
Cabal volumètric (m3/min)	Cabal màssic (kg/h)	Voltatge (V)
0,000	0,000	1,013
0,124	9,047	1,615
0,150	10,943	1,839
0,579	42,241	2,270
0,888	64,785	2,478
1,189	86,745	2,698
1,513	110,382	2,844
1,960	142,994	3,061
2,954	215,512	3,499
4,347	317,139	3,873
5,476	399,507	4,128
6,551	477,934	4,300

Condicions ambientals	
Temperatura ambient (ºC)	19
Humitat relativa (%)	27,10%
Pressió ambiental (bar)	1,019
Densitat referència (kg/m3)	1,216

Taula 9. Resultats primer assaig calibratge MAF.

Assaig 2		
Cabal volumètric (m3/min)	Cabal màssic (kg/h)	Voltatge (V)
0,000	0,000	1,010
0,324	23,613	1,914
0,568	41,396	2,187
1,115	81,262	2,593
1,716	125,064	2,945
2,277	165,950	3,201
2,805	204,431	3,437

3,686	268,640	3,701
4,565	332,702	3,909
5,094	371,256	4,031
5,989	436,485	4,191
6,309	459,807	4,250
7,011	510,969	4,350

Condicions ambientals	
Temperatura ambient (ºC)	19,3
Humitat relativa (%)	28,00%
Pressió ambiental (bar)	1,019
Densitat referència (kg/m3)	1,215

Taula 10. Resultats segon assaig calibratge MAF.

Per a obtenir el cabal màssic (kg/h) a partir del cabal volumètric (m^3/min) cal calcular la densitat de l'aire tenint en compte les condicions ambientals dels dos assajos. La densitat de de referència es calcula seguint la Llei dels gasos ideals, descrita a l'Equació 1:

$$P * V = m * R * T \qquad (Eq.1)$$

On **P** és la pressió ambiental de l'assaig (N/m^2), **V** és el volum del gas (m^3), **m** és la massa del gas (kg), **R** és la constant dels gasos ideals (R = 287 N*m/kg*K) i **T** és la temperatura ambiental de l'assaig (ºK).

Sabent que la densitat és la magnitud referida a la quantitat de massa en un determinat volum, a partir de l'Equació 1, s'obté la densitat mitjançant la fórmula expressada en l'Equació 2:

$$\rho = \frac{P}{R * T} \qquad (Eq.2)$$

Finalment la conversió del cabal volumètric (m^3/min) a cabal màssic (kg/h) es realitza a partir de la fórmula de l'Equació 3:

$$C_m = C_v * \rho * 60 \qquad (Eq.3)$$

On $\mathbf{C_m}$ és el cabal màssic (kg/h), $\mathbf{C_v}$ és el cabal volumètric (m^3/min) i $\boldsymbol{\rho}$ és la densitat de l'aire (kg/m^3).

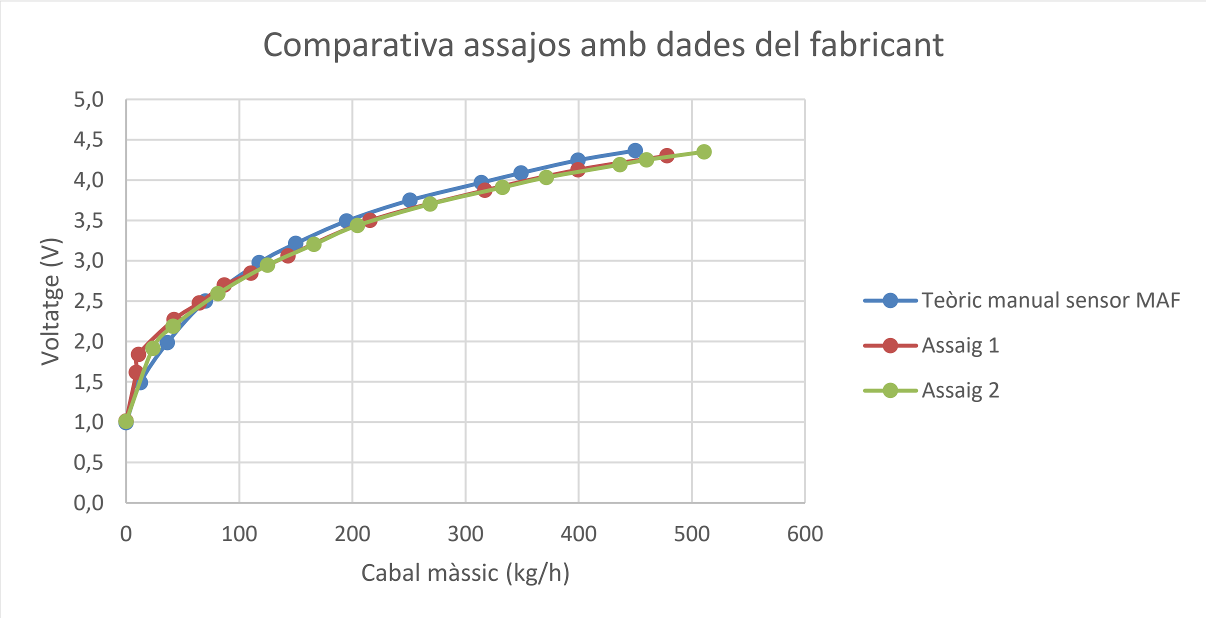
El catàleg del fabricant (Bosch) proporciona les dades teòriques del voltatge de sortida del sensor en funció del cabal màssic d'aire que circula a través del cabalímetre. A continuació, a la *Taula 11*, es mostren els valors de cabal màssic (kg/h) i voltatge (V) donats pel fabricant:

Dades teòriques manual sensor MAF (Bosch)	
Cabal màssic (kg/h)	Voltatge (V)
0,000	0,992
12,617	1,488
36,449	1,984
70,093	2,500
117,757	2,976
150,000	3,214
194,860	3,492
250,935	3,750
314,019	3,968
349,065	4,087
399,533	4,246
450,000	4,365

Taula 11. Dades teòriques sensor MAF (Bosch).

A partir dels resultats obtinguts dels dos assajos realitzats i les dades teòriques del fabricant s'elabora una gràfic per a determinar quin dels assajos ha donat uns resultats més fiables i obtenir finalment la corba de calibratge que s'introduirà al software d'adquisició de dades.

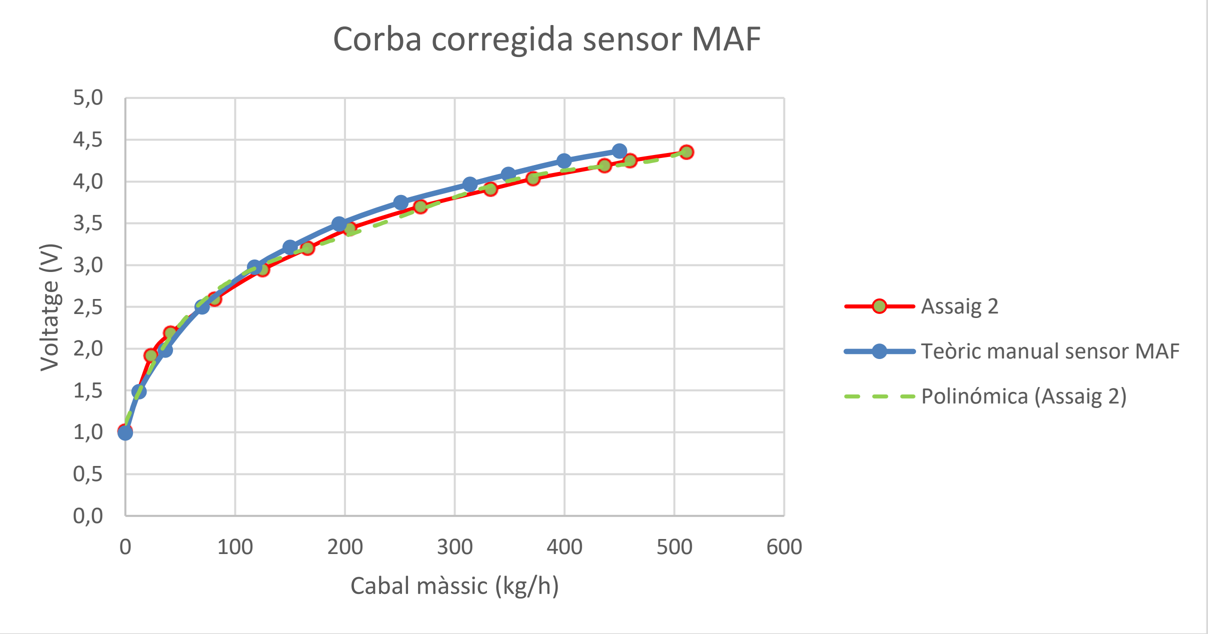
En el *Gràfic 1* es representa a l'eix vertical el voltatge de sortida (V) del sensor i a l'eix horitzontal el cabal màssic d'aire (kg/h). En blau es representen les dades teòriques del sensor, en vermell les dades obtingudes del primer assaig realitzat i en verd les del segon assaig.



Gràfic 1. Comparativa resultats assajos amb dades teòriques sensor MAF.

El *Gràfic* 1 mostra que les dades obtingudes del segon assaig s'ajusten més a la corba proporcionada pel fabricant. Per a cabals màssics petits, la dispersió és major en els valors obtinguts del primer assaig. És per aquest motiu, que el primer assaig es decideix desestimar i es continua amb els valors obtinguts del segon assaig.

Seguint amb les dades obtingudes del segon assaig, s'elabora una corba corregida mostrada en el *Gràfic 2* amb l'objectiu d'establir una tendència dels punts experimentals.



Gràfic 2. Corba corregida sensor MAF.

L'equació de la corba corregida que relaciona el voltatge (V) i el cabal màssic (kg/h) és l'expressada en l'Equació 4:

$$V = 1{,}179 * 10^{-12} * {C_m}^5 - 1{,}722 * 10^{-9} * {C_m}^4 + 9{,}380 * 10^{-7} * {C_m}^3 - 2{,}405 * 10^{-4} * {C_m}^2 + 3{,}369 * 10^{-2} * C_m + 1{,}1012 \qquad (Eq. 4)$$

On **V** és el voltatge de sortida del sensor (V) i **C_m** és el cabal màssic d'aire (kg/h)

Finalment s'elabora la *Taula 12* aplicant l'Equació 4 on es mostren els valors que s'introduiran al software de control i adquisició de dades:

Cabal màssic (kg/h)	Voltatge (V)
0	1,101
40	2,120
80	2,671
120	2,975
160	3,173

200	3,348
240	3,530
280	3,721
320	3,900
360	4,043
400	4,137
440	4,192
480	4,260
520	4,442
560	4,911

Taula 12. Dades per introduir al software.

Les dades s'introdueixen al software d'adquisició de dades on també es crea un canal calculat per a tenir en compte les condicions de la sala on es troba el motor. Amb el motor en funcionament, la temperatura de la sala augmenta comportant una disminució de la densitat de l'aire.

Conjuntament amb un altre canal calculat que obté la densitat de l'aire de la sala de proves a partir de les dades proporcionades per l'estació meteorològica s'utilitza l'expressió de l'Equació 5 per a calcular el cabal màssic d'aire a l'admissió del motor:

$$C_{m\,real} = C_{m\,ref} * \frac{\rho_{real}}{\rho_{ref}} \qquad (Eq. 5)$$

On $\mathbf{C_{m\,real}}$ és el cabal màssic real a l'admissió del motor (kg/h), $\mathbf{C_{m\,ref}}$ és el cabal màssic de referència obtingut a partir de l'assaig al banc de flux (kg/h), $\boldsymbol{\rho_{real}}$ és la densitat de la sala on es troba el motor (kg/m^3) i $\boldsymbol{\rho_{ref}}$ és la densitat de la sala on es realitza l'assaig al banc de flux (kg/h).

Al software SportDyno v4.1 es crea el canal calculat (C80) per a determinar la densitat de l'aire a la sala on es troba el motor. La fórmula utilitzada és la següent:

$$C80 = \frac{CD6 * 100}{287 * (CD7 + 273)}$$

Finalment es crea el canal calculat C82 per a obtenir el cabal màssic d'aire a l'admissió del motor. La fórmula introduïda és la següent:

$$C82 = C4C * \frac{C80}{1.216}$$

4.2. Sonda lambda

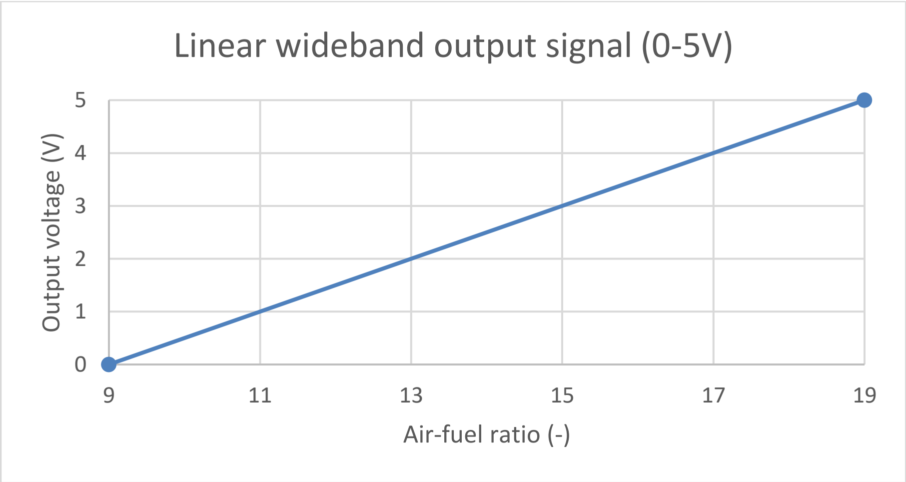
El sensor d'oxigen de banda ample disposa d'un controlador per el condicionament, tractament i lectura de la senyal proporcionant un voltatge de sortida de 0 a 5 Volts.

Aquest rang de voltatge manté una relació lineal amb la relació aire-combustible (AFR) oferint un rang de mesura de 9 a 19 AFR. L'expressió que relaciona el voltatge de sortida i la relació aire-combustible és la descrita a l'Equació 6:

$$AFR = 2 * V_{out} + 9 \qquad (Eq.6)$$

L'expressió anterior s'introdueix al software d'adquisició de dades, concretament al canal 4B, per tal de monitoritzar a temps real la relació aire-combustible del motor del banc de proves.

L'expressió lineal que relaciona el voltatge de sortida del sensor d'oxigen amb la relació AFR és la que es mostra al *Gràfic 4*, tot seguit:



Gràfic 3. Relació voltatge - AFR sonda lambda SportDevices.

La comprovació de la veracitat de les dades obtingudes amb el sistema d'adquisició de dades SP6 es realitza mitjançant un detector de gasos de la marca MAHA, model MGT 5, capaç de mesurar el factor lambda dels gasos d'escapament a partir d'una sonda que s'introdueix directament al tub d'escapament del motor. El detector de gasos utilitzat es mostra a la *Figura 41*.

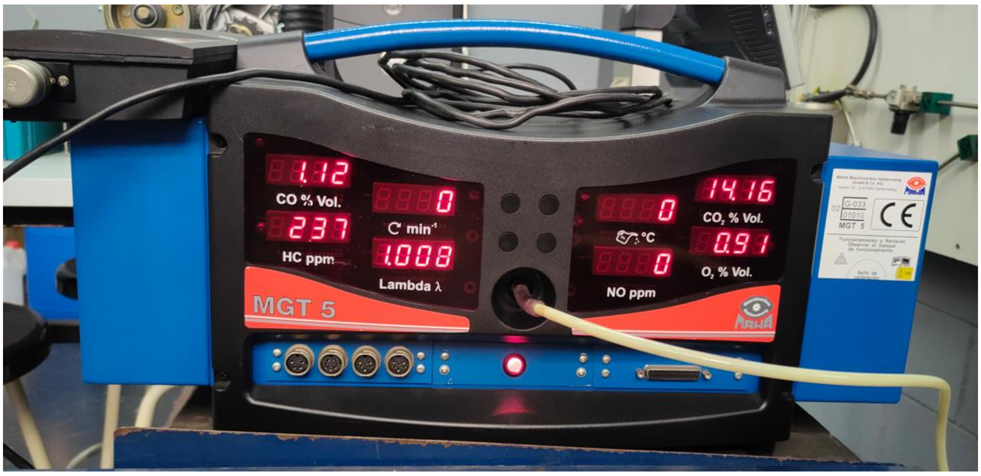


Figura 41. Detector de gasos MAHA MGT 5.

L'expressió que relaciona el factor lambda amb la relació aire-combustible és la que es descriu a l'Equació 7:

$$\lambda = \frac{AFR}{AFR_e} \qquad (Eq. 7)$$

On **AFR** és la relació aire-combustible obtinguda a partir de la mesura efectuada pel sensor d'oxigen i **AFR_e** és la relació aire-combustible estequiomètrica que pren un valor constant de 14,7.

S'observa que la relacions AFR obtingudes amb la sonda lambda connectada al mòdul SP6 i el detector de gasos són les mateixes. Es conclou que el sensor d'oxigen amb controlador de la marca SportDevices funciona de manera correcte i precisa.

4.3. Sondes de temperatura

El calibratge de les sondes de temperatura termoparell de tipus K es realitza amb un calibrador de temperatura de la marca CEM, model BX-150, el qual es mostra a la *Figura 42*. Es tracta d’una font de calor que permet comprovar la precisió de les sondes de temperatura dins d’un rang de 33 ºC fins a 300 ºC.

Simplement, s’ajusta la font de calor a la temperatura desitjada de prova i s’insereix l’extrem de la sonda de temperatura a un dels varis orificis del qual disposa el calibrador i es realitza la comparació entre la temperatura de prova i la temperatura que s’obté a partir del mòdul d’adquisició de dades.

Figura 42. Calibrador de temperatura CEM BX-150.

S’observa que la temperatura de prova i la temperatura que es monitoritza no coincideixen. És per aquest motiu que es calcula un factor d’escala que s’introdueix al software per aconseguir la màxima precisió en la mesura de temperatures.

A continuació, a la *Taula 13* es mostren els resultats obtinguts del calibratge de les sondes de temperatura termoparell de tipus K i el factor d’escala obtingut a introduir al programari.

	Temperatura de prova (ºC)	Temperatura adquisició (ºC)	Factor d'escala
Cilindre 1	317	296	1,0709
Cilindre 3	297,5	296,1	1,0047
Cilindre 4	298,7	296	1,0091
Temperatura entrada motor	100,2	96,3	1,0405
Temperatura sortida motor	99,9	98,7	1,0122

Taula 13. Resultats calibratge sondes de temperatura.

4.4. Configuració accelerador

El software de control SportDyno incorpora una finestra per a configurar l'accelerador governat pel servomotor. Dins d'aquesta finestra és possible configurar les posicions de començament i acabament del servomotor.

Per tal de trobar l'ajustatge de la posició de l'accelerador es mou la barra lliscant lentament observant les dades de percentatge d'obertura de la papallona d'admissió proporcionades pel sensor TPS amb connexió a la centraleta del motor.

S'observa que un 0% de càrrega de l'accelerador correspon a una posició del servomotor del 60%. Per tant l'ajust de posició mínima del servomotor s'ajusta a un 60%. Aquesta posició depèn de l'arquitectura del motor i del posicionament del servomotor. L'ajust de posició màxima, s'ajusta a un 100%.

Un altre paràmetre a tenir en compte és la velocitat d'obertura i tancament del servomotor. S'ajusta el paràmetre a 1, tant en l'obertura com en el tancament. D'aquesta manera el servomotor es mourà el més lent possible, garantint un moviment segur i precís.

La configuració de l'accelerador introduïda al software d'adquisició de dades és la que es mostra a la *Figura 43*.

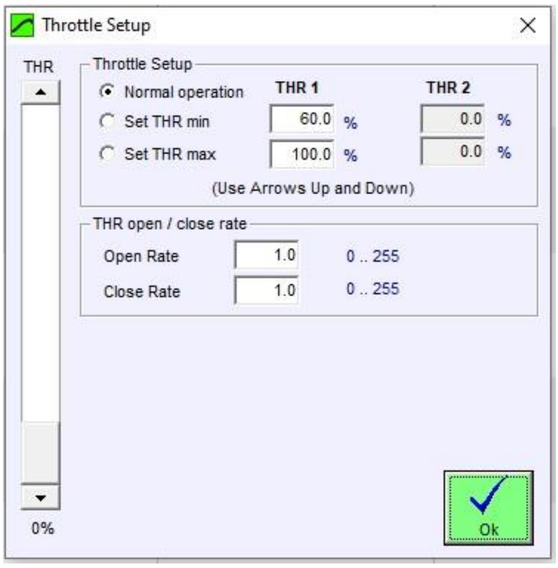


Figura 43. Configuració accelerador SportDyno v4.1.

4.5. Configuració del PID

El mòdul d'adquisició de dades SP6 incorpora un controlador PID. Un controlador PID corregeix l'error entre un valor mesurat, normalment per un sensor, i el valor que es vol obtenir. El controlador regula la sortida en funció de la diferència entre la senyal d'entrada i la senyal de referència.

Un controlador PID el composen tres paràmetres: part proporcional, part integral i part derivativa. Modificant aquestes variables s'aconsegueix que la diferència entre la consigna o valor objectiu i la sortida o valor mesurat sigui la mínima possible. A l'Equació 8 es detalla l'expressió característica d'un controlador PID.

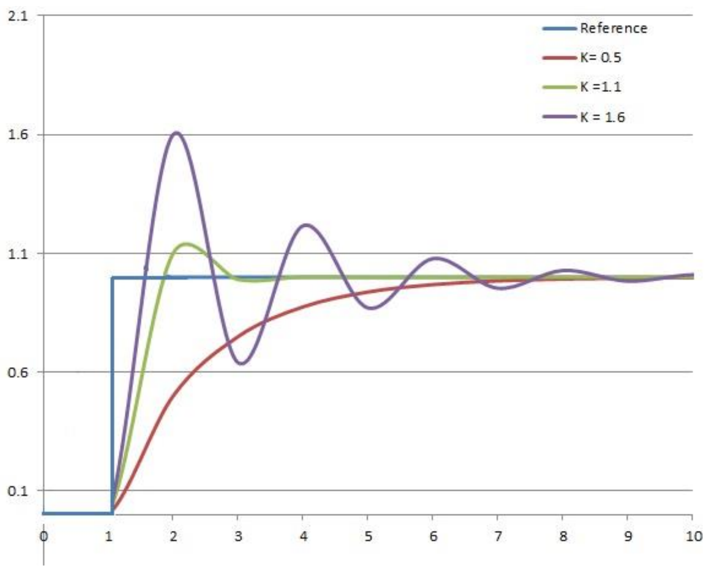
$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)\, d\tau + K_d \frac{de(t)}{dt} \qquad (Eq. 8)$$

On $\mathbf{K_p}$ és el guany proporcional, $\mathbf{K_i}$ és el guany integral, $\mathbf{K_d}$ és el guany derivatiu, **e(t)** és l'error (diferència entre el valor objectiu i real), **t** és el temps o temps instantani (present) i **τ** és la variable d'integració (agafa valors des de temps "0" fins a temps present "t").

Per a l'aplicació del controlador al banc de proves de motors, els coeficients del controlador PID determinen la resposta del fre a la diferència entre la velocitat desitjada i la velocitat real o error.

El controlador PID que incorpora el mòdul SP6 s'ajusta mitjançant la constant proporcional o K_p, el temps integral o T_i i el temps derivatiu o T_d.

L'acció proporcional (K_p) dona una senyal de control proporcional a l'error. Augmentar el valor de K_p accelera la resposta del sistema, però si s'augmenta en excés provoca inestabilitat. La constant proporcional s'ha d'ajustar buscant l'equilibri entre la rapidesa de la resposta i l'estabilitat del sistema. No obstant, l'acció proporcional no és capaç d'eliminar completament l'error en estat estacionari, que és la diferència constant entre la velocitat desitjada i la velocitat real quan el sistema està en règim permanent. La variació de la resposta a un sistema davant el canvi del guany proporcional és la que es mostra al *Gràfic 4*, a continuació:

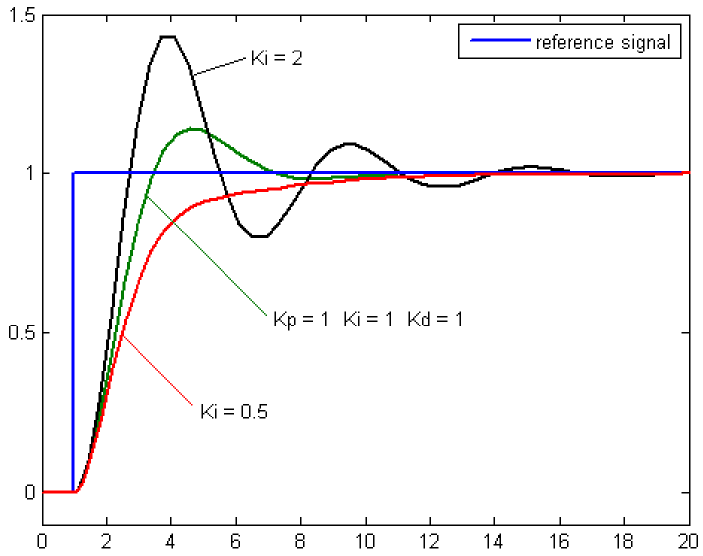


Gràfic 4. Variació de la resposta d'un sistema al canvi del guany proporcional. (Font: https://en.wikipedia.org/wiki/Proportional%E2%80%93integral%E2%80%93derivative_controller)

L’objectiu de la part integral (K_i) és eliminar l’error estacionari per entrades de tipus graó. L’acció integral s’utilitza perquè la velocitat desitjada i la velocitat real convergeixin. Com s’ha esmentat amb anterioritat, l’ajust de la part integral es fa mitjançant el temps integral. La relació entre la constant integral (K_i) i el temps integral es la detallada a l’Equació 9:

$$K_i = \frac{K_p}{T_i} \qquad (Eq.9)$$

Si el valor de T_i disminueix, la velocitat desitjada i real convergeixen més ràpid. No obstant, valors massa baixos de T_i a la pràctica fan que el controlador funcioni pitjor. Apareixen oscil·lacions més accentuades i s’obté pitjor resposta dinàmica o adaptabilitat al canvi de la consigna. Per tant, no es recomanen valors inferior a 1. En el *Gràfic 5*, es mostra el canvi en la resposta d’un sistema si es modifica la constant integral.



Gràfic 5. Variació de la resposta d'un sistema al canvi de la constant integral. (Font: https://en.wikipedia.org/wiki/Proportional%E2%80%93integral%E2%80%93derivative_controller)

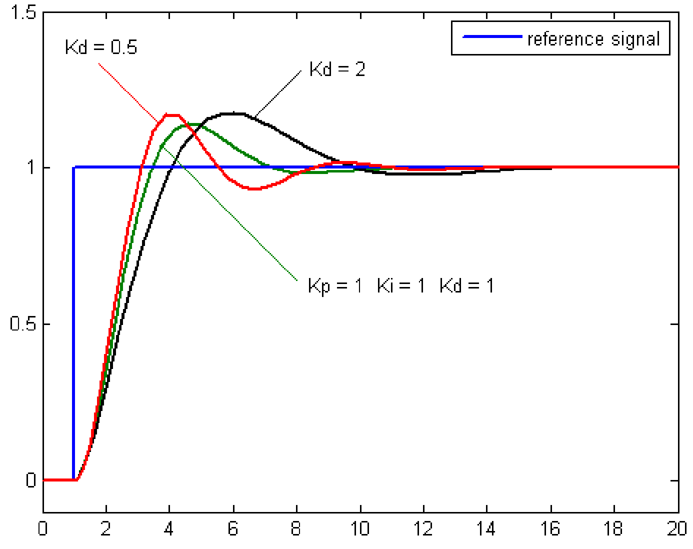
L’acció derivativa (K_d) proporciona velocitat a la resposta. Només és eficaç en períodes transitoris. És per aquesta raó que mai s’utilitza sola, sempre va acompanyada de l’acció proporcional (en controladors PD) o de l’acció proporcional i integral (en controladors PID).

L'ajust de l'acció derivativa es realitza a partir del temps derivatiu (T_d). La relació entre ambdós paràmetres és la descrita a l'Equació 10:

$$K_d = K_p * T_d \qquad (Eq. 10)$$

El paràmetre T_d té el caràcter de previsió, fet que es tradueix en una major rapidesa de l'acció de control. Per altra banda, té l'inconvenient important que amplifica les senyals de soroll i pot provocar que l'actuador entri en un estat de saturació.

Quan una acció de control derivativa s'afegeix a un controlador proporcional, permet obtenir un controlador d'alta sensibilitat, és a dir, que respon a la velocitat del canvi de l'error i produeix una correcció significativa abans que aquesta magnitud augmenti en excés. Tot i que el control derivatiu no afecta directament a l'error en estat estacionari, afegeix esmorteïment al sistema i, per tant, permet un valor més alt del guany, provocant una millora en la precisió en estat estable. El *Gràfic 6*, mostra com canvia la resposta d'un sistema si s'augmenta o es disminueix el valor de la constant derivativa.



Gràfic 6. Variació de la resposta d'un sistema al canvi de la constant derivativa. (Font: https://en.wikipedia.org/wiki/Proportional%E2%80%93integral%E2%80%93derivative_controller)

Augmentar el valor del temps derivatiu es tradueix en una millora de la inestabilitat però s'afegeix lentitud en el temps de resposta. Pel contrari, si es disminueix el valor del paràmetre augmenta la inestabilitat, però s’afegeix velocitat al temps de resposta. Cal buscar el valor òptim per a intentar trobar l’equilibri.

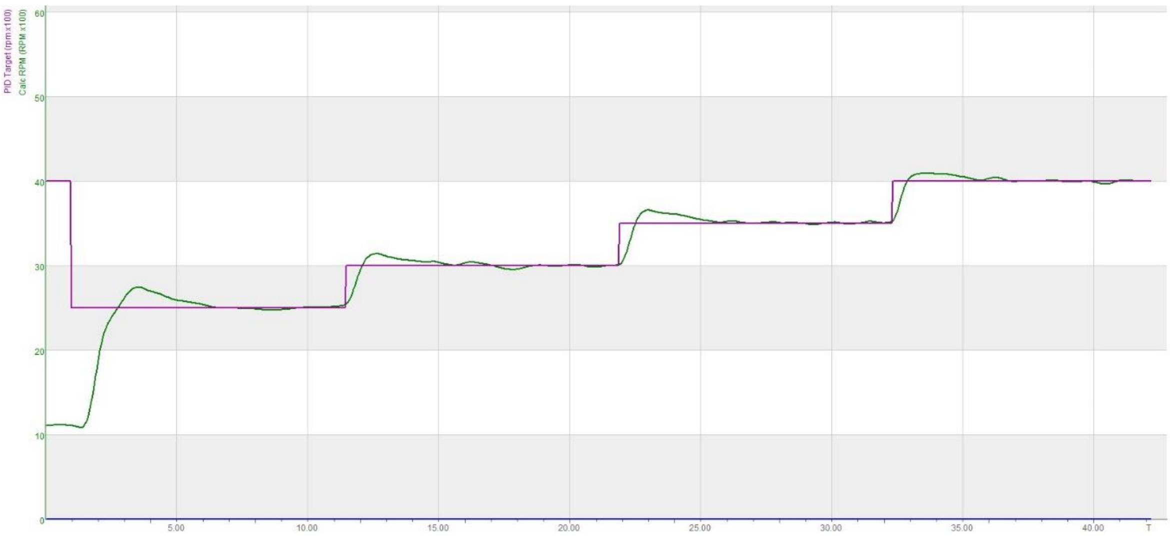
És complicat trobar els paràmetres òptims del controlador PID, a la vegada que imprescindible. Trobar els paràmetres, a la pràctica, es realitza a mode de prova i error o utilitzant un mètode de sintonització empírica, com el mètode de Ziegler-Nichols.

Al banc de proves, s’ajusta el controlador PID a mode de prova i error, observant la resposta davant entrades de tipus graó. Finalment, s’arriba a la conclusió que els valors més òptims del controlador són els que es mostren a la *Taula 14*.

Configuració PID	
Kp	1,2
Ti	1,5
Td	0,04

Taula 14. Valors del controlador PID.

A continuació, en el *Gràfic 7*, es mostren els resultats obtinguts de l’ajustatge del controlador PID. A l’eix vertical, es representen les revolucions del motor (rpm) i l’eix horitzontal és una escala de temps, on es representa el temps de duració del cicle de prova (s). De color lila, es representa la consigna o *PID Target*, i en verd la resposta del sistema davant l’entrada de tipus graó.



Gràfic 7. Resultats ajustatge controlador PID.

Tal i com s’observa en el *Gràfic 7*, la resposta del sistema a una entrada de tipus graó és bona, bastant ràpida i prou estable. Després de provar moltes configuracions del controlador PID, s’arriba a la conclusió que la inestabilitat és impossible d’eliminar. Al ser un banc de proves de tipus estacionari amb fre dinamomètric, la inèrcia del sistema és molt baixa, fet que provoca que l’acció de control del PID sobre el fre sigui brusca, comportant una oscil·lació que s’ha reduït el màxim possible però que resulta impossible d’eliminar.

5. ASSAJOS AL LABORATORI

5.1. Determinació del cabal dinàmic d'un injector

5.1.1. Objectiu de la prova

L'objectiu de la prova és comprovar, estudiar el funcionament i obtenir la corba de cabal dinàmic de l'injector del motor SEAT AFT 1.6 litres, per tal de determinar la quantitat de combustible injectat al motor.

La injecció del motor SEAT AFT 1.6 litres és de tipus multipunt seqüencial. Aquest sistema d'injecció es caracteritza per disposar d'un injector per a cada cilindre, els quals són governats de manera independent per la unitat de control electrònica.

Per a la realització de la prova s'utilitza una màquina capaç de provar i netejar injectors. Es tracta del model CT400 de la marca AUTOOL.

La vàlvula d'injecció és el model 0 218 156 374 de la marca BOSCH amb una pressió de funcionament de 3 bar i un cabal estàtic mig de 154,3 g/min amb combustible n-heptà.

5.1.2. Fonament teòric

La funció d'un injector de combustible és introduir una determinada quantitat de combustible a la cambra de combustió de manera polvoritzada, distribuint-lo el més homogèniament possible dins de l'aire contingut en la cambra.

Un injector convencional de combustible disposa d'una connexió elèctrica de dos pins. Un d'ells es connecta a l'alimentació de 12 V de la bateria. L'altre pin, corresponent al negatiu, es connecta a la unitat de control electrònica del motor. La ECU proporciona un camí de massa a l'injector a través d'un transistor excitador. Quan el transistor està activat, circula corrent a massa a través del bobinat de l'injector i el transistor, obrint la vàlvula d'injecció.

El temps de treball de l'injector de combustible es pot expressar en mil·lisegons d'amplada d'impuls i indica la quantitat de combustible subministrat als cilindres del motor. Una major amplada d'impuls significa més quantitat de combustible, si es manté la pressió de combustible invariable.

Quan el temps de treball de l'injector comença, la intensitat del corrent elèctric va augmentant gradualment, comportant un augment de la força magnètica generada al bobinat de l'injector. Aquesta força magnètica estira l'agulla de l'injector provocant el moviment d'obertura. Aquest moviment d'obertura, ocupa un cert instant del temps de treball de l'injector, on no s'està injectant combustible ja que la força magnètica ha d'augmentar per a ser capaç de vèncer les inèrcies que apareixen a l'iniciar el moviment dels cossos mecànics de la vàlvula des d'una posició inicial de repòs, i la fricció viscosa generada a partir de la viscositat del combustible. En el moment en què la força magnètica és suficient per a vèncer els efectes anteriors, l'agulla es desplaça, quedant enganxada al nucli de la bobina. És en aquest instant, quan l'injector està completament obert i el combustible és polvoritzat. Les parts més importants d'un injector de combustible es mostren a la *Figura 44*.

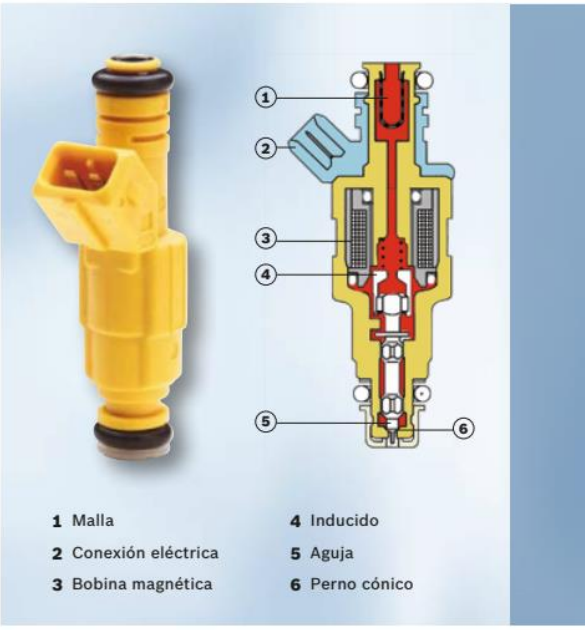


Figura 44. Parts d'un injector de combustible. (Font: Sistemas de Inyección Electrónica. Bosch)

A continuació, a la *Figura 45*, es mostra una imatge de la senyal elèctrica característica d’un injector convencional de gasolina, on es senyalen també les diferents etapes de treball:

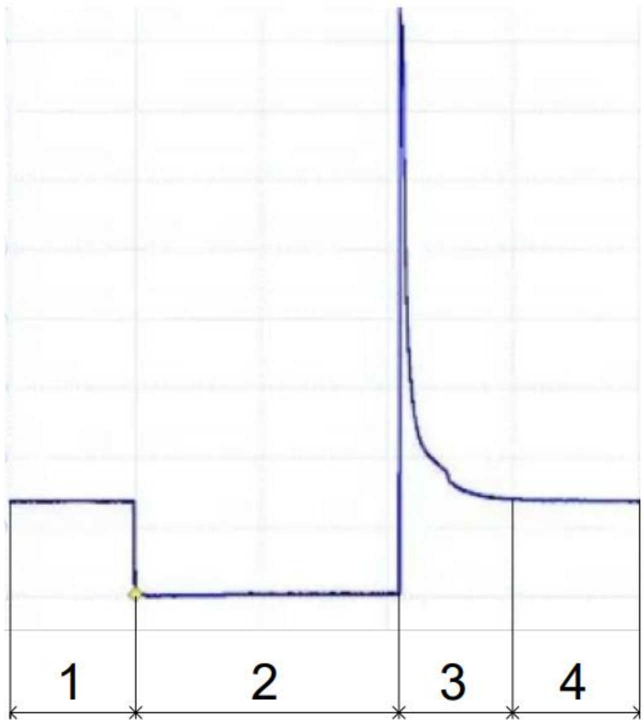


Figura 45. Senyal característica d'un injector i etapes de treball.

En la primera fase, el transistor excitador està desactivat. L’injector és alimentat per la tensió de la bateria del vehicle. A continuació, el transistor excitador s’activa, desplaçant l’agulla de l’injector i iniciant el moviment d’obertura. Quan el moviment d’obertura finalitza, comença l’alimentació de combustible.

Immediatament després de finalitzar el temps d’injecció de combustible, el transistor excitador es desactiva i interromp el pas de corrent. En aquest instant, el voltatge augmenta considerablement fins a assolir un valor molt superior a la tensió d’alimentació del vehicle. Aquest fet es produeix perquè la bobina de l’injector ha estat sotmesa al pas de corrent i ha quedat magnèticament carregada. En el moment en què s’interromp el pas de corrent, el camp magnètic s’anul·la però hi queda una acumulació d’energia. A causa de l’autoinducció, es genera un voltatge entre els terminals de la bobina de l’injector que intenta que el corrent segueixi circulant en el mateix sentit. En aquest moment, es produeix el pic de tensió que s’observa a la *Figura 45*.

Finalment, l'injector queda alimentat a la tensió de la font d'alimentació fins a la pròxima injecció de combustible.

5.1.3. Procediment experimental

Per tal d'obtenir la corba de cabal dinàmic de l'injector es realitzen proves amb la màquina AUTOOL CT400 aprofitant els diferents modes de prova que incorpora. El primer mode s'anomena *idle speed test* i correspon a la injecció de combustible en un estat de ralentí del motor. Per a aquest mode de prova, el temps de treball de l'injector és ajustable en un rang de 0 a 20 mil·lisegons. El segon mode s'anomena *medium speed test* i correspon a la injecció a mitges revolucions. Es permet ajustar el temps d'injecció en un rang de 0 a 7.5 mil·lisegons. Finalment, el tercer mode que s'utilitza per a les proves rep del nom de *high speed test* i correspon a la injecció de combustible quan el motor funciona a altes revolucions. L'impuls d'injecció és ajustable en un rang de 0 a 4 mil·lisegons.

Per cadascun dels tres modes de prova descrits anteriorment, es realitza una mesura del volum d'injecció en un temps determinat, utilitzant com a fluid de prova alcohol isopropílic, per a diferents temps de treball de l'injector. Finalment, amb l'ajuda de l'oscil·loscopi per a ordinador RS Pro, s'adquireix la freqüència d'injecció amb l'objectiu de determinar el nombre d'injectades.

A continuació, a la *Figura 46*, es mostra el muntatge experimental de la prova. A la dreta de la imatge es mostra la màquina AUTOOL CT400 amb l'injector de combustible del motor del banc de proves muntat.

Figura 46. Muntatge experimental prova d'injecció de combustible.

5.1.4. Càlculs i resultats

A partir de les dades adquirides de volum d'injecció, temps de treball de l'injector, temps d'injecció i freqüència d'injecció s'elabora una taula per a calcular la quantitat de combustible per cada mil injeccions.

El nombre d'injectades es calcula a partir de l'expressió descrita a l'Equació 11:

$$n^{\underline{o}}\ injectades = f * t * 60 \qquad (Eq. 11)$$

On **f** és la freqüència d'injecció (Hz) i **t** és el temps total d'injecció de combustible (minuts).

La quantitat de combustible per cada mil injeccions es calcula amb la fórmula de l'Equació 12:

$$q_{ci} = \frac{V}{n^{\underline{o}}\ injectades} * 1000 \qquad (Eq. 12)$$

On $\mathbf{q_{ci}}$ és la quantitat de combustible en mil injectades (mL / 1000 * injectades) i **V** és la quantitat de combustible injectat en cada assaig (cm^3)

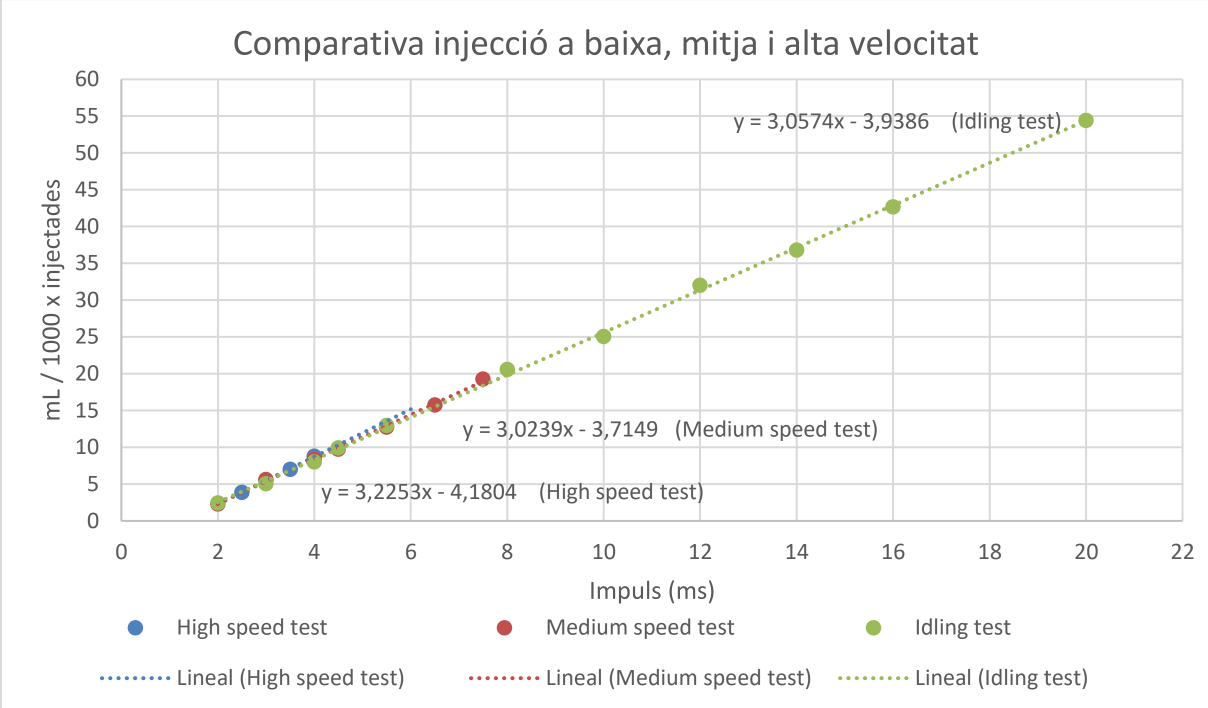
Els resultats dels càlculs descrits anteriorment es mostren a la *Taula 15* tot seguit:

	Nº test	Item	Temps (min)	Impuls (ms)	Volum (cm3)	Freqüència (Hz)	Període (ms)	Nº injectades	mL / injectada	mL / 1000 x injectades
High speed test	1	4	5	4	88	33,33	30,0030	9999	0,008801	8,8009
	2	4	3	3,5	42	33,33	30,0030	5999,4	0,007001	7,0007
	3	4	3	3	33	33,33	30,0030	5999,4	0,005501	5,5006
	4	4	4	2,5	31	33,33	30,0030	7999,2	0,003875	3,8754
	5	4	5	2	23	33,33	30,0030	9999	0,002300	2,3002
Med. speed test	6	3	5	4	42	16,67	59,9880	5001	0,008398	8,3983
	7	3	4	4,5	39	16,67	59,9880	4000,8	0,009748	9,7481
	8	3	4	5,5	51	16,67	59,9880	4000,8	0,012747	12,7475
	9	3	4	6,5	63	16,67	59,9880	4000,8	0,015747	15,7469
	10	3	4	7,5	77	16,67	59,9880	4000,8	0,019246	19,2462
Idling test	11	2	7	4	21	6,25	160,0000	2625	0,008000	8,0000
	12	2	7	8	54	6,25	160,0000	2625	0,020571	20,5714
	13	2	9	3	17	6,25	160,0000	3375	0,005037	5,0370
	14	2	25	2	23	6,25	160,0000	9375	0,002453	2,4533
	15	2	7	4,5	26	6,25	160,0000	2625	0,009905	9,9048
	16	2	7	5,5	34	6,25	160,0000	2625	0,012952	12,9524
M. S	17	3	5	3	28	16,67	59,9880	5001	0,005599	5,5989
	18	3	10	2	23	16,67	59,9880	10002	0,002300	2,2995
Idling test	19	2	5	10	47	6,25	160,0000	1875	0,025067	25,0667
	20	2	5	12	60	6,25	160,0000	1875	0,032000	32,0000
	21	2	5	14	69	6,25	160,0000	1875	0,036800	36,8000
	22	2	5	16	80	6,25	160,0000	1875	0,042667	42,6667
	23	2	5	20	102	6,25	160,0000	1875	0,054400	54,4000

Taula 15. Resultats mesures experimentals test injector.

A partir dels resultats obtinguts mostrats a la taula anterior, es realitza un gràfic de dispersió pels tres modes de prova diferents, per tal d'observar el comportament de l'injector a baixa, mitja i alta velocitat.

En el *Gràfic 8* es representa la quantitat de combustible polvoritzat per cada mil injectades en funció de l'impuls o temps d'injecció i la freqüència d'injecció. En verd, es representen les dades obtingudes a baixa velocitat, en vermell les mesures experimentals a mitja velocitat i en blau les dades a alta velocitat.



Gràfic 8. Comparativa assajos baixa, mitja i alta velocitat.

Observant el gràfic de dispersió anterior, s'observa que el comportament de l'injector és similar pels diferents estats de velocitat del motor. Al mateix gràfic, es realitzen tres regressions lineals per a obtenir les equacions de les rectes que estableixen la relació entre el temps de treball de l'injector i la quantitat de combustible per cada mil injectades.

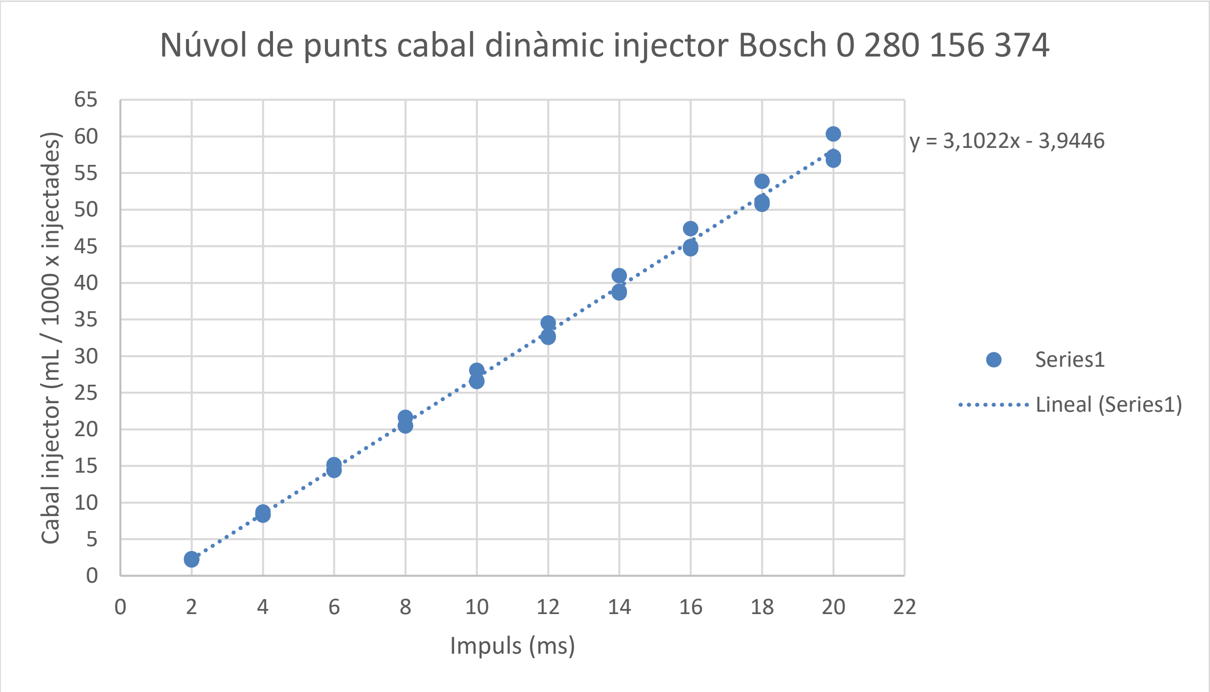
Aquestes equacions permeten realitzar una extrapolació dels assajos d'alta i mitja velocitat fins a temps de treball de l'injector de l'ordre de 20 mil·lisegons. Els resultats de l'extrapolació es mostren a la *Taula 12*, tot seguit:

Idling test		Medium speed test		High speed test	
Impuls (ms)	mL / 1000 x injectades	Impuls (ms)	mL / 1000 x injectades	Impuls (ms)	mL / 1000 x injectades
2	2,1762	2	2,3329	2	2,2702
4	8,2910	4	8,3807	4	8,7208
6	14,4058	6	14,4285	6	15,1714
8	20,5206	8	20,4763	8	21,6220
10	26,6354	10	26,5241	10	28,0726
12	32,7502	12	32,5719	12	34,5232
14	38,8650	14	38,6197	14	40,9738
16	44,9798	16	44,6675	16	47,4244

18	51,0946	18	50,7153	18	53,8750
20	57,2094	20	56,7631	20	60,3256

Taula 16. Extrapolació assajos d'alta, mitja i baixa velocitat.

Després de realitzar l'extrapolació pels tres estats de velocitat, s'opta per realitzar un altre gràfic de dispersió on a partir d'una altra regressió lineal s'obté l'equació que relaciona la quantitat de combustible per cada mil injectades i el temps de treball o impuls, sense fer distinció d'estats de velocitat del motor. El núvol de punts obtingut es mostra en el *Gràfic 9*, on es representa el cabal dinàmic de l'injector a l'eix vertical (mL / 1000 injectades) i el temps d'injecció (ms) a l'eix horitzontal.



Gràfic 9. Núvol de punts cabal dinàmic injector.

L'equació 13 mostra l'expressió final obtinguda d'aplicar una regressió lineal al núvol de punts anterior i que permet relacionar la quantitat de combustible injectat en funció del temps d'injecció.

$$C_{vi} = 3.1022 * t - 3.9446 \qquad (Eq. 13)$$

On **C_{vi}** és el cabal volumètric dinàmic de l'injector (mL / 1000 * injectades) i **t** és el temps de funcionament de l'injector (mil·lisegons).

No obstant, el cabal màssic d'injecció de combustible, depèn de la velocitat de gir del motor, l'arquitectura i de si es tracta d'un motor de dos o quatre temps.

El nombre d'injectades de combustible al motor es calcula a partir de l'expressió detallada a l'Equació 14:

$$nº\ injectades = \omega * n_c * k \qquad (Eq. 14)$$

On **ω** correspon al règim de gir del motor (rpm), **k** és una variable en funció del tipus de motor (0.5 per a motors 4 temps i 1 per a motors 2 temps). En aquest cas, pren el valor de 0.5 ja que en un motor 4 temps es produeix una injectada per cada dues voltes complertes del cigonyal. **n_c** correspon al nombre de cilindres del motor. El motor del banc de proves disposa de 4 cilindres.

Combinant l'Equació 13 amb l'Equació 14, s'obté l'expressió que permet calcular la quantitat de combustible injectat en funció del temps de funcionament de l'injector, el règim de gir del motor i la densitat del combustible empleat:

$$q_{mi} = (0.0031022 * t - 0.0039446) * \omega * n_c * k * 0.06 * \rho_{mot} \qquad (Eq. 15)$$

On **q_{mi}** és el cabal màssic d'injecció (kg/h), **t** és el temps de funcionament de l'injector, **ω** és el règim de gir del motor (rpm), **n_c** correspon al nombre de cilindres del motor (pren el valor de 4), **k** correspon a una constant en funció del tipus de motor (0.5 ja que el motor és de 4 temps), **ρ_{mot}** fa referència a la densitat del combustible del motor (0.75 kg/l).

Finalment, es realitza un assaig al motor per a diferents règims de gir, on s'adquireixen les dades de cabal màssic d'aire a l'admissió del motor gràcies al sensor de massa d'aire aspirada i la relació AFR mesurada amb la sonda lambda, ambdós sensors instal·lats en aquest projecte. Mitjançant l'adquisició dels dos paràmetres característics anteriors, es calcula la quantitat de combustible injectat per tal de comparar la veracitat dels resultats obtinguts dels assajos experimentals.

L'expressió per a calcular la quantitat de combustible injectat a partir de les dades de cabal màssic d'aire i la relació AFR és la detallada a l'Equació 16:

$$q_{mc} = \frac{q_{ma}}{AFR} \qquad (Eq. 16)$$

On q_{mc} és la quantitat de combustible injectat (kg/h), q_{ma} és el cabal màssic d'aire mesurat a l'aspiració del motor (kg/h) i **AFR** és la relació aire-combustible mesurada amb la sonda lambda.

L'assaig per a l'adquisició del cabal màssic d'aire a l'admissió i la relació AFR es realitza amb el seqüenciador del programa SportDyno v4.1 a partir d'ordres simples que faran funcionar el motor a diferents velocitats i estats de càrrega. Les ordres creades es mostren a la *Figura 47*:

	Acción	Valor	Coment.
1	RECORD=	on	
2	MODE=	S	
3	THR=	22	
4	REF=	2500	
5	TIME=	10	
6	THR=	32	
7	REF=	3000	
8	TIME=	10	
9	THR=	45	
10	REF=	3500	
11	TIME=	10	
12	THR=	55	
13	REF=	4000	
14	TIME=	10	
15	THR=	0	
16	RECORD=	off	

Figura 47. Ordres assaig injector.

Els paràmetres adquirits després de realitzar l'assaig anteriorment descrit es mostren a la *Taula 17* inserida a continuació:

	1 - 3 % etanol			
	Test 1	Test 2	Test 3	Test 4
Velocitat (rpm)	2500	3000	3500	4000
Potència (kW)	6,2	10,8	15,8	24,5

Parell (N*m)	23,45	34,18	43,42	58,22
AFR	14,76	14,62	14,65	14,51
Cabal màssic (kg/h)	32,747	45,194	64,519	88,656
Throttle position ECU	20,5%	30,8%	41,2%	50,1%
Throttle position servo	16%	25%	34%	43%
Ignition advance (º)	23	24,6	29	25
Pulse width (ms)	3,92	4,9	5,5	6,6
Engine MAP (kPa)	38,8	43,3	47,5	56,6
Temp in engine (ºC)	23,5	24,5	26,6	28,1
Temp cyl 1 (ºC)	692,7	729,4	753,7	761,4
Temp cyl 3 (ºC)	713	757,8	790,3	782,9
Temp cyl 4 (ºC)	715,5	734,9	761,3	777,7
Avg exh temp (ºC)	707,25	740,69	768,43	773,97
Coolant temp (ºC)	82	82	87	84
Manifold air temp (ºC)	37	39	41	46

Taula 17. Paràmetres adquirits assaig injector per diferents règims de gir i estats de càrrega.

Finalment, els càlculs obtinguts d'aplicar les equacions descrites anteriorment i que permeten comparar els resultats dels assajos de l'injector i els paràmetres obtinguts amb el motor en funcionament, donen com a resultats les quantitats de combustible injectat que es mostren a la *Taula 18*. A la segona columna s'expressa el combustible injectat amb el motor en funcionament i a la tercera columna el càlcul de combustible injectat a partir de les equacions obtingudes experimentalment de l'assaig amb la màquina AUTOOL CT400.

Velocitat (rpm)	Fuel (AFR) (kg/h)	Fuel (injector test) (kg/h)	Dif (AFR-inj. Test) (kg/h)
2500	2,2186	1,8256	0,3931
3000	3,0912	2,9705	0,1208
3500	4,4040	4,1604	0,2437
4000	6,1100	6,1027	0,0073

Taula 18. Resultats obtinguts de la prova amb la màquina CT400 i assaig amb el motor en funcionament.

5.1.5. Conclusions

A partir dels càlculs realitzats, s'observa una petita diferència entre els resultats obtinguts d'aplicar les equacions obtingudes empíricament i els obtinguts a partir de les dades proporcionades pels sensors de massa d'aire aspirada i sonda lambda.

Aquestes discrepàncies poden ser degudes a la inestabilitat del sensors anteriorment mencionats, possiblement provinent del soroll no desitjat de l’entorn de proves. Per altra banda, l’obtenció experimental de les fórmules que permeten calcular la quantitat de combustible injectat pot induir a imprecisions en l’obtenció de les mesures. Igualment, el model de regressió lineal, comporta errors d’aproximació.

Per altra banda, la poca inèrcia del sistema influeix també a la falta de precisió en algunes de les mesures obtingudes. Quan es vol regular la velocitat del motor, el controlador PID actua sobre el fre de manera brusca, degut a la baixa inèrcia del sistema (només es té la inèrcia del motor), provocant una oscil·lació molt difícil d’esmorteir.

No obstant, podem concloure que la diferència és molt reduïda, per tant, s’accepta l’equació obtinguda empíricament vàlida per al càlcul de la quantitat de combustible injectat al motor.

5.2. Determinació de les pèrdues mecàniques del motor

5.2.1. Objectiu de la prova

L'objectiu de la prova és determinar les pèrdues mecàniques del motor SEAT AFT 1,6 litres. Per a estimar les pèrdues mecàniques del motor s'aplicarà el mètode Morse i es mesurarà la potència efectiva del motor eliminant la combustió dels cilindres per diferents estats de càrrega i velocitats.

5.2.2. Fonament teòric

Per a augmentar el rendiment efectiu dels motors de combustió interna alternatius (MCIA) es treballa en dues direccions. La primera dirigida a millorar els procediments termodinàmics del cicle de treball augmentant el treball indicat, i la segona va dirigida a millorar el rendiment mecànic, és a dir, reduint les pèrdues entre el treball que transfereixen els gasos al pistó i el treball mecànic disponible a l'eix de sortida. La diferència entre el treball indicat i el treball efectiu s'anomena treball de pèrdues mecàniques.

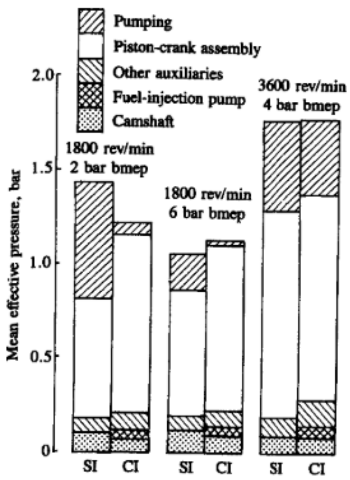
El treball de pèrdues mecàniques comprèn els següents tipus de pèrdues:

1. Pèrdues per bombeig: Es defineixen com el treball mecànic realitzat pel pistó contra els gasos durant els processos d'admissió i escapament. És a dir, energia consumida per a realitzar el procés de renovació de la càrrega. En motors dos temps no existeixen aquest tipus de pèrdues ni tampoc en motors sobrealimentats quan la pressió d'admissió sigui superior a la d'escapament.

2. Pèrdues per fricció: Es produeix degut a la resistència al moviment relatiu de totes les parts mòbils del motor. Això inclou la fricció entre els anells del pistó, entre la paret del pistó i la del cilindre, fricció en el cigonyal, arbre de lleves, engranatges, corretges o politges del motor.

3. Pèrdues per altres elements auxiliars: Es produeix degut a l'accionament de diferents elements auxiliars del motor. Inclou pèrdues produïdes per el ventilador, bomba d'aigua, bomba d'oli o bomba de combustible, entre d'altres.

A continuació, en el *Gràfic 10,* es realitza una comparació sobre com afecten els tipus de pèrdues mecàniques descrites anteriorment, expressades a partir de la pressió mitja efectiva (bar), en funció del tipus de motor (encesa provocada (SI) o encesa per compressió (CI)), les revolucions i diferents estats de càrrega:



Gràfic 10. Pèrdues mecàniques en motors SI i CI. (Font: Heywood, John B. Internal combustion engine fundamentals)

Tal i com s'observa al gràfic anterior, les pèrdues mecàniques s'incrementen amb el règim de gir. Les pèrdues produïdes pel procés de renovació de la càrrega (pèrdues per bombeig) són majors a menor grau de càrrega degut a la estrangulació del conducte d'admissió.

Per a obtenir les pèrdues per fricció, els mètodes més comuns són els que es detallen tot seguit:

1. Mètode de desacceleració lliure: Consisteix en mesurar la desacceleració angular instantània del motor originada a l'eliminar el subministrament de combustible o interrompre l'encesa.

Determinant l'evolució de la velocitat de rotació i coneixent el moment d'inèrcia del conjunt, el parell resistent es pot calcular a partir de l'expressió de l'Equació 17:

$$M_{pm} = I * \alpha \qquad (Eq. 17)$$

On $\mathbf{M_{pm}}$ és el parell resistent de pèrdues mecàniques, **I** és la inèrcia del conjunt i **α** és la desacceleració angular.

En el cas de no conèixer el moment d'inèrcia del conjunt, s'incorpora un volant d'inèrcia amb inèrcia coneguda. Es realitzen dues mesures, una amb el motor original i l'altre amb el volant incorporat. Llavors, es planteja un sistema de dues equacions amb l'Equació 17 i una equació que inclou la inèrcia del volant incorporat, indicada a l'Equació 18:

$$M_{pm} = (I + I_V) * \alpha \qquad (Eq. 18)$$

On $\mathbf{I_V}$ és la inèrcia del volant.

El principal inconvenient d'aquest mètode és que la mesura es realitza amb el motor sense combustió, fet que comporta que les càrregues que actuen sobre els elements mòbils no són idèntiques a les del funcionament normal del motor.

2. Mètode d'arrossegament: Aquest procediment consisteix en determinar la potència necessària per arrossegar el motor amb el subministrament de combustible interromput o l'encesa desconnectada, és a dir, sense procés de combustió. L'arrossegament es realitza generalment amb l'ajuda d'un dinamòmetre elèctric reversible, que pot treballar com a motor o com a fre.

L'inconvenient més important d'aquest mètode és que al no existir combustió, la pressió i la temperatura en els cilindres i per tant les càrregues a les que està sotmès el motor no coincideixen amb les que es donarien en funcionament real.

Per aproximar-se a les condicions operatives del motor, els assajos d'arrossegament han de realitzar-se immediatament després d'haver tingut el motor en funcionament i utilitzant condicionadors de temperatura per tal de mantenir l'estat tèrmic de l'oli i el refrigerant.

Aquest mètode, a més de determinar les pèrdues mecàniques totals, permet mesurar les pèrdues element per element, determinant la diferència en la potència d'arrossegament a l'anar desmuntant i desconnectant successivament els components del motor associats a cada tipus de pèrdua.

3. Mètode de Willans: Aquest mètode està basat en la relació existent entre el consum horari de combustible i la pressió mitja efectiva quan el règim de gir es manté constant. Per aplicar aquest mètode és necessari mesurar el parell, el règim de gir i el consum horari de combustible durant l'experiment.

La validesa d'aquest mètode està condicionada a que el consum específic indicat de combustible o bé el rendiment indicat és mantinguin constants per un règim de gir determinat. Aquesta condició, es compleix en motors d'encesa per compressió o dièsel, ja que en aquest tipus de motors es regula la càrrega (pme) modificant la quantitat de combustible injectat, perdent-se el comportament lineal només per càrregues molt elevades, on el rendiment disminueix a causa dels elevats dosats de la mescla aire-combustible.

En el cas de motors d'encesa provocada, aquest mètode no dona resultats fiables ja que al reduir la càrrega per un règim de gir determinat, les pèrdues de bombeig augmenten de manera considerable.

La utilització d'aquest mètode implica realitzar un gran nombre d'execucions i els resultats obtinguts no sempre justifiquen la seva laboriositat. Només permet conèixer les pèrdues mecàniques globals, fet que comporta una limitació respecte els dos mètodes anteriorment descrits.

4. Mètode Morse: Aquest mètode consisteix en desconnectar l'encesa o interrompre el subministrament de combustible en un dels cilindres i mesurar la potència efectiva del motor en aquesta condició, repetint l'operació per cada cilindre. A l'eliminar la combustió d'un dels cilindres, la potència efectiva mesurada correspon a la suma entre la potència entregada pels cilindres actius i la potència de pèrdues originada pel cilindre arrossegat.

Aquest mètode presenta similitud amb el mètode d'arrossegament, però en aquest cas són els cilindres actius els que arrosseguen els components mòbils del cilindre on no es produeix la combustió. Per a realitzar aquest assaig cal fer funcionar el motor amb tots els cilindres actius fins a estabilitzar la temperatura de l'oli i del refrigerant. Una vegada aconseguir, es procedeix a desactivar un cilindre i a l'adquisició de mesures de parell i règim de gir, per determinar la potència entregada pel motor.

La principal objecció que es pot senyalar amb aquest mètode, és que al desactivar un cilindre, algunes condicions operatives canvien, com la pressió en el cilindre, fenòmens dinàmics en el col·lector d'admissió. Si el motor és turboalimentat també es veu alterat el treball del grup de sobrealimentació.

5. Mètode del diagrama indicador: Aquest mètode consisteix en obtenir de manera simultània el diagrama pressió-volum, a partir del qual podem obtenir la pressió mitja indicada (pmi) i el parell efectiu del motor per determinar la pressió mitja efectiva (pme). La diferència entre la pmi i la pme constitueix la pressió mitja per pèrdues mecàniques (pmpm). Durant l'experiment és precís controlar el grau de càrrega, el règim de gir i la temperatura de l'oli i del refrigerant.

En el cas de voler estudiar cadascun dels conceptes que integren les pèrdues mecàniques, aquest mètode permet obtenir les pèrdues de bombeig gràficament, la potència absorbida pels elements auxiliars del motor, desconnectant element per element o assajant-los per separat. Finalment les pèrdues per fricció es determinen a partir de l'Equació 19:

$$pmR = pmi - pme - pmb - pma \qquad (Eq. 19)$$

On **pmR** són les pèrdues mecàniques per fricció, **pmi** és la pressió mitja indicada, **pme** és la pressió mitja efectiva, **pmb** són les pèrdues mecàniques per bombeig i **pma** són les pèrdues mecàniques per elements auxiliars.

Aquest mètode permet mesurar les pèrdues amb el motor en funcionament, essent probablement el més exacte. No obstant, per portar a terme aquest mètode, és necessari disposar de la instrumentació adequada. Cal disposar d'un captador de pressió dinàmica, el més habitual és el transductor piezoelèctric, que cal situar en contacte amb l'interior de la cambra de combustió. Per altra banda, es necessita un codificador angular, adequadament situat en un dels extrems del cigonyal. A més a més, cal portar a terme un tractament de les senyals adquirides adequat. És el mètode que presenta més complexitat.

5.2.3. Procediment experimental

Analitzant la complexitat i viabilitat dels mètodes descrits anteriorment s'opta per dur a terme el mètode Morse. Tot i que el mètode més exacte i que permet diferenciar tots els tipus de pèrdues mecàniques és el mètode del diagrama indicador, es descarta per falta de la instrumentació adequada i complexitat. El mètode d'arrossegament es descarta per la seva complexitat referent a la instrumentació requerida i fiabilitat qüestionable. El mètode de Willans no és adequat pel tipus de motor del banc de proves i finalment es descarta el mètode de desacceleració lliure ja que el mètode Morse implica, en major mesura, la utilització dels components instal·lats en aquest projecte.

Per a la realització del mètode Morse, es decideix avaluar la potència efectiva del motor per a diferents règims de gir i estats de càrrega durant un temps suficient que permeti al sistema estabilitzar-se el màxim possible per a obtenir precisió en les mesures.

A la *Taula 19* es mostren els règims de gir i graus de càrrega escollits per a dur a terme la prova d'obtenció de les pèrdues mecàniques del motor pel mètode Morse:

1500		2000		3000		4000	
Càrrega (%)	temps (s)	Càrrega (%)	temps (s)	Càrrega (%)	temps (s)	Càrrega (%)	temps (s)
15	10	20	10	30	10	40	10
20	10	30	10	40	10	50	10
30	10	35	10	50	10	60	10
						70	10

Taula 19. Punts de càrrega prova Morse.

Per a la realització del mètode Morse, en primer lloc, cal posar en funcionament el motor amb tots els cilindres en funcionament, fins a assolir una temperatura adequada de l'oli del motor i refrigerant. Aquesta temperatura es situa entre els 80 ºC i 90 ºC.

A continuació, aprofitant l'opció que ofereix el software d'adquisició de dades del seqüenciador, on es pot crear un fitxer de text a partir d'ordres simples, s'ordena al sistema de control una seqüència per a diferents graus de càrrega i règims de gir del motor gràcies al mòdul SP6 i el servomotor d'alt parell.

Els fitxers creats per a la prova es mostren a les *Figures 47, 48, 49* i *50*:

	Acción	Valor	Coment.
1	RECORD=	on	
2	MODE=	S	
3	THR=	14	15%TPS
4	REF=	1500	
5	TIME=	10	
6	THR=	18	20%TPS
7	REF=	1500	
8	TIME=	10	
9	THR=	27	30%TPS
10	REF=	1500	
11	TIME=	10	
12	THR=	0	
13	RECORD=	off	

Figura 48. Fitxer seqüenciador Morse 1500 rpm.

	Acción	Valor	Coment.
1	RECORD=	on	
2	MODE=	S	
3	THR=	18	20%TPS
4	REF=	2000	
5	TIME=	10	
6	THR=	27	30%TPS
7	REF=	2000	
8	TIME=	10	
9	THR=	32	35,4%TPS
10	REF=	2000	
11	TIME=	10	
12	THR=	0	
13	RECORD=	off	

Figura 49. Fitxer seqüenciador Morse 2000 rpm.

	Acción	Valor	Coment.
1	RECORD=	on	
2	MODE=	S	
3	THR=	27	30%TPS
4	REF=	3000	
5	TIME=	10	
6	THR=	37	40%TPS
7	REF=	3000	
8	TIME=	10	
9	THR=	47	50%TPS
10	REF=	3000	
11	TIME=	10	
12	THR=	0	
13	RECORD=	off	

Figura 50. Fitxer seqüenciador Morse 3000 rpm.

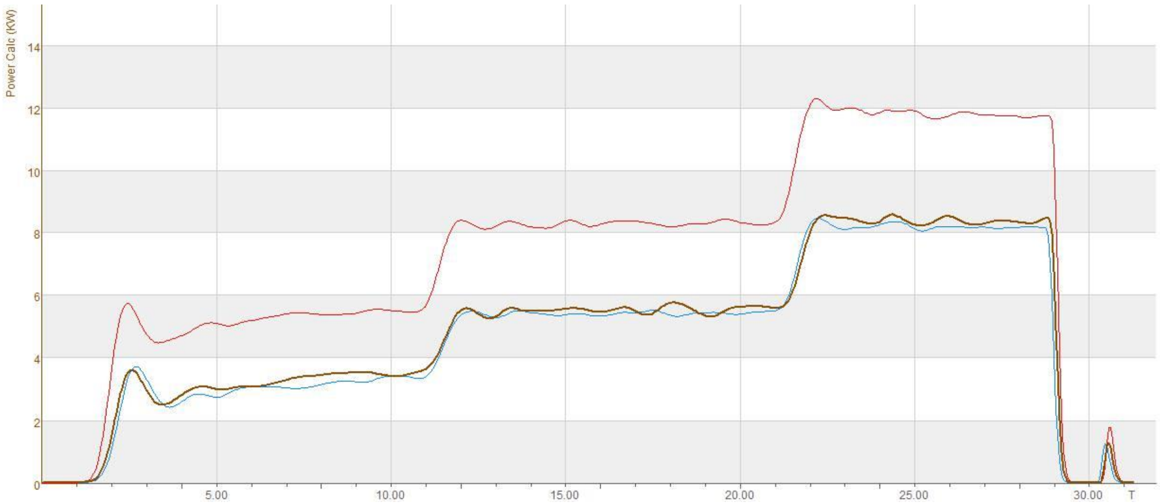
	Acción	Valor	Coment.
1	RECORD=	on	
2	MODE=	S	
6	THR=	37	40%TPS
7	REF=	4000	
8	TIME=	10	
9	THR=	47	50%TPS
10	REF=	4000	
11	TIME=	10	
12	THR=	58	60%TPS
13	REF=	4000	
14	TIME=	10	
15	THR=	70	70%TPS
16	REF=	4000	
17	TIME=	10	
18	THR=	0	
19	RECORD=	off	

Figura 51. Fitxer seqüenciador Morse 4000 rpm.

Es repetirà aquesta seqüència per a la mesura de la potència efectiva del motor, primerament, amb tots els cilindres en funcionament i, posteriorment, procedint amb la desconnexió de cadascun dels 4 cilindres del motor, un per un.

Finalment, a partir dels gràfics obtinguts al programa d'adquisició i control, s'extreuen les dades de potència efectiva per a cadascuna de les etapes anteriorment descrites, i es procedeix a la realització de càlculs.

A continuació, en el *Gràfic 15*, es mostra un exemple dels gràfics obtinguts de realitzar el mètode Morse. En aquest cas es tracta del gràfic obtingut de realitzar l'assaig a un règim de gir de 1500 rpm. L'eix vertical correspon a la potència mesurada en kW i l'eix horitzontal és l'escala de temps on es representa la duració de l'assaig. En vermell es representa la potència efectiva del motor amb els 4 cilindres en funcionament. El grafisme en blau correspon a la potència mesurada eliminant la combustió del cilindre nº1 i en color marró la potència mesurada amb el cilindre nº4 sense combustió.



Gràfic 11. Potència efectiva del motor mètode Morse 1500 rpm.

5.2.4. Càlculs i resultats

A continuació es mostren les mesures de potència efectiva entregada pel motor obtingudes amb els 4 cilindres en funcionament, i posteriorment, eliminant la combustió de cadascun dels cilindres. Cal mencionar, que degut a la dificultat per a la desconnexió dels cilindres 2 i 3, els valors de potència efectiva s'obtenen realitzant una extrapolació dels valors obtinguts a l'eliminar la combustió dels cilindres 1 i 4.

Les mesures obtingudes per a diferents estats de càrrega i règims de gir del motor es detallen a la *Taula 20*:

	TPS	4 cilindres	Cyl 1 off	Cyl 4 off	Cyl 2 off	Cyl 3 off
rpm	Càrrega (%)	Potència (kW)	Potència (kW)	Potència (kW)	Potència (kW)	Potència (kW)
1500	15	5,4	3,2	3,3	3,25	3,25
	20	8,3	5,4	5,5	5,45	5,45
	30	11,8	8,2	8,4	8,3	8,3
2000	20	6,7	3,9	4	3,95	3,95
	30	12,5	8,5	8,4	8,45	8,45
	35,4	14,8	10,2	10,1	10,15	10,15
3000	30	9,7	5,5	5,6	5,55	5,55
	40	16,4	10,4	10,6	10,5	10,5
	50	25,8	17,3	17,4	17,35	17,35
4000	40	13	6,7	6,9	6,8	6,8
	50	24,9	15,8	15,9	15,85	15,85
	60	41,5	27,9	27,4	27,65	27,65
	70	51,7	34,9	34,7	34,8	34,8

Taula 20. Dades de potència mètode Morse.

Per a calcular la potència de pèrdues mecàniques, es sap que, a l'eliminar la combustió en un cilindre, la potència efectiva mesurada correspon a la suma entre la potència entregada pels cilindres actius i la potència de pèrdues originada pel cilindre arrossegat.

En el cas del motor del banc de proves, es poden establir les Equacions 20, 21, 22 i 23:

- Cilindre nº 1 sense combustió:

$$N_e{}^{(1)} = N_e{}^{(2)} + N_e{}^{(3)} + N_e{}^{(4)} - N_{pm}{}^{(1)} \qquad (Eq. 20)$$

- Cilindre nº 2 sense combustió:

$$N_e{}^{(2)} = N_e{}^{(1)} + N_e{}^{(3)} + N_e{}^{(4)} - N_{pm}{}^{(2)} \qquad (Eq. 21)$$

- Cilindre nº 3 sense combustió:

$$N_e{}^{(3)} = N_e{}^{(1)} + N_e{}^{(2)} + N_e{}^{(4)} - N_{pm}{}^{(3)} \qquad (Eq. 22)$$

- Cilindre nº 4 sense combustió:

$$N_e^{(4)} = N_e^{(1)} + N_e^{(2)} + N_e^{(3)} - N_{pm}^{(4)} \qquad (Eq. 23)$$

Sumant les quatre equacions anteriors membre a membre s'obté l'expressió detallada a l'Equació 24:

$$\sum_{i=I}^{IV} N_e^{(i)} = 3\left(N_e^{(1)} + N_e^{(2)} + N_e^{(3)} + N_e^{(4)}\right) - \left(N_{pm}^{(1)} + N_{pm}^{(2)} + N_{pm}^{(3)} + N_{pm}^{(4)}\right) \qquad (Eq. 24)$$

Obtenint-se com a resultat l'expressió de l'Equació 25:

$$\sum_{i=I}^{IV} N_e^{(i)} = 2N_e - N_{pm} \qquad (Eq. 25)$$

On $\sum \mathbf{N_e^{(i)}}$ és la suma de totes les potències mesurades a l'eliminar la combustió en cada cilindre, $\mathbf{N_e}$ és la potència efectiva mesurada quan tots els cilindres estan actius i $\mathbf{N_{pm}}$ és la potència de pèrdues mecàniques.

Per a expressar les pèrdues mecàniques es sol utilitzar també el terme de pressió mitja efectiva (pme) que es calcula mitjançant la fórmula de l'Equació 26:

$$pme = \frac{P * n_g * 10^3}{V_d * N} \qquad (Eq. 26)$$

On **pme** és la pressió mitja efectiva (kPa), **P** és la potència (kW), $\mathbf{n_g}$ és el nombre de revolucions del cigonyal per cada cicle de potència (pren el valor de 2 per motors de 4 temps), $\mathbf{V_d}$ és la cilindrada (dm^3) i **N** és el règim de gir del motor (rev/s).

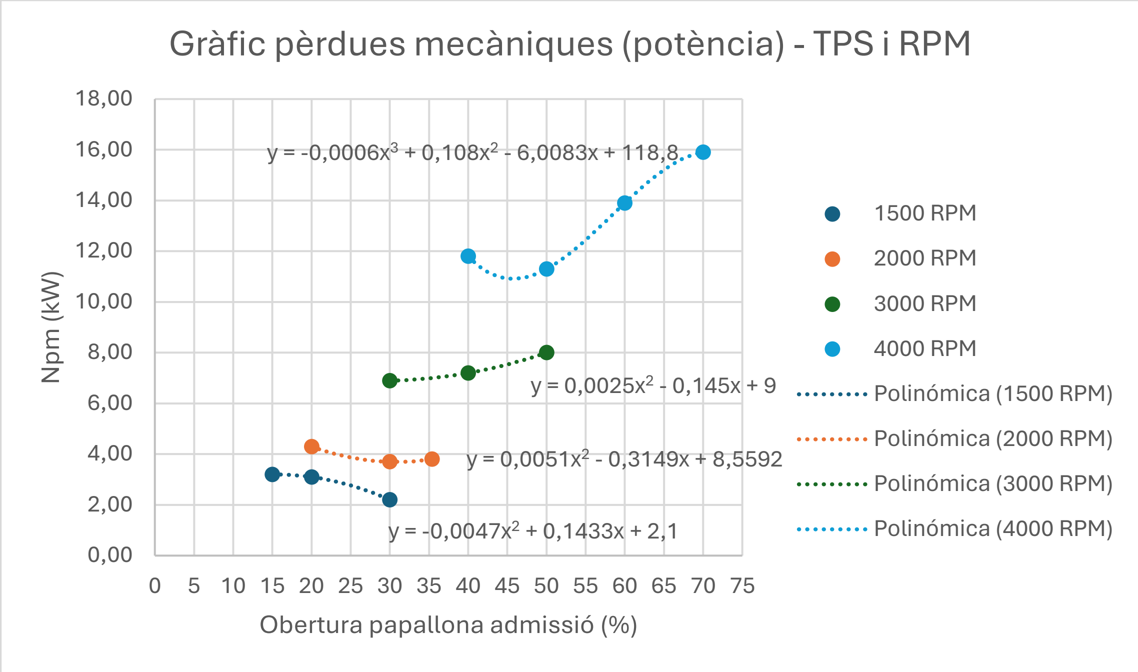
Els resultats del càlcul de les pèrdues mecàniques obtinguts es mostren a la *Taula* :

rpm	Càrrega (%)	Npm (kW)	pme pm (Kpa)	pme pm (bar)	pme total (kPa)	pme total (bar)	%
1500	15	3,20	160,50	1,61	270,85	2,71	59,26
	20	3,10	155,49	1,55	416,30	4,16	37,35
	30	2,20	110,34	1,10	591,85	5,92	18,64
2000	20	4,30	161,76	1,62	252,04	2,52	64,18
	30	3,70	139,18	1,39	470,22	4,70	29,60
	35,4	3,80	142,95	1,43	556,74	5,57	25,68
3000	30	6,90	173,04	1,73	243,26	2,43	71,13
	40	7,20	180,56	1,81	411,29	4,11	43,90
	50	8,00	200,63	2,01	647,02	6,47	31,01
4000	40	11,80	221,94	2,22	244,51	2,45	90,77
	50	11,30	212,54	2,13	468,34	4,68	45,38
	60	13,90	261,44	2,61	780,56	7,81	33,49
	70	15,90	299,06	2,99	972,41	9,72	30,75

Taula 21. Pèrdues mecàniques mètode Morse.

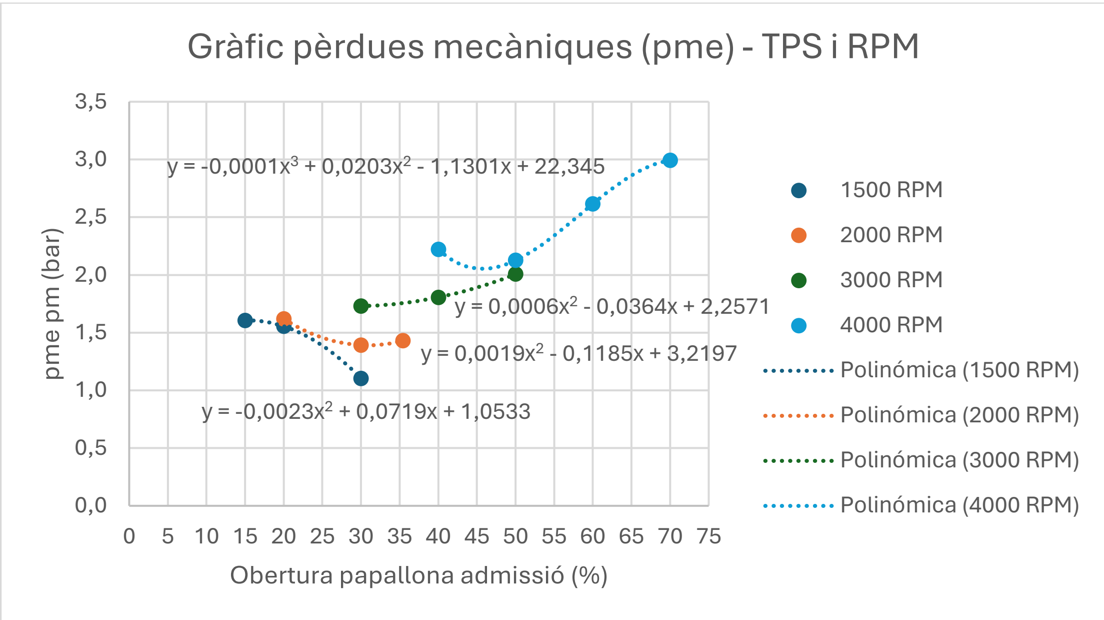
A continuació es realitzen dos gràfics per tal d'extreure una equació que permeti obtenir les pèrdues mecàniques del motor per baixa velocitat del motor (1500 rpm), mitja velocitat (2000 – 3000 rpm) i per alta velocitat (4000 rpm) a partir de la posició de la papallona d'admissió mesurada pel sensor TPS.

En el *Gràfic* 12 es representa a l'eix vertical les pèrdues mecàniques obtingudes pel mètode Morse (kW) en funció del grau de càrrega, representat a l'eix horitzontal, i el règim de gir del motor. Es realitzen varis models de regressió polinòmica per a extreure les equacions que relacionin les pèrdues mecàniques i el grau de càrrega en funció del règim de gir del motor.



Gràfic 12. Pèrdues mecàniques (potència) en funció del grau de càrrega i RPM.

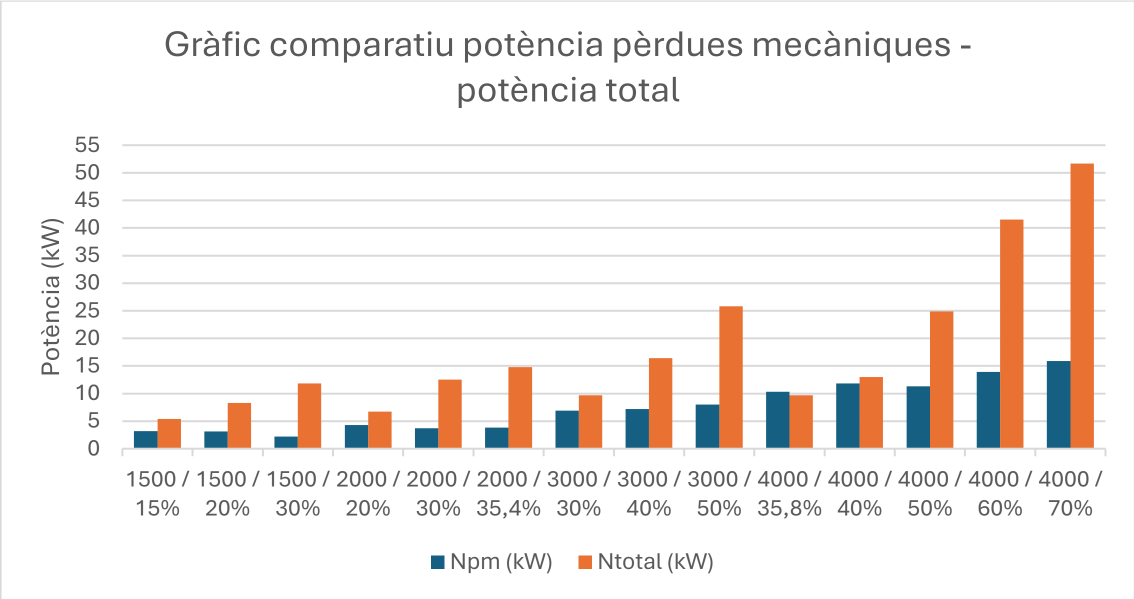
El *Gràfic 13* és molt similar al *Gràfic 12* però en aquest cas es representa les pèrdues mecàniques a partir de la pressió mitja efectiva. El *Gràfic 13* es mostra a continuació:



Gràfic 13. Pèrdues mecàniques (pme) en funció del grau de càrrega i RPM.

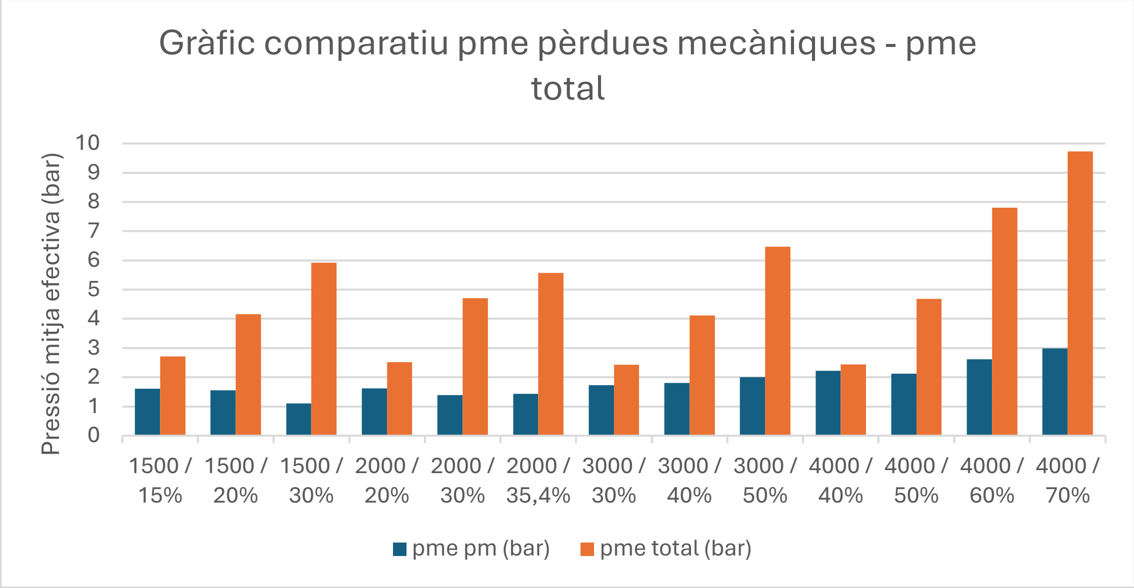
Finalment, es realitzen dos gràfics més per a comparar la contribució de la potència de pèrdues mecàniques dins la potència efectiva total entregada pel motor i per a observar com evolucionen les pèrdues mecàniques en funció del règim de gir i el grau de càrrega del motor.

En el *Gràfic 14* es representa la contribució de la potència de pèrdues mecàniques dins la potència efectiva total, en funció del règim de gir del motor i l'obertura de la papallona d'admissió.



Gràfic 14. Comparativa potència de pèrdues mecàniques i potència total efectiva.

En el *Gràfic 15* es realitza la mateixa comparació però utilitzant el termini de pressió mitja efectiva de pèrdues mecàniques i pressió mitja efectiva total:



Gràfic 15. Comparativa pme pèrdues mecàniques i pme total.

5.2.5. Conclusions

Els resultats obtinguts mostren com les pèrdues mecàniques augmenten quan el motor funciona a un règim de gir més elevat, per un mateix grau de càrrega. Això és degut a que les pèrdues per fricció i per bombeig augmenten quan el motor gira més ràpidament.

Referit a les pèrdues per fricció, a mesura que augmenta el règim de gir del motor, la velocitat lineal mitja del pistó incrementa. Aquest efecte comporta un augment de les forces d'inèrcia, fet que es tradueix en un augment de les pèrdues mecàniques per fricció.

Es pot observar també, a velocitats del motor baixes i mitges, per a un mateix règim, com disminueixen les pèrdues mecàniques a mesura que augmenta el grau de càrrega del motor. Això és degut a que les pèrdues per bombeig es veuen reduïdes, en part, perquè la vàlvula de papallona de l'admissió del motor ofereix menys resistència al pas de la mescla aire-combustible.

No obstant, per a règims de gir més elevats, aquest comportament no s'acaba de complir. Això pot ser degut a la dificultat per mantenir les temperatures d'oli i refrigerant estables. Amb el transcurs de l'assaig, les temperatures han augmentat lleugerament i les condicions s'han vist afectades. També és degut a que les pèrdues per fricció són funció de la velocitat lineal mitja del pistó. Un increment del règim de gir suposa que les forces d'inèrcia creixen proporcionalment a la velocitat mitja del pistó al quadrat. Com a conseqüència les pèrdues mecàniques per fricció augmenten considerablement.

Per altra banda, al desconnectar un cilindre canvien algunes condicions operatives, com per exemple, la pressió en el cilindre o fenòmens dinàmics en el col·lector d'admissió .

Finalment, cal senyalar que augmenta la inestabilitat en l'adquisició de dades a mesura que augmenta el règim de gir del motor. Per aquest motiu alguns valors obtinguts a altes revolucions poden no ser del tot exactes. Al ser un banc de proves amb una inèrcia baixa, es dificulta la configuració del PID perquè les respostes obtingudes siguin les més ràpides i estables possibles per a tots els règims de gir. A mesura que augmenta la velocitat del motor, l'actuació del controlador PID sobre el fre per tal que la velocitat real i la velocitat objectiu convergeixin és més brusca, provocant una oscil·lació que afegeix inestabilitat en l'adquisició de dades experimentals.

6. POSSIBLES MILLORES

L'objectiu d'aquest capítol és aportar un conjunt de propostes que podrien ser de gran aportació per a millorar les tasques d'investigació i docència a partir de la solució adoptada en aquest projecte.

En primer lloc, es suggereix la implementació d'un polsador d'encesa i apagada del motor com els que s'utilitzen en cotxes actuals (Start/Stop). Aprofitant una de les sortides per al control i accionament de relés. D'aquesta manera, amb el software d'adquisició i control del banc de proves, es podria encendre o apagar el motor de manera molt simple i àgil.

En segon lloc, es creu que seria una bona opció per a la millora de la seguretat del banc de proves, la instal·lació d'un polsador d'emergència que permetria parar el motor en qualsevol moment a través del programa informàtic. Aquest polsador es connectaria a la sortida de "*Panic button"* de l'SP6. Accionant aquest contacte normalment obert, l'SP6 ordenaria aplicar un parell de frenada a través del fre que pararia el motor immediatament.

Per altra banda, es podria connectar part el sistema de refrigeració del banc de proves, com per exemple un ventilador, al mòdul SP6 aprofitant una altra sortida per al control i accionament de relés. D'aquesta manera es podria encendre o apagar a través del software de control en funció de les temperatures que també es monitoritzen en el programa.

Finalment, una altra possible millora a introduir és la configuració del controlador PID en funció del règim de gir del motor. En un banc de proves amb poca inèrcia, com és el cas del banc de proves que ocupa aquest projecte, la sensibilitat i la inestabilitat augmenten a altes velocitats. El sistema és més sensible al guany proporcional del PID. Aprofitant l'opció que incorpora el software SportDyno v4.1, anomenada *PID Map*, el valor del guany proporcional es pot ajustar en funció de la velocitat del motor. D'aquesta manera, a mesura que la velocitat del motor augmenta, baixant el valor de la constant proporcional (K_p), s'afavoriria al guany d'estabilitat del sistema i millora en la precisió de les dades adquirides per assajos del motor a altes revolucions.

7. RESUM DEL PRESSUPOST

A continuació, a la *Taula 22*, es mostra el resum del pressupost:

Concepte	Descripció	Import
1. Suport servomotor	Cost de materials, fabricació i muntatge del suport per al servomotor.	54,99 €
2. Suport sonda lambda	Cost de materials, fabricació i muntatge del suport per al controlador de la sonda lambda.	63,11 €
3. Suport sensor etanol	Cost de materials, fabricació i muntatge del suport per al sensor d'etanol.	32,33 €
4. Instal·lació elèctrica	Cost dels materials i la mà d'obra per a la realització de la instal·lació elèctrica.	321,71 €
5. Sensors	Cost dels sensors instal·lats en el projecte, així com el material utilitzat per a la instal·lació. Inclou el sensor MAF, sonda lambda i sensor de contingut d'etanol.	630,32 €
6. Actuadors	Cost dels actuadors instal·lats en el projecte. Inclou el servomotor d'alt parell.	695,00 €
7. Adquisició de dades i control	Cost dels components destinats a l'adquisició de dades i control del banc de proves així com la mà d'obra. Inclou el "KIT" d'adquisició de dades SP6 i l'oscil·loscopi.	3.843,94 €
	BASE IMPOSABLE	5.641,40 €
	IVA (21%)	1.184,69 €
	TOTAL	6.826,09 €

Taula 22. Resum del pressupost del projecte.

Puja el pressupost la quantitat de **SIS MIL VUIT-CENTS VINT-I-SIS AMB NOU CÈNTIMS (6.826,09 €).**

8. CONCLUSIONS

En el present projecte es considera que s'han satisfet els requeriments acordats a l'inici del mateix.

S'ha realitzat la instal·lació d'un nou sistema d'adquisició de dades conjuntament amb un software per a la visualització dels paràmetres adquirits i el control del banc de proves existent al laboratori de motors tèrmics.

S'ha implementat una sonda lambda per a la mesura de la relació aire-combustible, un paràmetre fonamental per a l'estudi de motors, que serà de gran ajuda en tasques d'investigació i docència.

Per altra banda, també s'ha realitzat la instal·lació d'un sensor capaç de mesurar el contingut d'etanol en el combustible. El sensor de contingut d'etanol resultarà útil per a tasques d'investigació on es podran estudiar les propietats i els beneficis d'aquest compost com a combustible.

De la mateixa manera, el sensor de massa d'aire aspirada permetrà estudiar paràmetres com la injecció de combustible per tal d'aconseguir extreure el màxim rendiment del motor.

La instal·lació d'un servomotor d'alt parell ajudarà a estudiar el motor per diferents estats de càrrega i velocitats i permetrà realitzar cicles de prova de manera automatitzada.

Finalment, la implementació d'un oscil·loscopi amb connexió a ordinador també facilitarà tasques de diagnosi i estudi del funcionament de sensors molt comuns en automoció.

Tota la instal·lació s'ha realitzat pensant en la compatibilitat del sistema anterior amb el nou. Els sensors muntats al banc de proves poden connectar-se i desconnectar-se de manera àgil d'un sistema a l'altre.

S'han pogut portar a terme proves amb tots els components implementats actius comprovant que funcionen de manera fiable i amb bons resultats.

No obstant, no s'han pogut portar a terme cicles de prova tipus WLTP o cicles específics "on demand" ja que requereixen d'un control molt precís i estable del banc de proves.

Cal recalcar que la baixa inèrcia del sistema provoca certa inestabilitat en el control del conjunt motor-fre i en l'adquisició de dades que, després de realitzar moltes proves per a determinar la configuració ideal del PID, s'arriba a la conclusió que és molt difícil d'eliminar. Degut a la baixa inèrcia del sistema (només es té la inèrcia del motor), quan el controlador actua sobre el fre, per tal que la resposta i la consigna convergeixin, ho fa de manera brusca produint una oscil·lació molt difícil d'esmorteir si es vol aconseguir una resposta bona i ràpida, com es busca en un banc de proves.

En altres bancs de proves, on la inèrcia del sistema és molt mes gran, com en un banc de corrons, on es té la inèrcia dels propis corrons, de les rodes del vehicle, de la transmissió i del propi motor es creu que el sistema d'adquisició de dades funcionaria amb més bons resultats. La major inèrcia faria que el controlador no actués de manera tan brusca afavorint l'estabilitat del sistema.

9. RELACIÓ DE DOCUMENTS

DOCUMENT 1. MEMÒRIA I ANNEXOS.

1. MEMÒRIA.

2. ANNEXOS.

ANNEX A: INFORMACIÓ TÈCNICA.

ANNEX B: ESQUEMES DE CONNEXIONAT.

ANNEX C: CÀLCULS ELÈCTRICS.

ANNEX D: MANUALS D'USUARI I INSTAL·LACIÓ.

DOCUMENT 2. PLÀNOLS.

DOCUMENT 3. PLEC DE CONDICIONS.

DOCUMENT 4. ESTAT D'AMIDAMENTS.

DOCUMENT 5. PRESSUPOST.

10. BIBLIOGRAFIA

- NEVOT CERCÓS, JAVIER. Diseño de un controlador avanzado basado en redes neuronales para la gestión de la mezcla aire-gasolina en un motor alternativo. Tesis doctoral. Automatización avanzada y robòtica. Institut d’Organització i Control de Sistemes Industrials. Universitat Politècnica de Catalunya. Desembre de 1999.

- Gerjets, Anna-Damaris. Estudi del sistema de refrigeració d’un banc d’assaig de motors tèrmics. Projecte / Treball Fi de Carrera. Enginyeria mecànica. Escola Politècnica Superior. Universitat de Girona. Setembre de 2015.

- Gallardo Pou, Marc. Sistema complet d’injecció electrònica en un motor MEP basada en tecnologia Megasquirt. Projecte / Treball Fi de Carrera. Enginyeria mecànica. Escola Politècnica Superior. Universitat de Girona. Setembre de 2020.

- López López, Ignacio. Transformación de la gestión electrónica de un vehiculo para adaptarlo a carreras deportivas. Projecte / Treball Fi de Carrera. Enginyeria mecànica. Escuela Técnica Superior de Ingeniería y Diseño Industrial. Universidad Politécnica de Madrid. Setembre de 2022.

- Ruiz Rosales, Santiago. Ensayo de Motor en Banco. Obtención de Curvas Características y Parámetros Efectivos. Universitat Politècnica de València (UPV). (https://www.youtube.com/watch?v=FuEFAdxK1IE , 8 de febrer de 2024).

- Payri, F., Desantes, J.M. Motores de combustión interna alternativos. Editorial Reverté. Universitat Politècnica de València (UPV). València. 2011.

- Heywood, John B. Internal combustion engine fundamentals. McGraw-Hill series in mechanical engineering. Estats Units. 1988.

11. GLOSSARI

Abreviatura / simbologia	Descripció
AFR	Air Fuel Ratio. Relació aire-combustible.
CI	Compression-ignition engine. Motor d'encesa per compressió.
CKP	Crankshaft position sensor. Sensor de posició del cigonyal.
CMP	Camshaft position sensor. Sensor de posició de l'arbre de lleves.
ECU	Unitat de control electrònica.
Kd	Constant derivativa controlador PID.
Ki	Constant integral controlador PID.
Kp	Constant proporcional controlador PID.
LC-1	Sonda lambda amb controlador LC-1.
MAF	Mass air flow sensor. Sensor de massa d'aire aspirada.
MAP	Manifold air pressure sensor. Sensor de pressió absoluta al col·lector.
MCIA	Motor de combustió interna alternatiu.
pma	Pèrdues mecàniques per elements auxiliars.
pmb	Pèrdues mecàniques per bombeig.
pme	Pressió mitja efectiva.
pmi	Pressió mitja indicada.
pmR	Pèrdues mecàniques per fricció.
PPM	Pulse position modulation. Senyal de modulació per posició d'impuls.
PWM	Pulse width modulation. Senyal de modulació per amplada d'impuls.
PWS	Font d'alimentació mòdul d'adquisició de dades.
SI	Spark-ignition engine. Motor d'encesa provocada.
SP4	Unitat d'adquisició de dades SportDevices SP4.
SP6	Unitat d'adquisició de dades SportDevices SP6.
Td	Temps derivatiu controlador PID.
Ti	Temps integral controlador PID.
TPS	Throttle position sensor. Sensor de posició de l'accelerador.
VAF	Vane air flow sensor. Sensor de massa d'aire aspirada de paleta o de tipus potenciòmetre.
λ	Factor lambda. Relació entre la mescla aire-combustible real i la ideal o estequiomètrica (14,7:1).

Taula 23. Glossari d'abreviatures i símbols.

ADRIA PEREZ MURIEL - DNI 41598401A

Firmado digitalmente por ADRIA PEREZ MURIEL - DNI 41598401A
Fecha: 2024.06.01 19:09:00 +02'00'

Adrià Pérez Muriel

La Bisbal d'Empordà, 1 de juny de 2024.

ANNEXOS A LA MEMÒRIA

A. INFORMACIÓ TÈCNICA

A.1. Motor SEAT AFT 1.6 litres

Característiques tècniques Motor SEAT AFT 1.6 litres	
Tipus de motor	AFT
Combustible	Gasolina E5 / E10
Cilindrada (cm3)	1595
Nombre de cilindres	4
Ø x cursa (mm)	81 x 77,4
Relació de compressió	10,3 : 1
Alimentació	Injecció multipunt
Potència màxima (kW / rpm)	74 / 5800
Parell màxim (N·m / rpm)	140 / 3800

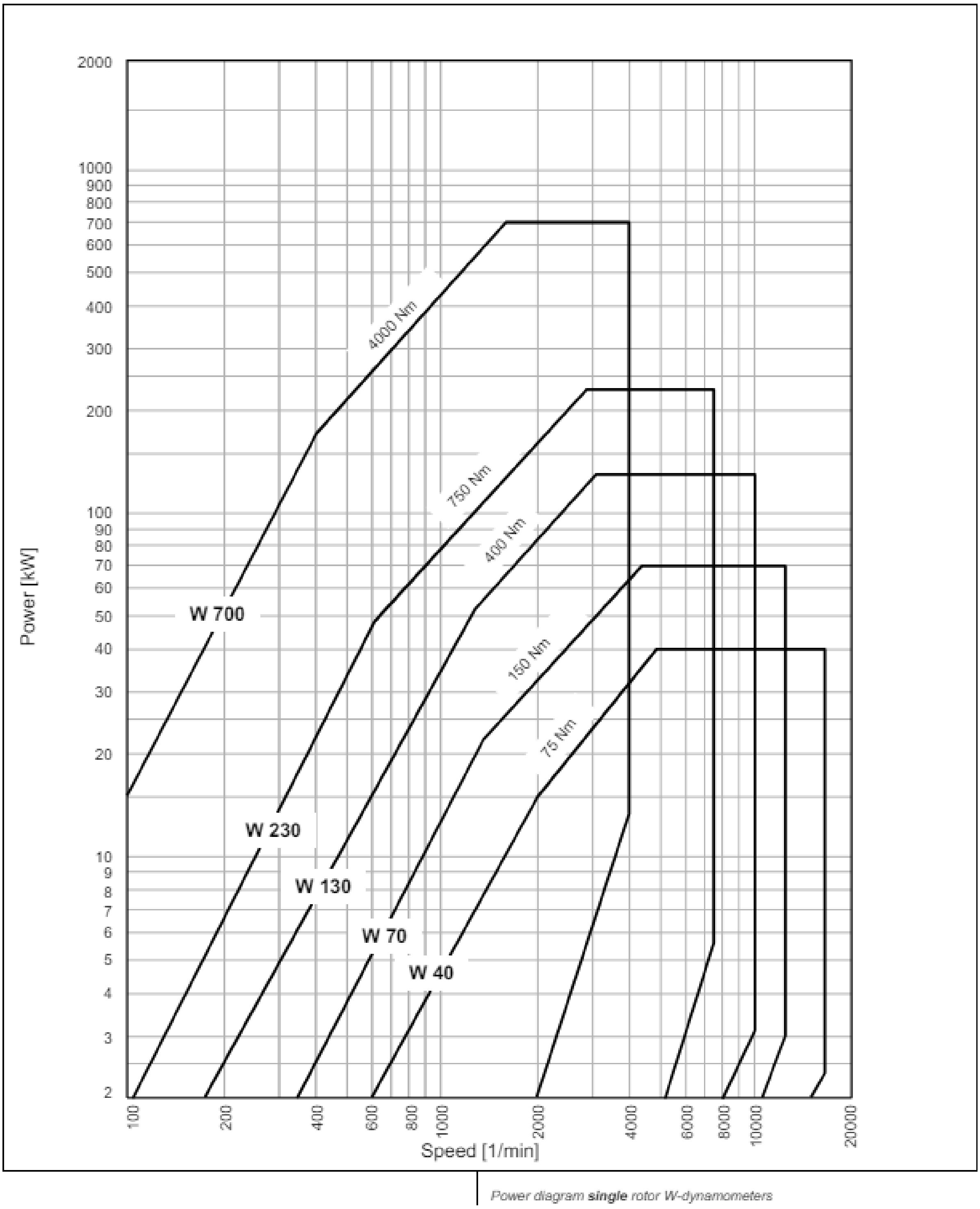
Taula 24. Característiques tècniques motor SEAT AFT 1.6 litres.

A.2. Fre dinamomètric SHENCK W130

Característiques tècniques fre SCHENCK W130	
Potència (kW)	130
Parell nominal (N·m)	400
Velocitat mínima a parell nominal (rpm)	1250
Velocitat màxima	10000
Velocitat mínima a parell nominal (rpm)	3104
Moment d'inèrcia (kg·m2)	0,14
Pes (kg)	270
Precisió en la mesura de velocitat (rpm)	± 1
Precisió en la mesura de parell (N·m)	0.2
Precisió en el control de la velocitat (rpm)	± 10
Precisió en el control del parell (%)	± 1
Alimentació (V / Hz)	230 / 50 - 60

Taula 25. Característiques tècniques fre SCHENCK W130.

Corba de potència fre SCHENCK W130:



Gràfic 16. Corba de potència fre SCHENCK W130.

A.3. Servomotor d'alt parell 9IMOD

Característiques tècniques servomotor alt parell 9IMOD	
Força màxima (kN)	37
Parell màxim (kg·cm / V)	130 / 12
Rang de gir (º)	180
Sistema de control	PWM / RC
Tipus de senyal	Digital
Tipus de motor	Sense escombretes
Freqüència de funcionament (Hz)	50 - 330
Rang d'amplada d'impuls (µs)	500 - 2500
Velocitat de posicionament sense càrrega (s / º)	0,15 - 0,18 / 60
Dimensions (l x h x w)	88 x 33 x 84,3
Pes (kg)	0,363

Taula 26. Característiques tècniques servomotor d'alt parell.

A.4. Sonda lambda amb controlador SportDevices

Característiques tècniques sonda lambda amb controlador SportDevices	
Sensor d'oxigen	
Tipus de sensor	Bosch LSU 4.2 banda ample ZnO2
Precisió (%)	± 0,7
Rang de mesura factor lambda	0,65 a ∞
Tipus de combustible compatible	Gasolina sense plom
Pressió màxima gasos d'escapament (major pressió amb menor precisió) (bar)	2,5
Temperatura màxima gasos d'escapament (ºC)	1030
Temperatura màxima cable i funda protectora (ºC)	250
Muntatge (rosca) (mm)	M18 x 1,5
Controlador SportDevices	
Senyal de sortida	Analògica 0 - 5 V
Rang de mesura AFR	9 a 19
Precisió AFR	< 0.1
Consum màxim de potència (W)	25

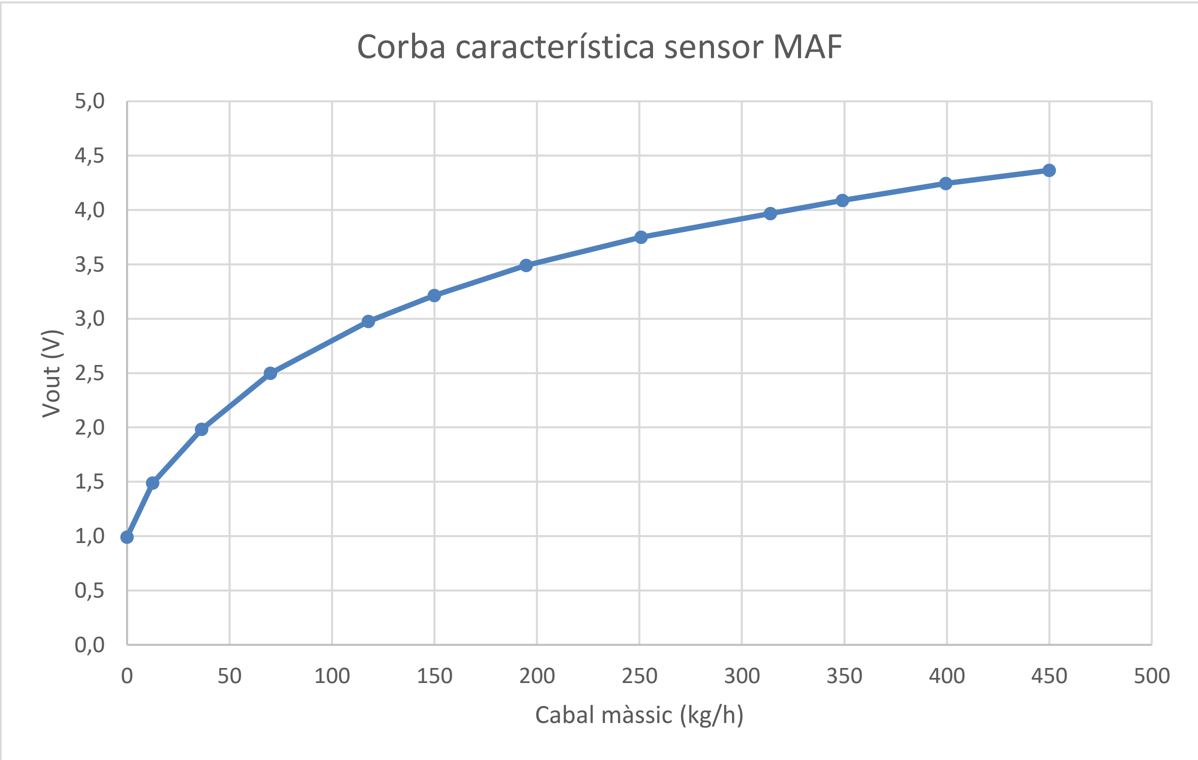
Alimentació (V)	10 a 15

Taula 27. Característiques tècniques sonda lambda amb controlador SportDevices.

A.5. Sensor MAF

Característiques tècniques sensor MAF Bosch	
Cabal màssic nominal (kg/h)	370
Rang de mesura cabal màssic (kg/h)	-15 a 480
Tensió d'alimentació nominal (V)	14
Rang de tensió d'alimentació (V)	6 a 17
Precisió (%)	± 3
Rang de temperatura (ºC)	-40 a 120
Intensitat (A)	< 0.1
Constant de temps **τ**63 (ms)	≤ 15
Constant de temps **τ** (ms)	≤ 30

Taula 28. Característiques tècniques sensor MAF.



Taula 29. Corba característica teòrica sensor MAF.

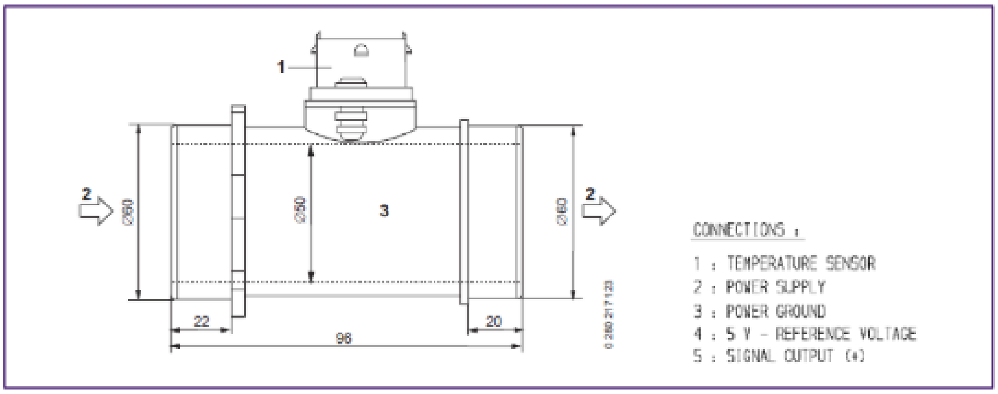


Figura 52. Pinout sensor MAF.

A.6. Sensor flex fuel etanol GM Continental E85

Característiques tècniques sensor flex fuel etanol GM Continental E85	
Rang de mesura (% etanol)	0 a 100
Senyal de sortida (Hz)	50 - 150
Precisió (%)	± 5
Resolució (%)	0.1
Tensió d'alimentació (V)	sep-18
Rang de temperatura ambiental (ºC)	-40 a 125
Rang de temperatura combustible (ºC)	-40 a 90
Temps de resposta (s)	< 1
Pressió màxima de combustible (bar)	13.5
Cabal màxim (l/h)	400

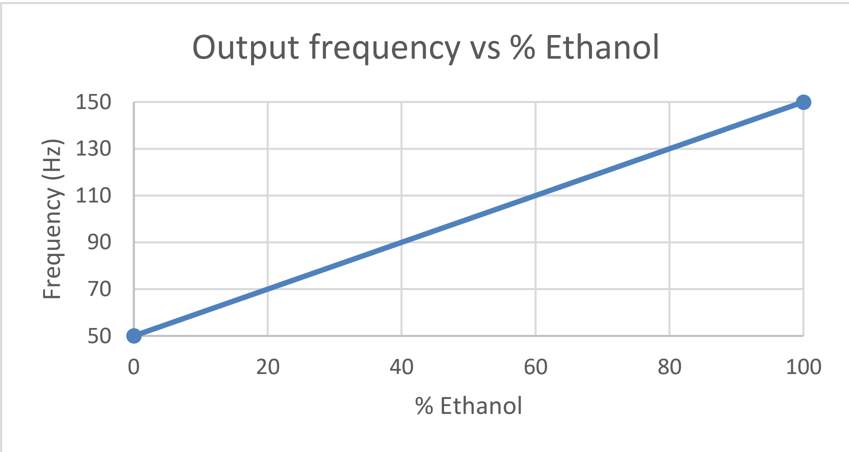
Taula 30. Característiques tècniques sensor de contingut d'etanol.

Codis d'error sensor contingut d'etanol:

Codi d'error	Senyal de sortida (Hz)
Falles internes sensor (reemplaçament)	170 - 179
Composició combustible fora del rang de mesura del sensor (capacitància). Pot indicar presència d'aigua en el combustible.	180

Composició combustible fora del rang de mesura del sensor (conductivitat). Pot indicar presència d'aigua ionitzada al combustible.	190
Composició combustible fora del rang de mesura del sensor. Pot indicar presència d'aigua ionitzada al combustible.	171

Taula 31. Codis d'error sensor de contingut d'etanol.



Gràfic 17. Relació freqüència - percentatge d'etanol.

A.7. Injector Bosch 0 218 156 374

Característiques tècniques injector Bosch 0 218 156 374	
Fluid	N-Heptà
Pressió (bar)	3
Resistència (Ω)	14,5
Tensió d'alimentació (V)	14
Cabal estàtic (g/min)	154.3
Combustibles compatibles	E85 / M100
Màxima pressió del sistema (bar)	8
Màxima temperatura de combustible (ºC)	≤ 70

Taula 32. Característiques tècniques injector de combustible.

A.7. Oscil·loscopi RS PRO per a PC

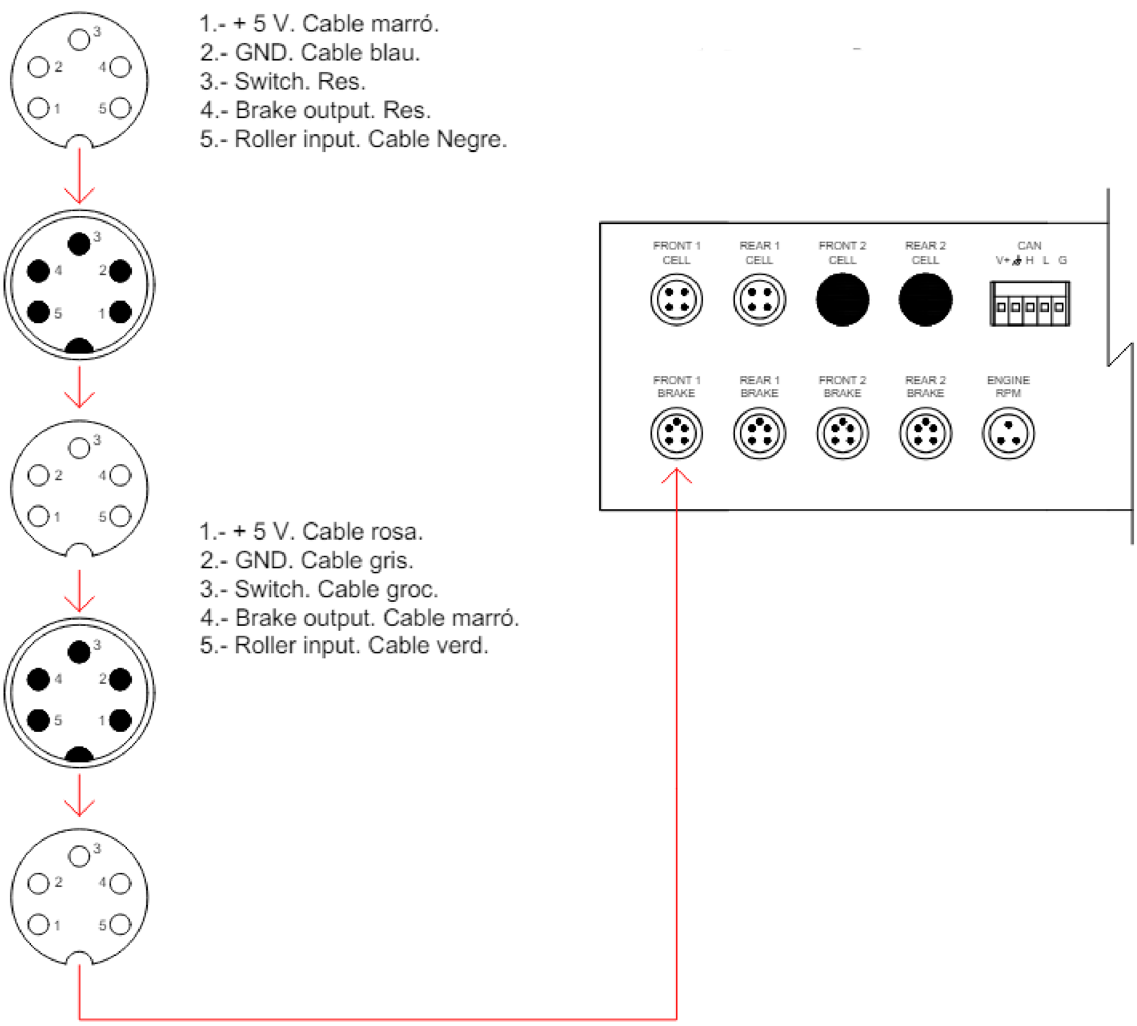
Característiques tècniques oscil·loscopi RS PRO 2205864	
Tipus d'oscil·loscopi	per a PC
Tipus de connexió	USB
Nombre de canals analògics	4 amb possibilitat d'adquirir 2 senyals simultàniament
Amplada de banda (MHz)	70
Taxa de mostreig (GSa/s)	1
Voltatge màxim d'entrada (V)	35

Taula 33. Característiques tècniques oscil·loscopi per a PC.

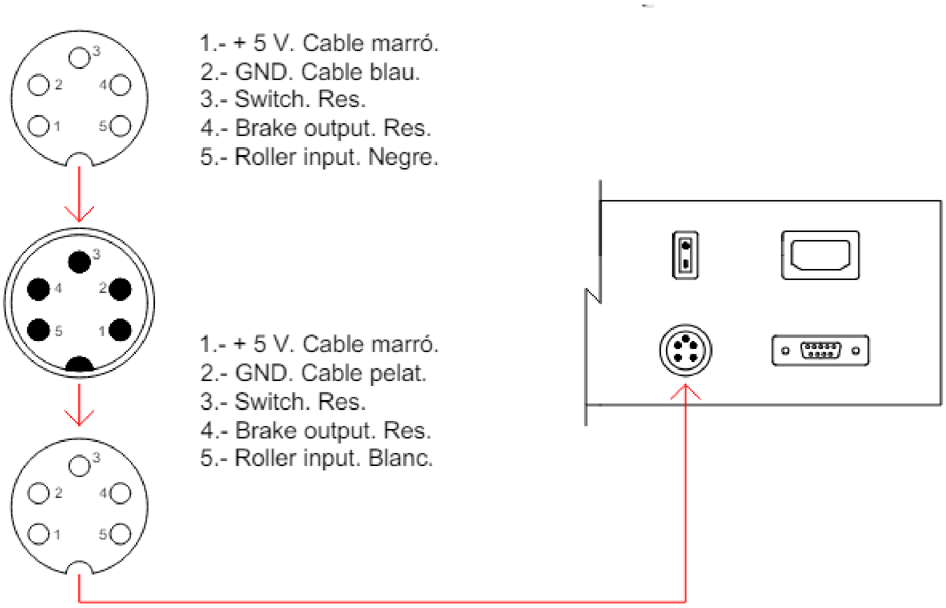
B. ESQUEMES DE CONNEXIONAT

B.1. Roller speed

B.1.1. Roller speed SP6

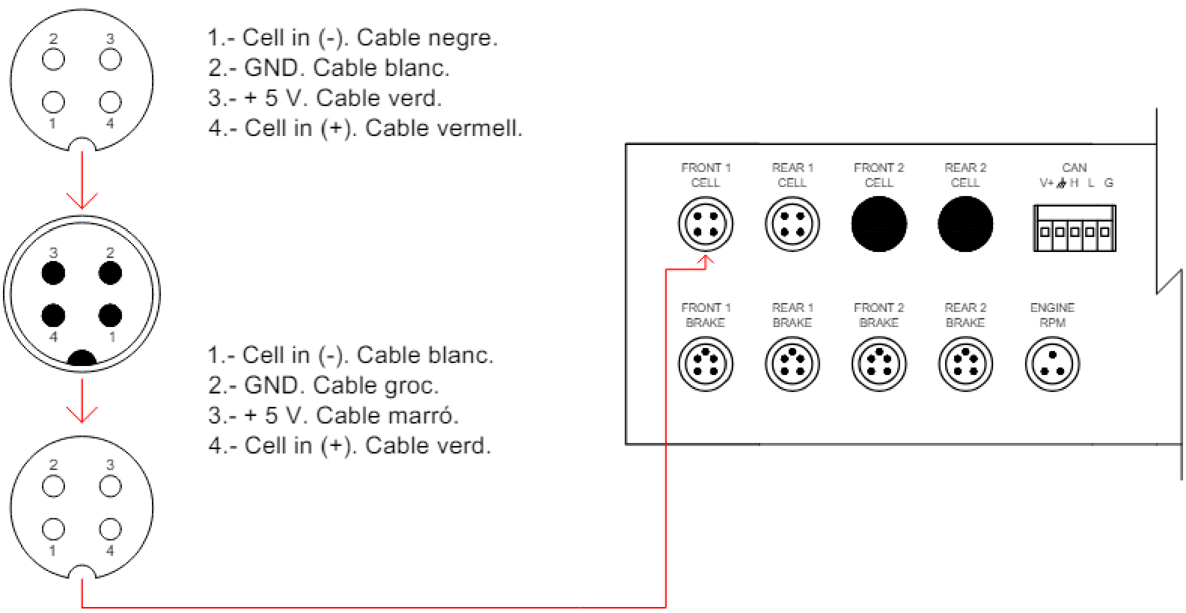


B.1.2. Roller speed SP4

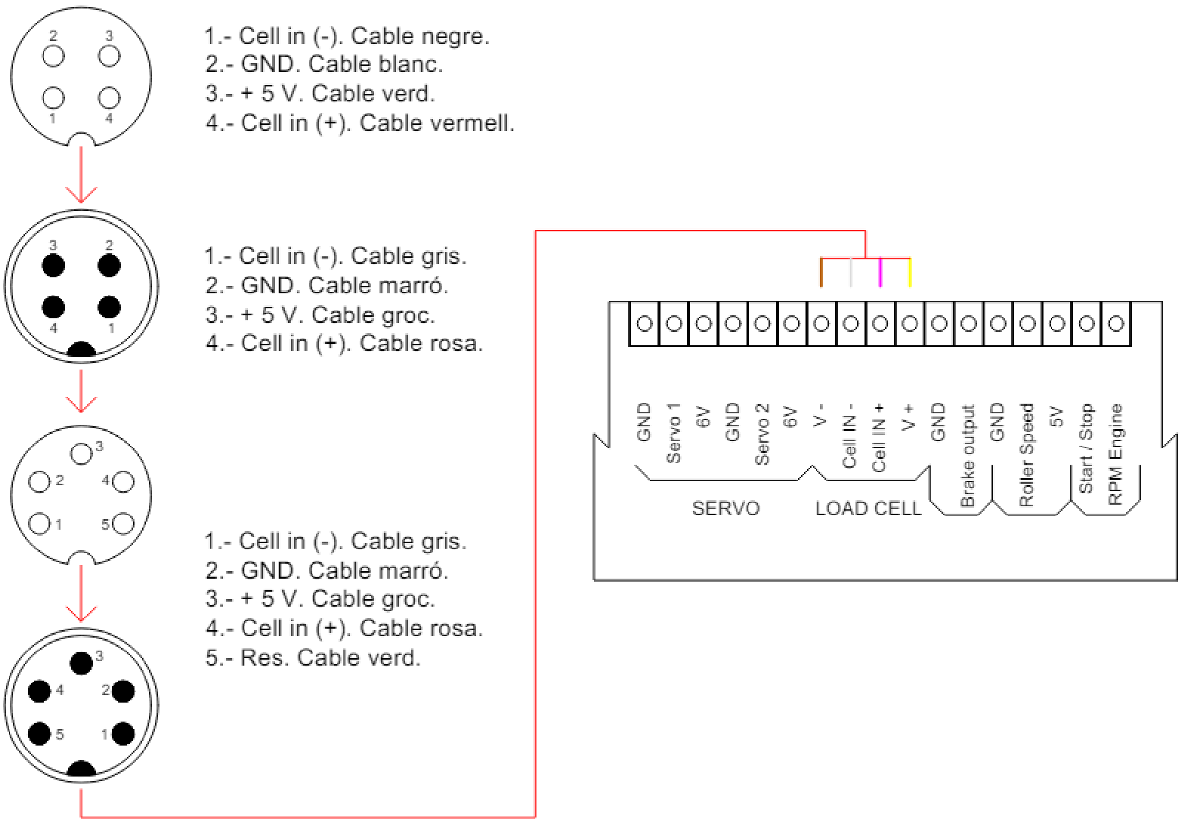


B.2. Load Cell

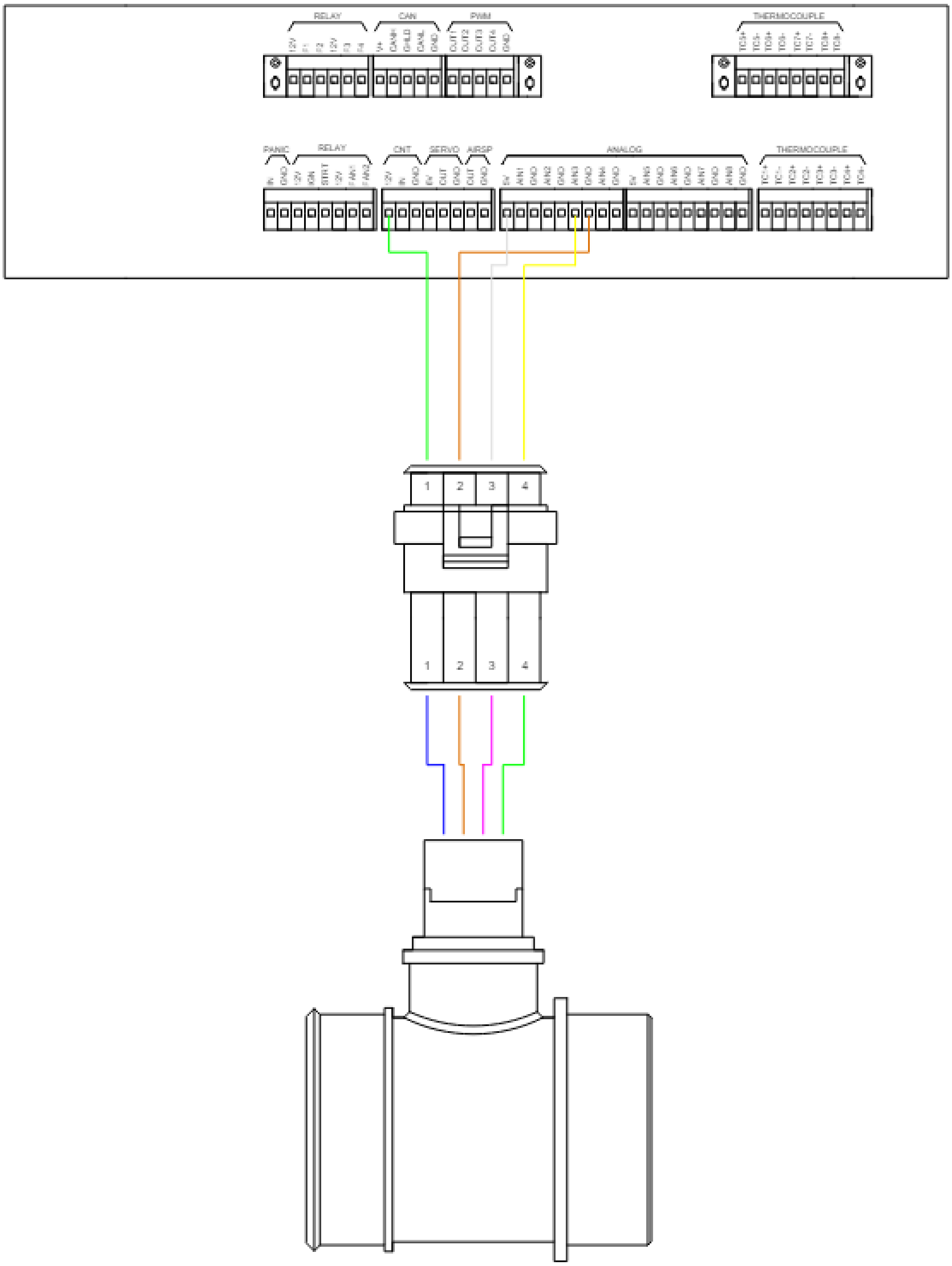
B.2.1. Load Cell SP6



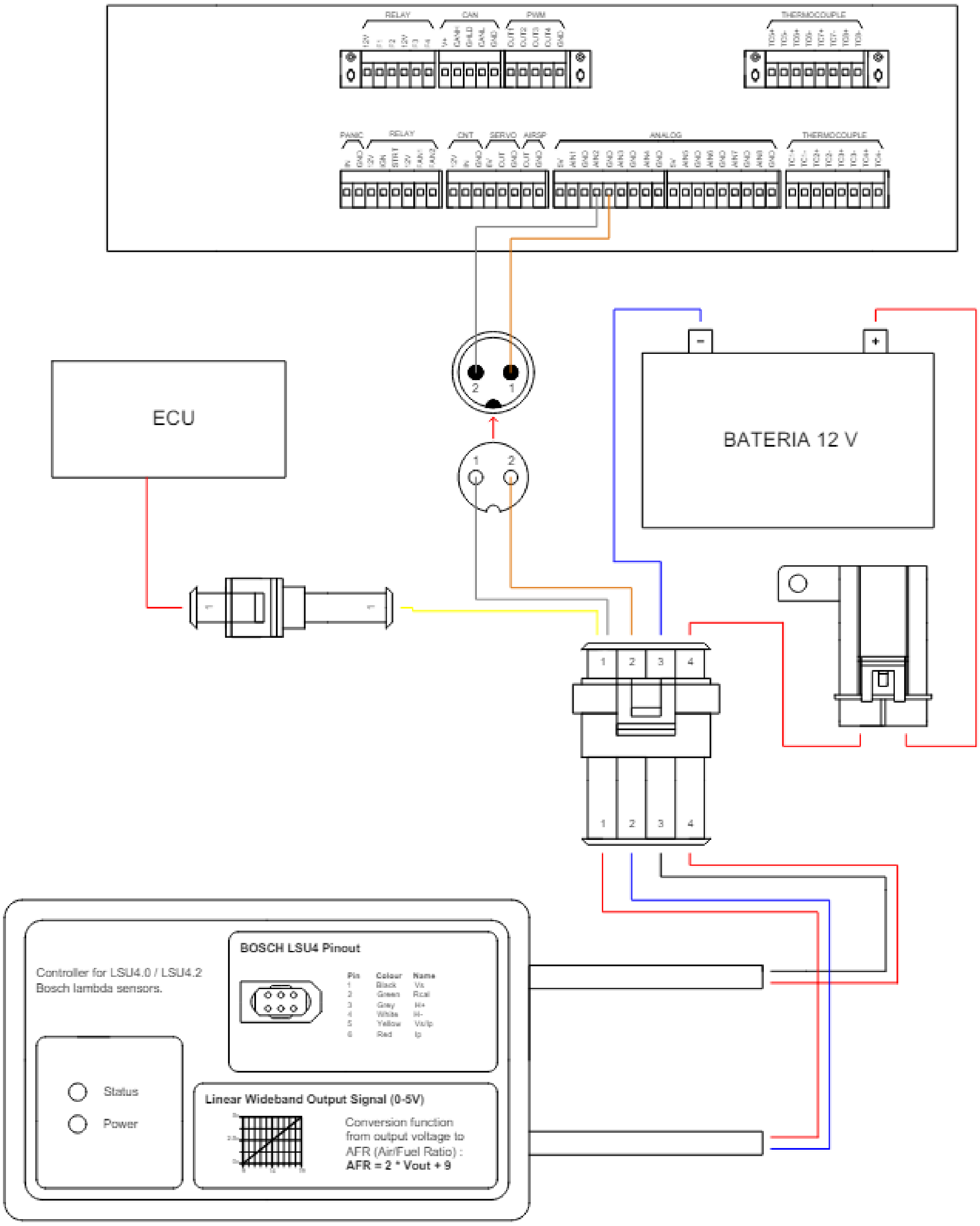
B.2.2. Load Cell SP4



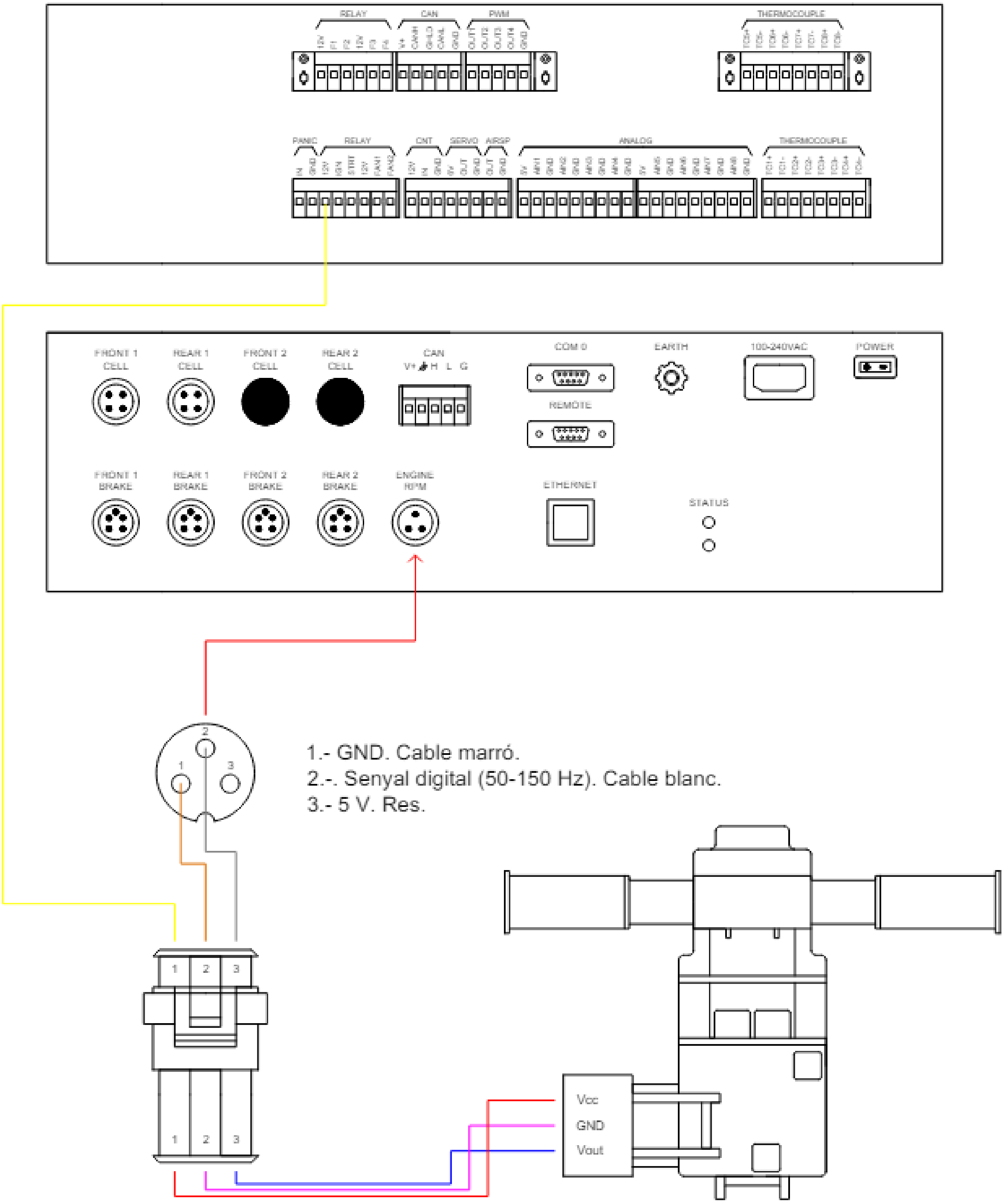
B.3. Sensor MAF



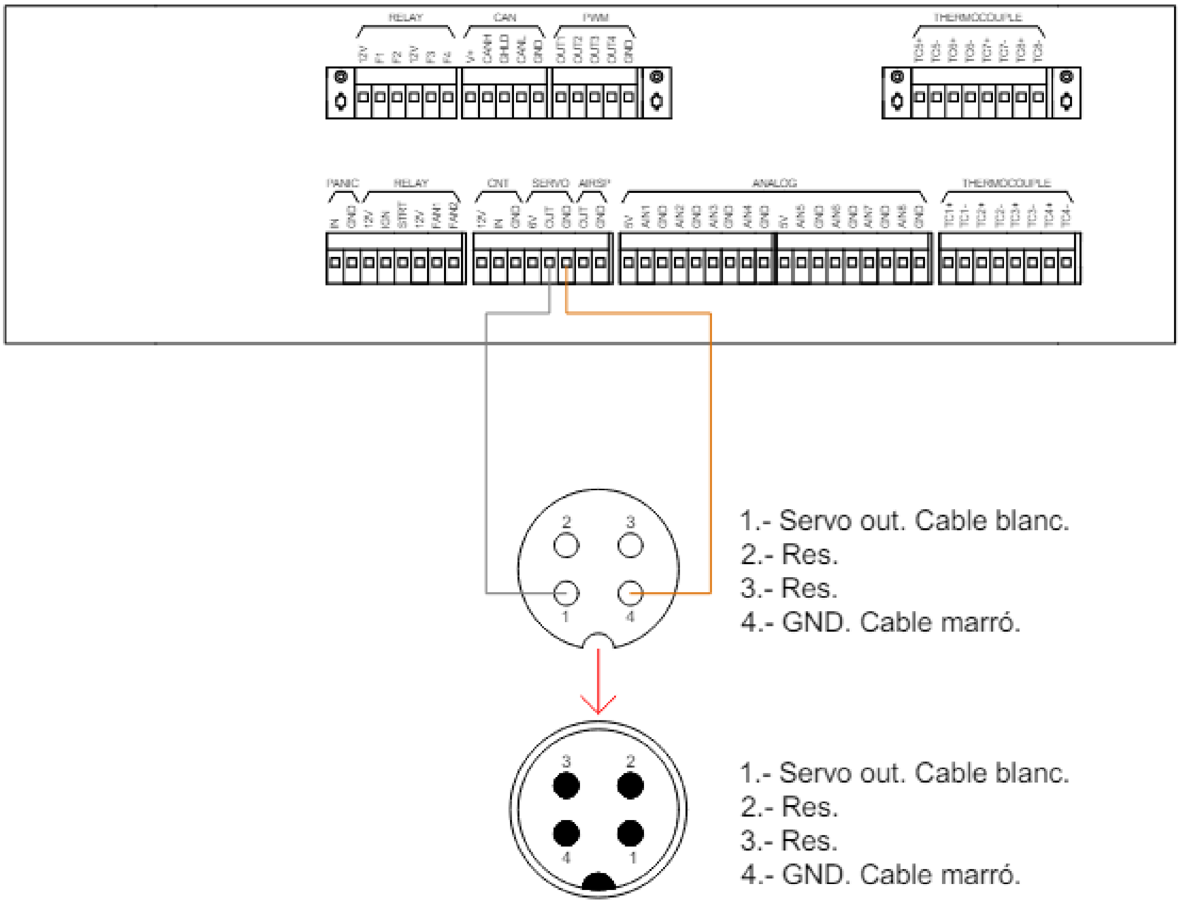
B.4. Sonda lambda

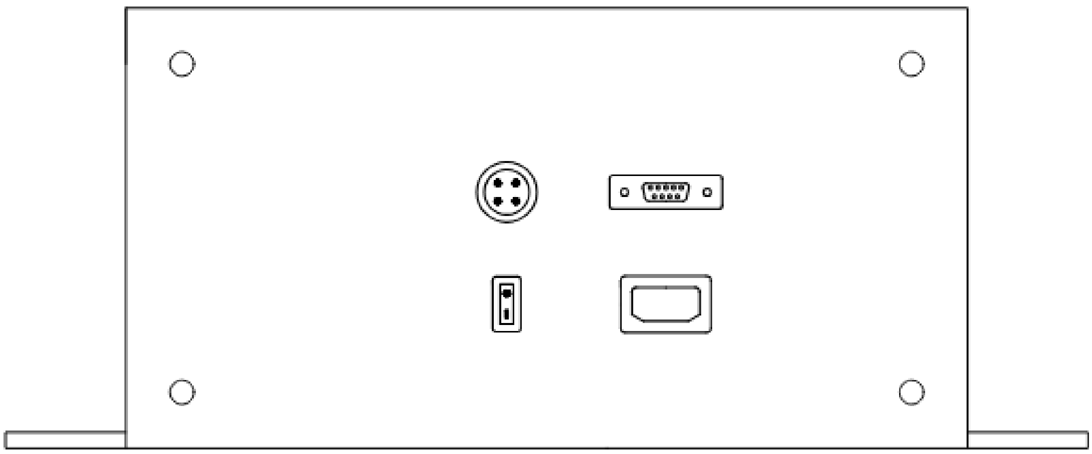


B.5. Sensor d'etanol

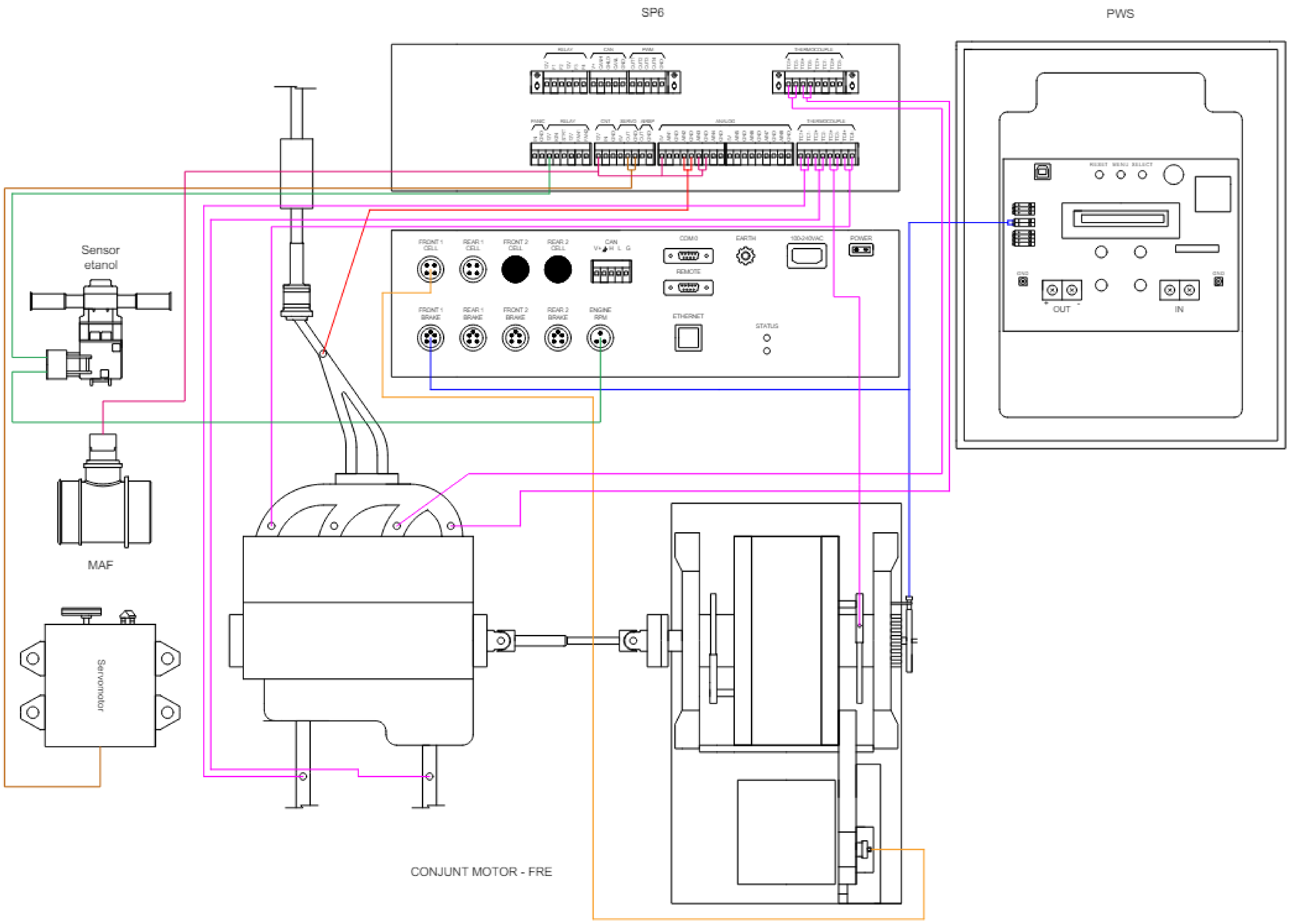


B.6. Servomotor

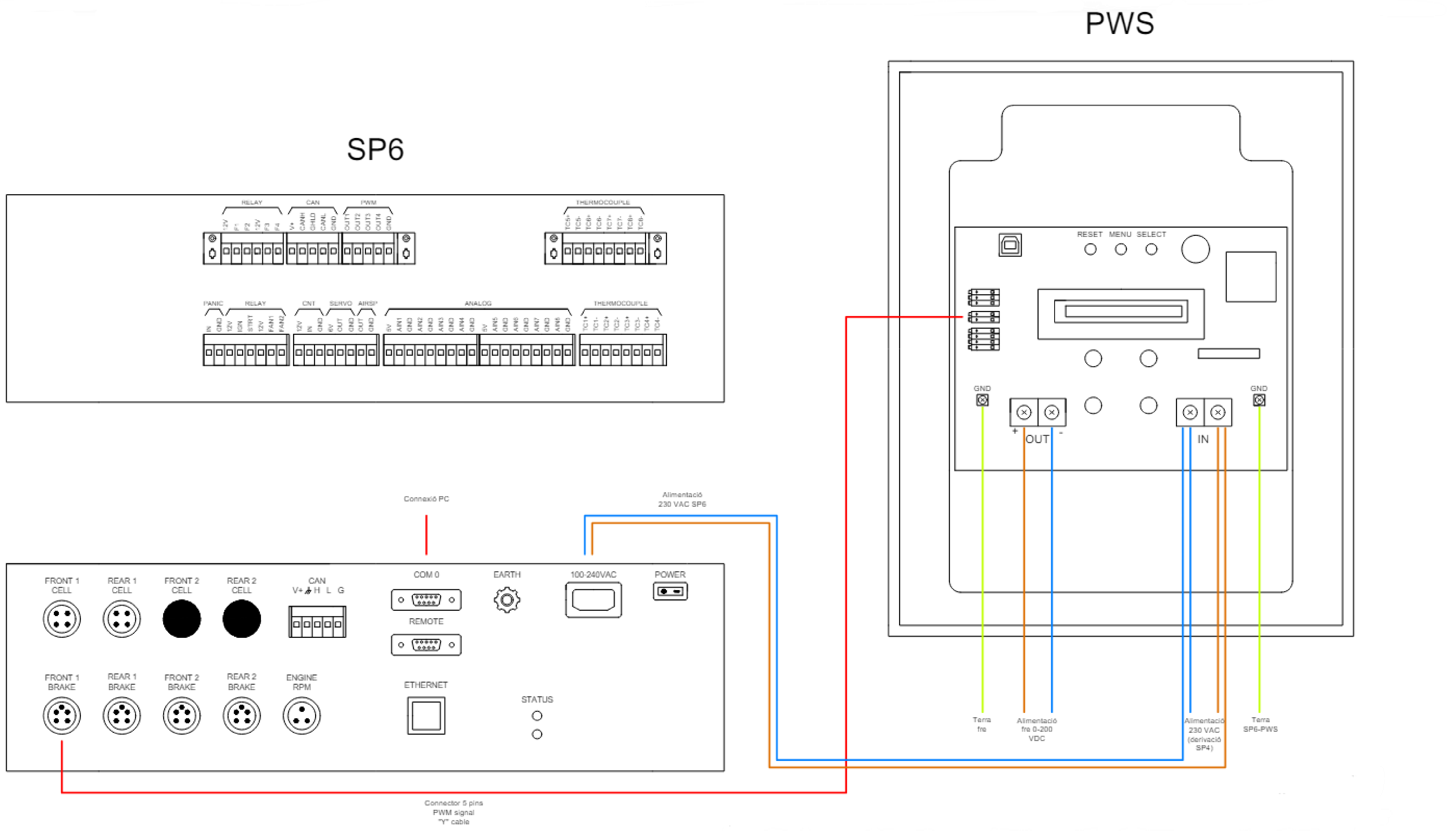




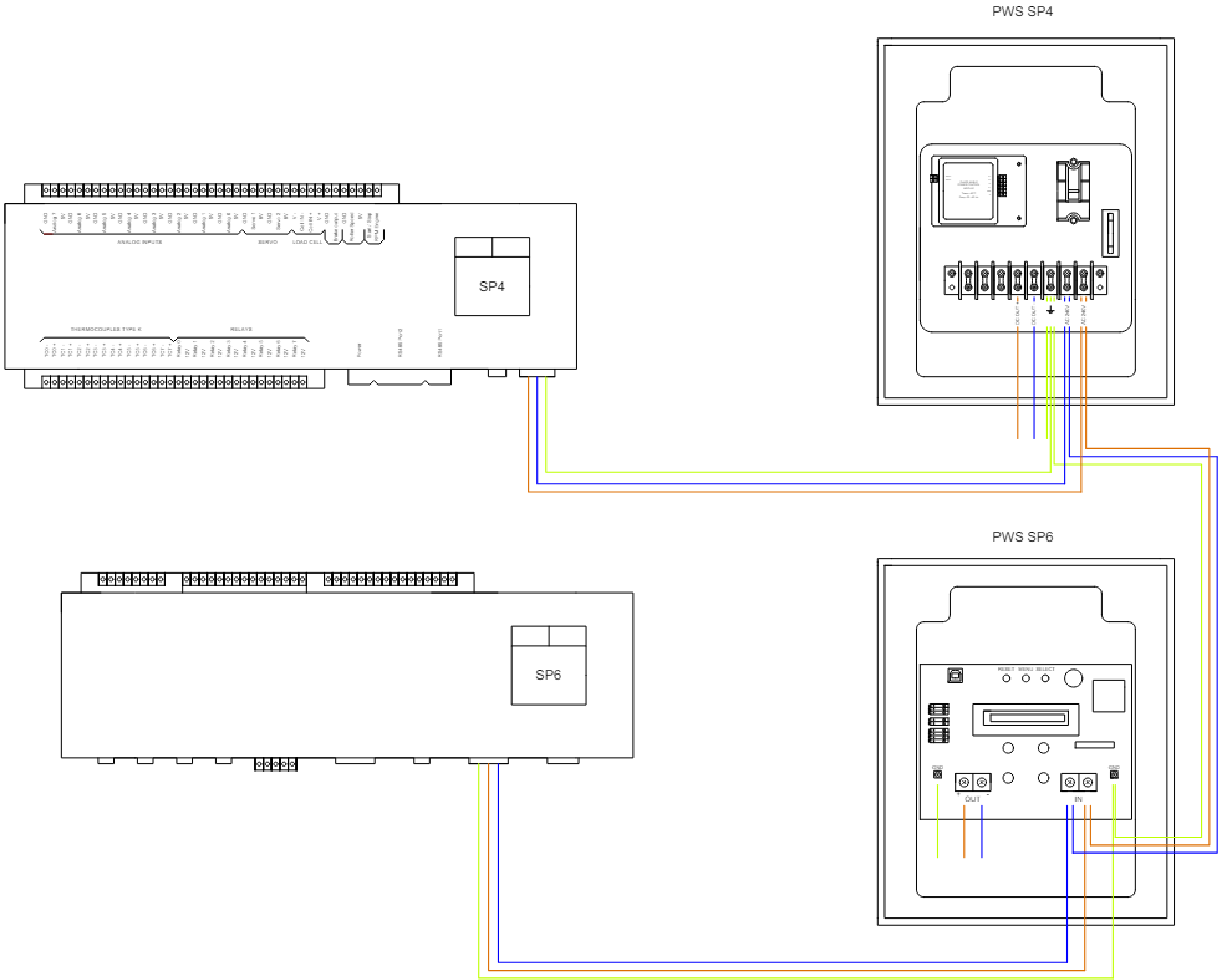
B.7. Connexions generals



B.8. Connexió SP6 i PWS



B.9. Connexió SP6, SP4 i PWS



C. CÀLCULS ELÈCTRICS

En aquest annex es justifica la secció escollida pels cables d'alimentació del mòdul d'adquisició de dades SP6, la seva corresponent font d'alimentació i el dispositiu de protecció escollit.

Per altra banda, també es mostren els càlculs efectuats per al dimensionament de la línia d'alimentació del fre dinamomètric per mitjà d'una caixa combinada de dos preses de corrent de 16 A amb connexió directa als mòduls d'adquisició de dades SP6 i SP4.

La instal·lació del cablejat es realitza aprofitant les safates perforades horitzontals ja instal·lades a la sala de proves.

Les seccions dels conductors i les intensitats màximes admissibles corresponents s'extreuen de la Taula 1, de la ITC-BT-19 del REBT (Reglament Electrotècnic per a Baixa Tensió).

C.1. Càlcul elèctric alimentació SP6, PWS i fre

C.1.1. Intensitat màxima admissible

Tal i com s'indica al manual d'usuari i instal·lació de la unitat SP6, el consum màxim de potència és de 40 W.

Per altra banda, en el manual d'usuari i instal·lació de la font d'alimentació, s'indica un consum de potència màxim de 3,2 kW.

La intensitat nominal es calcula a partir de la l'expressió detallada a l'Equació 27:

$$I = \frac{P}{V * cos\varphi} \qquad (Eq. 27)$$

On **P** és la potència activa (W), **V** és la tensió nominal (V) i **cosφ** és el factor de potència (cosφ=1).

Les potències i intensitats de càlcul es mostren a la *T*aula 34 tot seguit:

Línia	Descripció	Potència de càlcul (W)	Intensitat de càlcul (A)
L1	Alimentació 230 V AC SP6 i font d'alimentació	3240	14,09
L2	Alimentació DC fre dinamomètric des de font d'alimentació SP6 mitjançant caixa combinada de 2 preses de corrent de 16 A.	3680	16,00

Taula 34. Potències i intensitats de càlcul SP6, PWS i fre.

Per al càlcul de la intensitat màxima admissible s'apliquen factors de correcció, en funció de la temperatura ambient i per agrupament de cables multi conductors en safata perforada. Els factors de correcció utilitzats per al càlcul de la intensitat màxima admissible, extrets del REBT, es mostren a la *Taula 35*:

Factors de correcció intensitat	
Temperatura ambient (30 ºC)	1,1
Agrupació de 4 cables multiconductors en safata perforada	0,8

Taula 35. Factors de correcció intensitat màxima admissible.

Finalment, el dispositiu de protecció escollit, així com, la intensitat màxima admissible i les seccions dels conductors escollides es mostren a la *Taula 36*:

Línia	L1	L2
Mètode d'instal·lació	E (ITC-BT-19)	E (ITC-BT-19)
Conductors	Multiconductors Cu / XLPE	Multiconductors Cu / XLPE
Tensió nom. Aïllament	0,6 / 1 kV	0,6 / 1 kV
Intensitat calculada (A)	14,09	16,00
Int. Nominal disp. Protecció	16 A	
Fases / Secció	1 / 1,5 mm2	1 / 1,5 mm2
Intensitat màxima admissible (A)	21,12	21,12

Taula 36. Càlcul d'intensitat màxima admissible alimentació SP6, PWS i fre.

C.1.2. Caiguda de tensió màxima admissible

La caiguda de tensió màxima permesa és del 5% i ve donada per l'expressió de l'Equació 28:

$$e = \frac{2 * P * L}{c * U * S} \qquad (Eq. 28)$$

On **e** és la caiguda de tensió (V), **P** és la potència activa (W), **L** és la longitud del conductor (m), **c** és la conductivitat del material (Ω mm^2/m) (Conductors de coure, pren el valor de 44 Ω mm^2/m a 90 ºC), **U** és la tensió nominal (V) i **S** és la secció del conductor (mm^2).

Finalment es mostra, a la *Taula 37*, el càlcul de les caigudes de tensió i les característiques dels conductors escollits:

Línia	L1	L2
Mètode d'instal·lació	E (ITC-BT-19)	E (ITC-BT-19)
Conductors	Multiconductors Cu / XLPE	Multiconductors Cu / XLPE
Tensió nom. Aïllament	0,6 / 1 kV	0,6 / 1 kV
Intensitat calculada (A)	14,09	16,00
Int. Nominal disp. Protecció	16 A	
Fases / Secció	1 / 1,5 mm2	1 / 1,5 mm2
Intensitat màxima admissible (A)	21,12	21,12
Descripció línia elèctrica	2x1,5+1,5+1,5	2x1,5+1,5+1,5
Longitud (m)	7,5	8
Caiguda de tensió (%)	1,39	1,69

Taula 37. Càlcul de caiguda de tensió i característiques conductors alimentació SP6, PWS i fre.

Els conductors utilitzats per a la instal·lació del mòdul SP6, la font d'alimentació i la corresponent connexió amb el fre, seran del tipus RCT RV-K 0.6/1kV 3G1,5.

La instal·lació estarà protegida per un interruptor magnetotèrmic de 16 A.

C.2. Càlcul elèctric alimentació SP4, PWS i fre

C.2.1. Intensitat màxima admissible

El càlcul d'intensitat màxima admissible per al dimensionament dels conductors d'alimentació de la unitat SP4 amb la seva font d'alimentació i la corresponent connexió amb el fre mitjançant la caixa combinada de dues preses de corrent de 16 A, es realitza seguint el mateix criteri descrit anteriorment.

Tot seguit es mostra a la *Taula 38*, les potències i intensitats de càlcul:

Línia	Descripció	Potència de càlcul (W)	Intensitat de càlcul (A)
L3	Alimentació 230 V AC SP4 i font d'alimentació	3240	14,09
L4	Alimentació DC fre dinamomètric des de font d'alimentació SP4 mitjançant caixa combinada de 2 preses de corrent de 16 A.	3680	16,00

Taula 38. Potències i intensitats de càlcul SP4, PWS i fre.

A continuació es mostra a la *Taula 39* el càlcul de les intensitats màximes admissibles i les seccions dels conductors escollides:

Línia	L3	L4
Mètode d'instal·lació	E (ITC-BT-19)	E (ITC-BT-19)
Conductors	Multiconductors Cu / XLPE	Multiconductors Cu / XLPE
Tensió nom. Aïllament	0,6 / 1 kV	0,6 / 1 kV
Intensitat calculada (A)	14,09	16,00
Int. Nominal disp. Protecció	16 A	
Fases / Secció	1 / 1,5 mm2	1 / 1,5 mm2
Intensitat màxima admissible (A)	21,12	21,12

Taula 39. Càlcul d'intensitat màxima admissible alimentació SP4, PWS i fre.

C.2.2. Caiguda de tensió màxima admissible

El criteri per a la comprovació de la caiguda de tensió és el mateix que s'ha descrit anteriorment, amb un límit del 5%.

Els càlculs efectuats així com les característiques dels conductors escollits es mostren a la *Taula 40*:

Línia	L3	L4
Mètode d'instal·lació	E (ITC-BT-19)	E (ITC-BT-19)
Conductors	Multiconductors Cu / XLPE	Multiconductors Cu / XLPE
Tensió nom. Aïllament	0,6 / 1 kV	0,6 / 1 kV
Intensitat calculada (A)	14,09	16,00
Int. Nominal disp. Protecció	16 A	
Fases / Secció	1 / 1,5 mm2	1 / 1,5 mm2
Intensitat màxima admissible (A)	21,12	21,12
Descripció línia elèctrica	2x1,5+1,5+1,5	2x1,5+1,5+1,5
Longitud (m)	7	7,5
Caiguda de tensió (%)	1,30	1,58

Taula 40. Càlcul de caiguda de tensió i característiques conductors alimentació SP4, PWS i fre.

Els conductors utilitzats per a la instal·lació del mòdul SP4, la font d'alimentació i la corresponent connexió amb el fre, seran del tipus RCT RV-K 0.6/1kV 3G1,5.

La instal·lació estarà protegida per un interruptor magnetotèrmic de 16 A.

D. MANUALS D’USUARI I INSTAL·LACIÓ

D.1. Manual d’usuari i instal·lació SP6

SP6 INSTALLATION AND SETUP MANUAL

Contents

2.1 SAFETY: When Working Inside Your Device

DISCLAIMERS

Limitations of warranties and liability: This Software, including the embedded SPx DAQ firmware, is provided and licensed by SportDevices on an "as is" basis, without any other warranties or conditions, express or implied, including, but not limited to, warranties of merchantable quality, satisfactory quality, merchantability or fitness for a particular purpose or non-infringement, or those arising by law, statute, usage of trade, course of dealing or otherwise. The entire risk as to the results and performance of the software is assumed by you. To the maximum extent permitted by applicable law, neither SportDevices, its dealers or suppliers shall have any liability to you or any other person or entity for any indirect, incidental, special, or consequential damages whatsoever, including, but not limited to, loss of revenue or profit, lost or damaged data or other commercial or economic loss, even if SportDevices. has been advised of the possibility of such damages, or they are foreseeable. SportDevices is also not responsible for claims by a third party. Other possible damages INCLUDE VEHICLE OR ENGINE DAMAGES, DYNAMOMETER DAMAGES, AND PERSONAL INJURIES. The limitations set forth herein shall apply whether or not the alleged breach or default is a breach of a fundamental condition or term or a fundamental breach.

If you are downloading this Software, the following applies:

All risk of damage to the Software during transmission and download is assumed by you.

All "Software" products, including standard and beta release versions of SportDyno Software and SportDevices's Firmware are licensed on a (non-transferable) as-is, without warranty, basis only. There are no warranties which extend beyond those stated here. The purchase price of any SPx kit (SP1, SP3, SP4, SP6) includes an implicit software license. This software license does not include any setup, training, calibration, or other consulting services.

By installing and/or using the Software you certify that you have read, understood and agreed to comply with and be bound by the following terms and conditions. If you do not agree with these terms and conditions do not install and/or use the Software.

The only exception to the above is that the "Software's media" will be replaced (if found to be unreadable) for a duration of 30-days from the original invoice ship date from SportDevices or authorized distributor. Any implied warranty determined to be applicable to the "Software's media" is limited in duration to the duration of this warranty.

In the event of a media defect in material or workmanship, SportDevices's sole responsibility is to repair (or at its option - replace or refund) the defective media. Final warranty determination will be the decision of SportDevices.

SportDevices shall not be responsible for (a) labor, transportation or other incidental charges or (b) consequential or other damages incurred by use of SportDevices Software media.
Media replacement performance will be initiated by returning the alleged defective media freight prepaid to SportDevices with dated purchase invoice.

Any disputes arising between the parties over any products, services, warranties, terms, agreements, etc. shall be governed under the laws of Valencia (Spain) and in an appropriate court within its jurisdiction.

This Software License Warranty Disclaimer supersedes all prior warranty statements. Inquiries concerning this Software License Warranty Disclaimer should be directed to:

SportDevices
Cami del Port 145, 46470 Catarroja, Spain

2. General Safety Instructions

Use the following safety guidelines to help ensure your own personal safety and to help protect your equipment and working environment from potential damage.

SAFETY: General Safety

When setting up the equipment for use:

- Place the equipment on a hard, level surface. If the equipment is installed in a closed-in wall unit, ensure that there is enough ventilation.
- Avoid placing objects on top of this equipment to permit the airflow required for proper ventilation. Restricting airflow can damage the equipment.
- Keep your device away from radiators and heat sources.
- Keep your equipment away from extremely hot or cold temperatures to ensure that it is used within the specified operating range. (check technical parameters section)
- Keep your equipment away from Electromagnetic emitting devices like CDI ignition, or electric motors / VFD (Variable Frequency Drive)
- Do not push any objects into the air vents or openings of your equipment. Doing so can cause fire or electric shock by shorting out interior components.
- Ensure that nothing rests on your equipment's cables and that the cables are not located where they can be stepped on or tripped over.

When operating your equipment:

- Do not use your equipment in a wet environment, for example, in a wet basement.
- Do not use AC powered equipment during an electrical storm.
- Do not spill food or liquids on your equipment.
- Before you clean your equipment, disconnect it from the electrical outlet. Clean your device with a soft cloth dampened with water. Do not use liquids or aerosol cleaners, which may contain flammable substances.
- Clean the display with a soft, clean cloth and water. Apply the water to the cloth, then stroke the cloth across the display in one direction, moving from the top of the display to the bottom. Remove moisture from the display quickly and keep the display dry.
- Long-term exposure to moisture can damage the display. Do not use a commercial window cleaner to clean your display.

⚠ **CAUTION: Do not operate your equipment with any cover(s) removed.**

- If your equipment does not operate normally - in particular, if there are any unusual sounds or smells coming from it - unplug it immediately and contact an authorized dealer or service center.

⚠ **WARNING: To prevent the spread of fire, keep open flames away from this product at all times.**

2.1 SAFETY: When Working Inside Your Device

Do not attempt to service the equipment yourself, except as explained in your documentation or in instructions otherwise provided to you by SportDevices. Always follow installation and service instructions closely.

2.2 SAFETY: General Power Safety

By default, if other values are not specified all SportDevices equipment are rated for **230 VAC / 50 Hz.** (115 VAC units will have a specific label for that)

Observe the following guidelines when connecting your equipment to a power source:

- Check the voltage rating before you connect the equipment to an electrical outlet to ensure that the required voltage and frequency match the available power source.
- Do not plug the equipment power cables into an electrical outlet if the power cable is damaged.
- To prevent electric shock, plug the equipment power cables into properly grounded electrical outlets. If the equipment is provided with a 3-prong power cable, do not use adapter plugs that bypass the grounding feature, or remove the grounding feature from the plug or adapter.
- If you use an extension power cable, ensure that the total ampere rating of the products plugged in to the extension power cable does not exceed the ampere rating of the extension cable.
- If you must use an extension cable or power strip, ensure the extension cable or power strip is connected to a wall power outlet and not to another extension cable or power strip. The extension cable or power strip must be designed for grounded plugs and plugged into a grounded wall outlet.
- If you are using a multiple-outlet power strip, use caution when plugging the power cable into the power strip. Some power strips may allow you to insert a plug incorrectly. Incorrect insertion of the power plug could result in permanent damage to your equipment, as well as risk of electric shock and/or fire. Ensure that the ground prong of the power plug is inserted into the mating ground contact of the power strip.
- Be sure to grasp the plug, not the cable, when disconnecting equipment from an electric socket.

2.3 SAFETY: If Your Device Gets Wet

⚠ **CAUTION: Before you begin any of the procedures in this section, see the SAFETY: General Safety section of this document.**

⚠ **CAUTION: Perform this procedure only after you are certain that it is safe to do so. If the device is connected to an electrical outlet, turn off the AC power at the circuit breaker, if possible, before attempting to remove the power cables from the electrical outlet. Use the utmost caution when removing wet cables from a live power source.**

1. Disconnect the AC cord from the electrical outlet, and then, if possible, disconnect the AC cord from the device.
2. Turn off any attached external devices, then disconnect them from their power sources, and then from the device.
3. Contact SportDevices support (info@sportdevices.com)

⚠ **Limited Warranties:** warranty is limited to normal usage of the device, any fault caused by inappropriate usage or accident will not be covered

2.4 SAFETY: If You Drop or Damage Your Equipment

⚠ **CAUTION: Before you begin any of the procedures in this section, see the SAFETY: General Safety and Power Safety sections of this document.**

4. **CAUTION: If any internal components can be seen through damaged portions, or if smoke or unusual odors are detected, disconnect the device from the electrical outlet and contact SportDevices support** (info@sportdevices.com)

1. Save and close any open files, exit any open programs, and shut down the computer.
2. Turn off the device and disconnect from the power source, and then disconnect from the computer.
3. Turn off any attached external devices, and disconnect them from their power sources and then from the computer.
4. Connect the device to the power source and turn on the device.
5. If the device does not start, or if and smoke or unusual odors are detected, or you cannot identify the damaged components, contact SportDevices support.

2.5 Protecting Against Electrostatic Discharge

⚠ **CAUTION: Disconnect product from mains power source in accordance with product specific safety information located on the "Safety Information" section of this website.**

Electrostatic discharge (ESD) events can harm electronic components inside your device. Under certain conditions, ESD may build up on your body or an object, such as a peripheral, and then discharge into another object, such as your device. To prevent ESD damage, you should discharge static electricity from your body before you interact with any of your device's internal electronic components, like the Bluetooth plug-in.

You can protect against ESD and discharge static electricity from your body by touching a metal grounded object (such as an unpainted metal surface on your device) before you interact with anything electronic.
You can also take the following steps to prevent damage from electrostatic discharge:

- When unpacking a static-sensitive component from its shipping carton, do not remove the component from the antistatic packing material until you are ready to install the component. Just before unwrapping the antistatic package, be sure to discharge static electricity from your body.
- When transporting a sensitive component, first place it in an antistatic container or packaging.
- Handle all electrostatic sensitive components in a static-safe area. If possible, use antistatic floor pads and work bench pads.

2.6 Dynamometer Important Safety Tips

- Securely fasten test vehicle using all available restraining ratchet straps. The more straps the better. Secure both front to back and side to side. Never move the steering wheel for front wheel drive vehicles while under test.
- Always inspect vehicles for fuel or oil leaks before testing as dyno electrical system can ignite fuel
- Always perform low speed test run to confirm vehicle is adequately secured and operational before doing extensive testing.
- Keep people away from the dyno test area and NEVER have people stand behind the rear of the vehicle. Debris may be stuck in the tires tread and may become projectiles during testing.
- When operating around rotating parts do not wear loose fitting clothing as they may get caught up in rotating pulleys or mechanical components
- Keep dyno area clean from all loose objects
- Keep all hands, feet, and other objects away from moving rolls during tests
- Always wear approved safety equipment such as eye protection and steel tow boots around dyno area
- The dynamometer rollers and power absorption units can become very hot during testing. Avoid contact with them as serious burns or injury can occur.
- The dynamometer power absorption units require high voltage DC current to operate.
- Contact with the high power electrical wires and boxes may be fatal. Disconnect all power to the electrical system before inspecting or servicing.
- During extended testing vehicle cooling system and engine may become very hot.
- Extreme caution is necessary when working near these components.
- Always inspect vehicle tires for wear or damage before testing and only operate with tires that are in good condition and at the proper tire pressure. FOR ALL TIRES TIRE PRESSURE SHOULD BE BETWEEN
- 1.8 to 2.5 bar (25-35 PSI)
- Never let untrained personal operate the vehicle during dyno testing
- Exhaust gasses are poisonous and may be fatal.

2.7 Technical Specs

- Supply Voltage 100-240 Vac
- Power Consumption: max 40 W
- Working Conditions: Temperature: -10ºC to 40ºC, humidity < 90%
- Storage Conditions: Temperature: -20ºC to 80ºC, humidity < 80%
- Provided supplies:
  - o 5 V-sensors (max 100 ma)
  - o 5V-load cells (max 50 ma / each)
  - o 12 V-relays (max 1.2A)

2.7.1 Input Specs

- 4 x **Roller speed input**. TTL input. Max 150 pulses/rev in single roller mode (without prescaler), **Prescaler settings**: 1:1, 2:1, 4:1, 8:1, 16:1 to allow usage of encoders.
- 1 x Engine Rpm Speed input (TTL levels). Capacitive and Inductive clamps available with TTL output.
- 8 x Analog inputs (0-5v) (14 bit)
- 8 x Thermocouple (type-k) Inputs (16 bit)
- 2 x Load Cell input (sampling > 30K SPS, 24 bit accuracy and digital zero/gain), includes a **digital filter.**
- 1 x Low frequency Pulse Counter Input (Ex. detonation counter), max freq is 1000 Hz
- 1 x Run/Stop Button (same as SP1)
- 1 x Panic Button (Emergency Stop)

Notes:

- Sampling frequency is > 30K SPS for load cells and 50 Hz for the rest of channels.
- SportDyno Software allows the usage on an **External analog card** (through CANBUS or MODBUS), for example DEIF CIO308 (CANBUS) provides 8 extra channels that can be configured in several scales for voltage, current or resistance measurement.

2.7.2 Output Specs

- 4 x PWM Brake Control Signal (0-5V, 2.4 KHz fixed, 10 bit, 0 to 100% duty cycle)
- 8 x Digital Outputs (12V Relays) (max 0.5 A sink, max recommended 100 ma)
- 1 x Air Speed Output (PWM 0-5v) (2.4 KHz fixed, 10 bit, 0 to 100% duty cycle)
- 1 x Servo output / Throttle. Selectable from: PWM 0-5v (10 bit), or RC pulse type (PPM, 50 Hz, 0.5 to 2.5 ms pulse)

2.7.3 Connectivity Specifications

- 2 x RS232 DB9 Connector (Computer and provision for serial Console)
- 1 x Ethernet RJ45 Connector (100 Mbps)
- 2 x CANBUS (CAN power supplies, and user data)
- 1 x Internal Bluetooth (available under request)

3 SP6 Installation

3.1 Introduction

The SP6 System consists of a Data Acquisition unit (DAQ) with up to four complete Roller control channels. There are two hardware versions: AWD/HUB-2 (up to 2 brakes and cells) and HUB-4 version (up to 4 brakes and cells). Each Roller Control Channel consists of:

- Roller speed measurement (hall effect sensor),
- Load Cell channel (brake torque measurement),
- Brake Control output channel

SP6 can be used to automate most functions on a dyno room (engine test bed) or to control a vehicle dynamometer (rolling road or hub dyno).
It has several inputs and outputs to acquire data from the engine and to control the brake(s) and other parts of the installation.

SP6 Kit includes:

- SP6 DAQ unit
- Hall effect sensor(s) to read speed from one roller or from brake
- Capacitive and Inductive clamps, for reading Engine RPM
- Load cell(s) for acquiring brake torque (several models available)
- Brake Power Supply: Input 230 Vac, Output: 200 Vdc, 21 Amp control based on current (40A model available optionally).
- USB to Serial adapter. Note that serial COM still has more immunity against electric noise than USB (specially with 2 stroke engines / CDIs), for this reason we prefer to have the serial cable as long as possible, and USB part close to the computer.
- Installation Cables
- Software CD / Pendrive

3.1.1 Connection with the PWS

PWS should use only one connection at a time: PWM or CAM, please check section 3.4.2.9

3.2 Dynamometer Installation.

Two basic types of dynamometers can be controlled with SP6:

- On **vehicle dynamometers** (roller or hub), SP6 performs basically data acquisition and speed control on the dynamometer roller(s). Normally SP6 is not used to control the vehicle operation, as the operator can actuate directly over the starter motor, throttle, clutch, etc. In some cases SP6 is often used to control certain dynamometer actuators: lifts, motors, etc.
- On **engine test bed dynamometers**, SP6 in addition of Data Acquisition and speed control, can also perform control over several parameters of the engine as engine start, fans, throttle, etc. And the installation can be splitted in a dyno room and a control room to allow the user to operate the engine in a safer and more comfortably way.

3.2.1 Vehicle Dynamometers

Both SP6 AWD and SP6-HUB-4 can be used on several types of vehicle dynamometers:

- Motorcycle dyno (single roller)
- **2WD Car dyno, 1 axle, single roller / twin roller**. Twin roller: Single sensor or double sensor
- **AWD Car Dyno: 2 axles**, single/twin roller. Twin roller: Single or double sensor (total 4 sensors)

- **HUB-2 dynamometer, 2 brakes**, one to each car hub (left / right) for 2WD cars
- **HUB-4 dynamometer: 4 brakes**, one to each car hub for 2WD or AWD cars. This configuration is only available with **SP6-HUB-4 version**
- Other dynos based on rollers, with a maximum of 4 speed sensors

Most sensors/devices are connected typically to SP6:

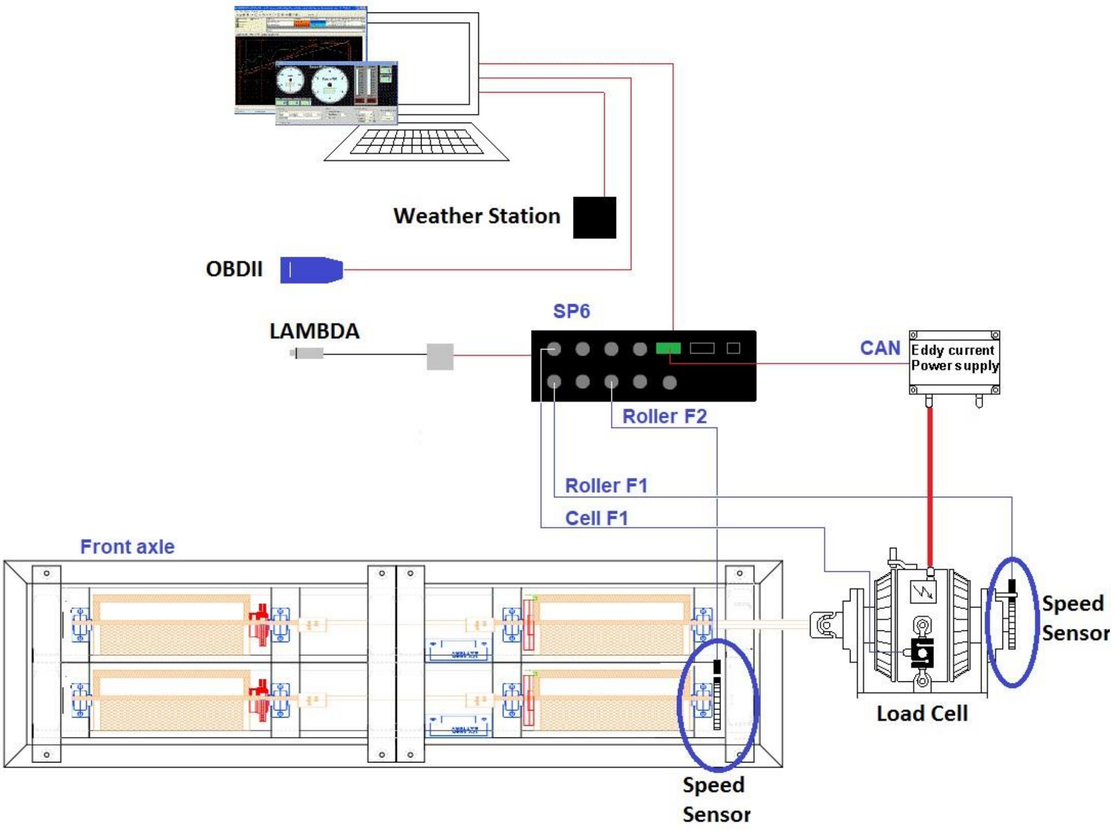
- Lambda (with external controller)
- Thermocouples (water, exhaust, etc) (up to 8)
- Other analog signals (up to 8)
- Remote control

But other devices are connected directly to Computer:

- USB Weather Station
- USB OBDII Interface
- xDS interface
- CAN Adapters
- Serial Exhaust Gas Analyzer

3.2.2 2WD Single / Twin Roller Dynamometer

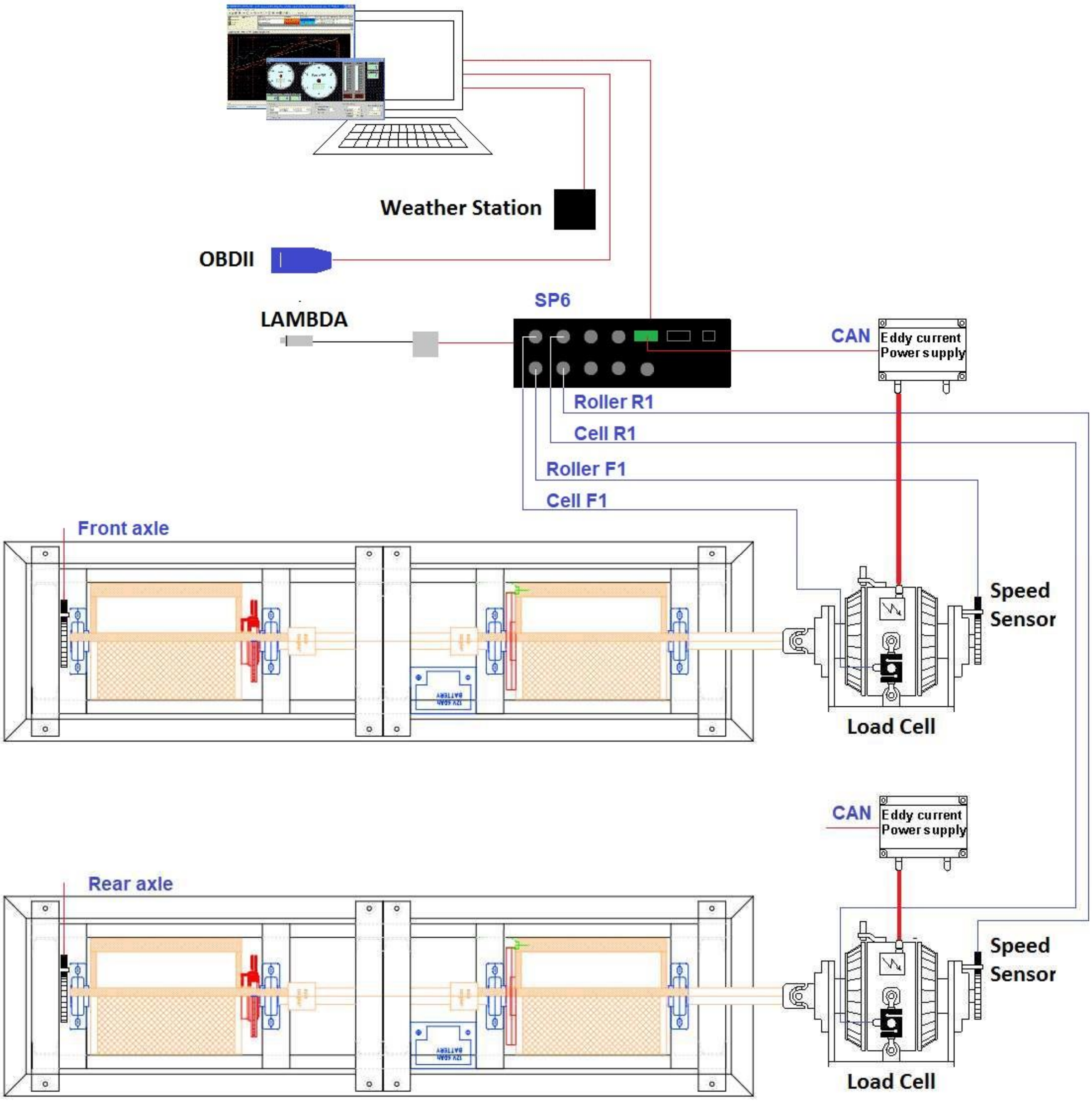
In 2WD dynamometers the main speed sensor (F1) is recommended to be installed at the brake side.
For **single roller dynamometers** there is obviously only one sensor (F1), one load cell (F1) and one power supply + brake, while for **twin roller dynamometers** the rear sub-axle could have its own auxiliary speed sensor connected to channel F2 if the dynamometer does not have a link between front and rear sub-axles in order to measure slippage or tire deformation effects.



Note: auxiliary sensor (F2) is optional

3.2.3 Single Roller AWD Dynamometer:

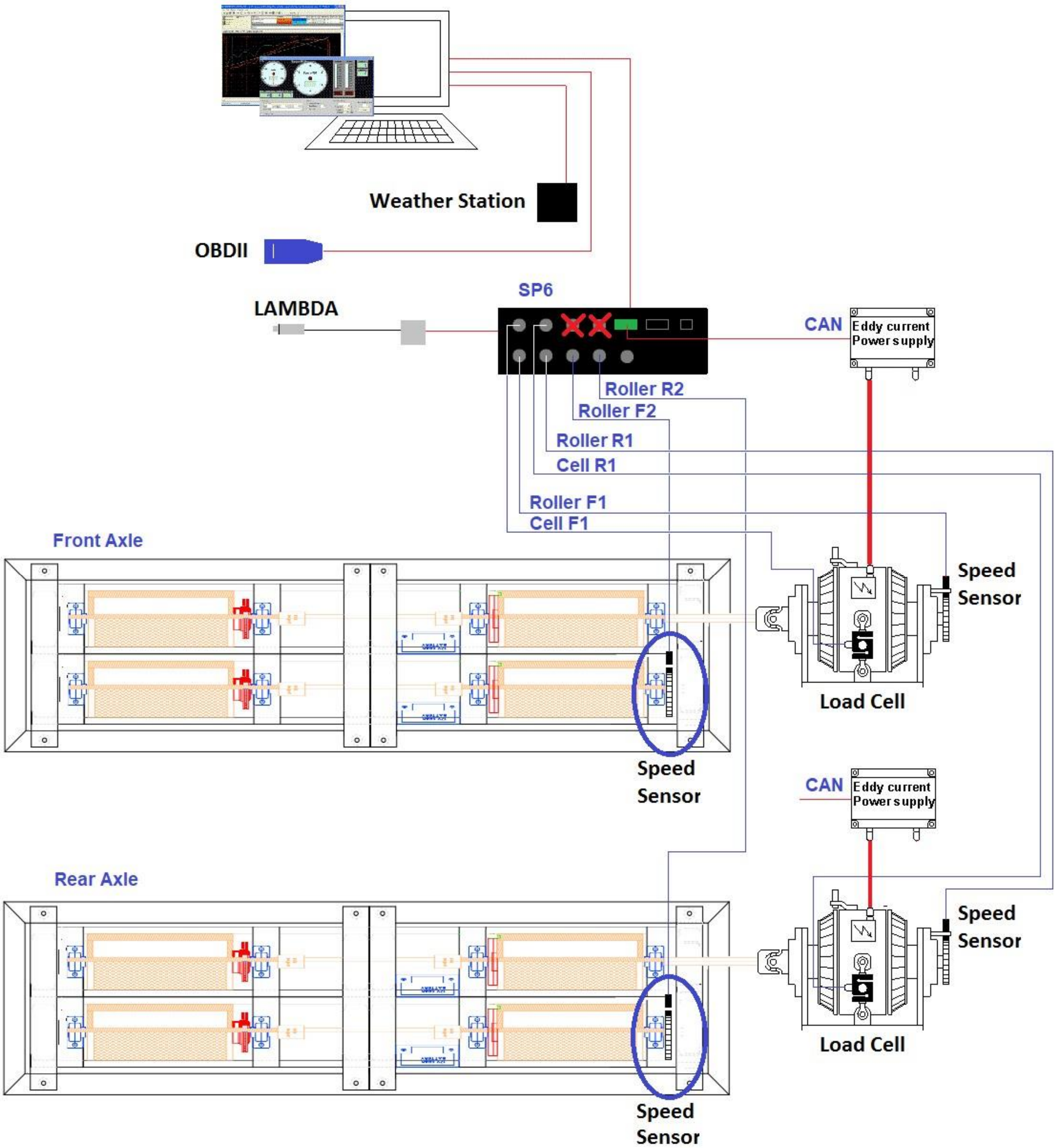
In single roller AWD dynamometers each axle has its own hall sensor, load cell, and power supply + brake using F1 and R1 channels, as shown in the picture.



Note: **speed sensor** is recommended to be mounted at **brake side** to avoid the oscillations caused by the elastic couplers

3.2.4 Twin roller AWD Dynamometer:

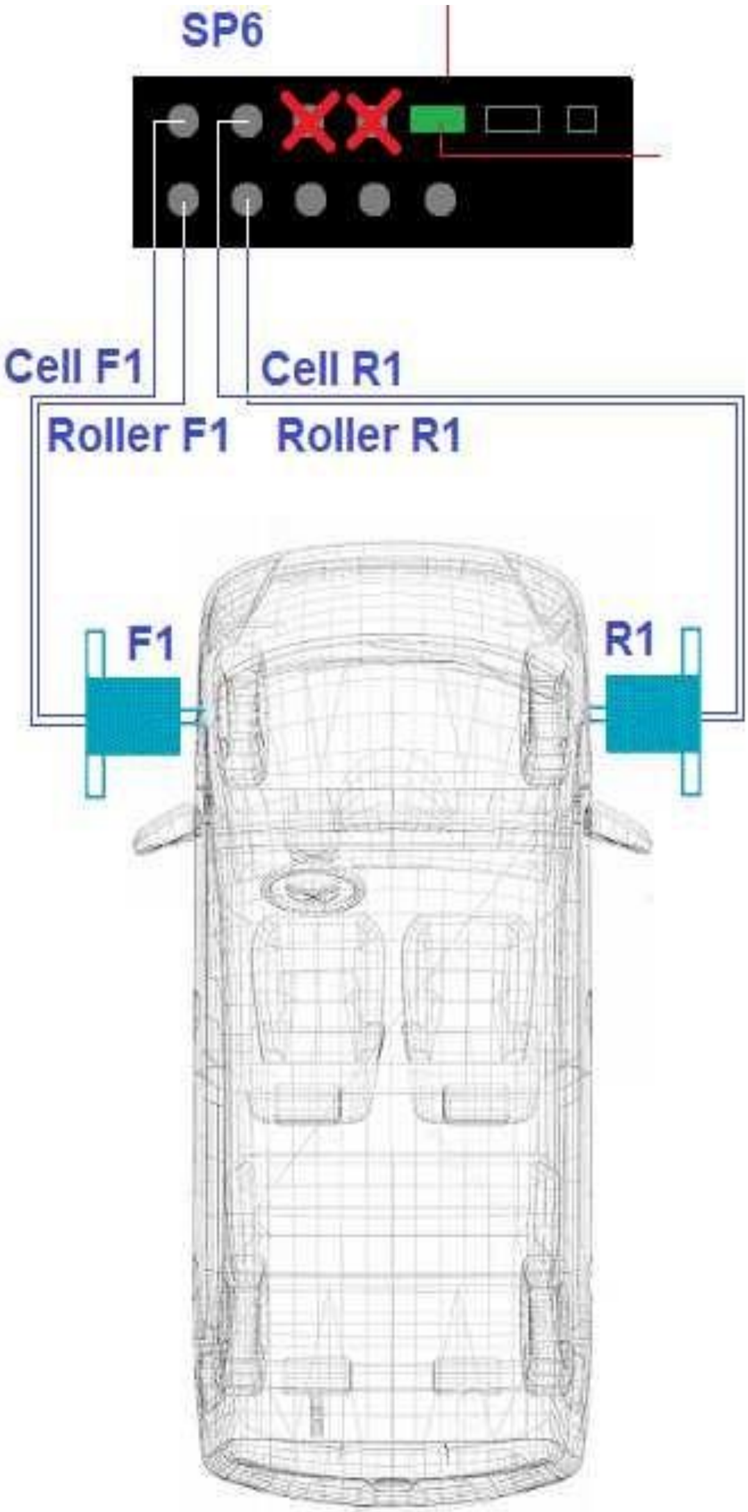
In **twin roller AWD dynamometers F1 and R1 channels** are used (roller and cell). Optionally SP6 could use the same configuration as 2WD twin roller dynamometers (**roller channels F2 and R2**) in order to measure speed at rear-subaxes (not braked), even with the **SP6 AWD version** (2 load cells), since the rear sub-axles are not braked and do not need a load cell.



Note: auxiliary sensors (F2 and R2) are optional

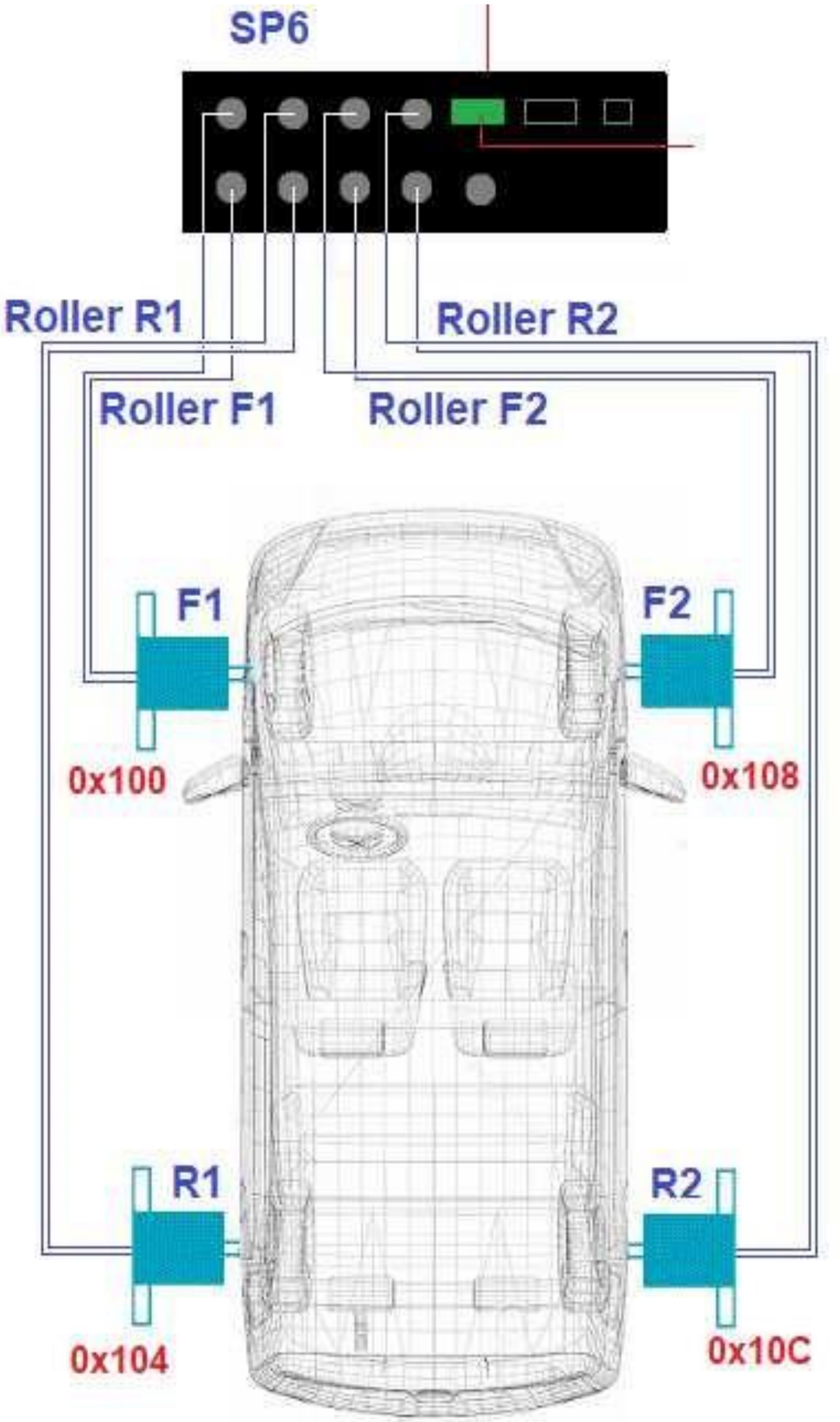
3.2.5 HUB-2 Dynamometer

When using **SP6 AWD/HUB-2** version for a HUB-2 dyno it is important to realize that **only channels F1 and R1 are complete:** rollers F2 and R2 can be used for auxiliary rollers, but **cells F2 and R2 do not exist**. Thus when using the DAQ with a HUB-2 dynamometer only "front" and "rear" channels can be used, then it is proposed to use Front (1) for left side, and Rear (1) for right side. This also happens with **SP5 AWD.**
Actually, left and right channels are swappable.



3.2.6 HUB-4 Dynamometer

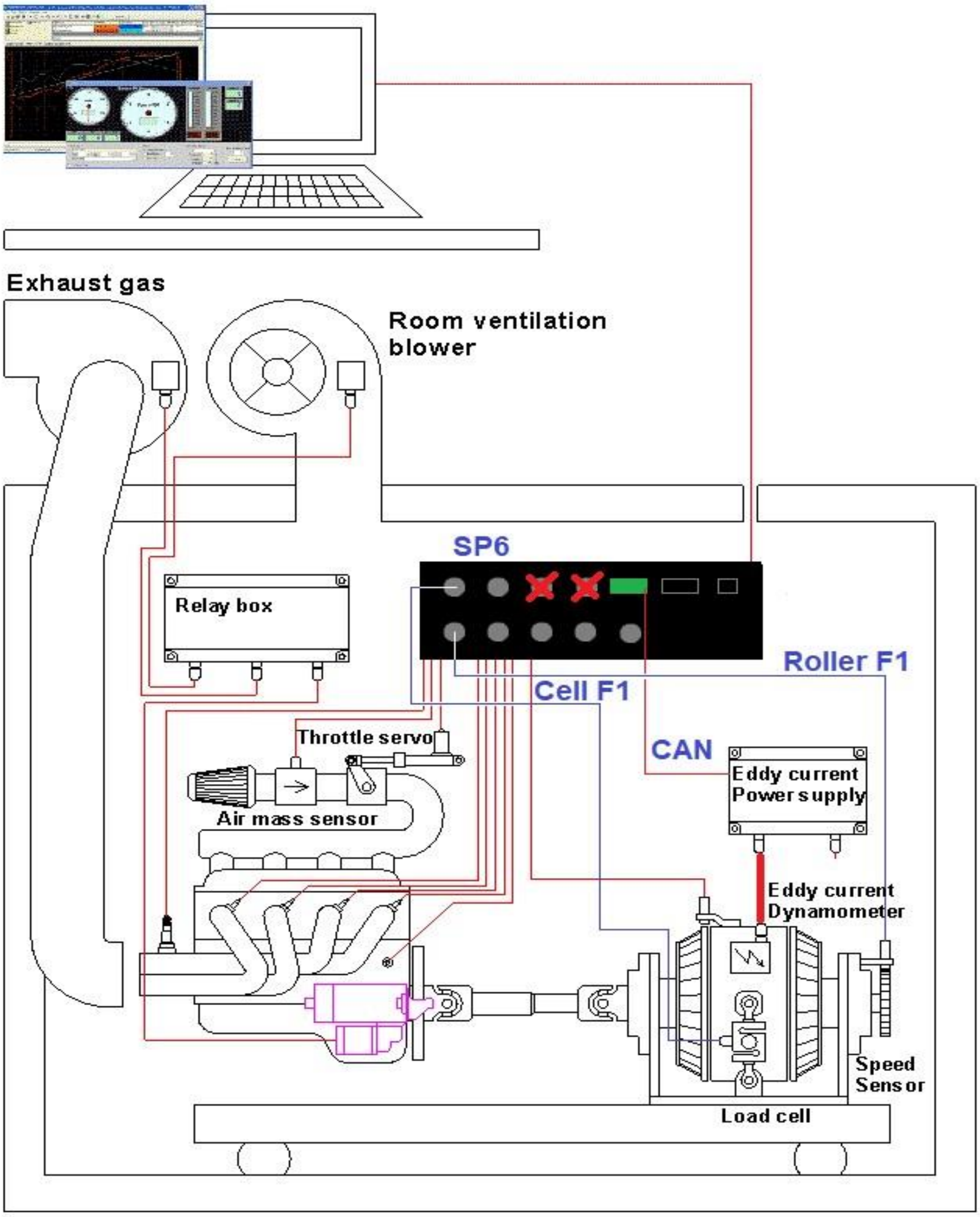
HUB-4 Dynamometer can only be implemented using **SP6-HUB-4 version** since it is the only one that implements the 4 load cells and has the 4 brakes sync active (HUB-2 version will not have it active). In the next picture **CAN IDs** are shown to ease the PWS connections.



3.2.7 Engine Test bed dyno installation

Below is shown a typical dyno room controlled with SP6. Typically a **SP6 2WD** version will be used, which is same HW version as **SP6-AWD** (with 2 load cells) without AWD activation. Typically only **channels F1 (roller F1 and cell F1)** will be used.

As **SP6 2WD still have two load cell inputs,** this feature can be used to control 2 dynamometers with a single DAQ using two SportDyno profiles. For instance a 2WD dynamometer with channels F1, and engine dynamometer with channels R1, but not at same time!



Note: SP6 can be installed close to the dyno / engine to shorten all data and control cables, and then only the serial cable will have to go through the wall to the computer. All control tasks will be performed

from the computer, although for safety critical actions (as turning the engine ignition OFF) it is recommended to have an extra switch in series, at the control room.
Nevertheless **it is not recommended to install either SP6 or power supplies directly over the chassis** as they are not rated for strong vibrations

3.3 Proposed installation parts.

- **SP6 DAQ module.** This unit provides both Data Acquisition and Speed Control functions.
- **Computer.** Any modern computer with Win7 - 10 will work. □ **USB-Serial adapter**, it is included with the kit
- **Hall Effect Sensor(s).** This sensor(s) is used to read the roller speed (rolling road dynamomer) or brake speed (engine test bed)
- **Gear Tooth.** Installed on the roller or at the eddy current brake to read its speed. Minimum recommended is 16 teeth and maximum 150 (for single brake, 80 for two brakes). Encoders can be used when the internal hardware prescaler is setup correctly.
- **Load Cell.** Reads the brake force / torque. Typical values are 300 kg for motorcycle dynos 500 - 1000 kg for car dynos, but it is recommended to do the math for each dyno.
- **Eddy Current Brake.** 192 volt rated. Normally brakes are rated in the range of 16 to 21 Amps **Brake Power supply:** Current models PWS3.2 and HS-PWS implement the brake control by controlling the brake current.
- **Throttle Servo [optional].** A high torque RC servo can be used to drive the throttle.
- **Ignition and Starter Relays [engine test bed].** 12 volt relays to control the engine. Additional relays can be controlled with the SP6 to control the fans on the room.
- **Fans / Turbines.** Some type of fans or turbines may be necessary for the following functions:
    - Feeding fresh air intake with from outdoor (air inside the room gets hot quickly) this turbine should be very high power (>2 KW, or >5KW) and high speed to simulate ontrack conditions, a variable speed driver is recommended + frequency to voltage converter to use the air speed. SP6 has a PWM output called "air-speed" that can control the speed of the air turbine as a function of roller/engine speed.
    - Exhaust extraction, first segment of this tube should be made with iron or steel because the high temperature of exhaust gas.
    - Engine cooling, engine should by cooled by a fan, a car's fan or a truck's fan can be used with a thermostat to ensure the coolant will be at a right temperature all time. A heat interchanger may be also used to increase cooling efficiency.
    - Engine and exhaust pipes cooling, when running on the track the exhaust pipes are being cooled as the vehicle runs, but when working on the dyno they may get too hot and can be damaged. For instance titanium exhaust pipes cannot work at high temperatures.
- **(VFD) Variable Frequency Drive [optional].** It is recommended to control air-intake turbine.

3.4 SP6 Connections

3.4.1 SP6 Front Panel

Front panel has the following Connectors:

9 x Round Connectors:

- 4 x 4-pin **Load Cell** Connectors (HUB-4 version, 2 connectors in AWD/HUB-2 version)
- 4 x 5-pin Connectors for **Roller, Brake Output** and Start/Stop Switch
- 1 x TTL Ignition RPM input (3-pin) the inductive clamp (black)

1 x CANBUS: PWS CAN and user data (250 Kbaud default)

2 x RS232 Serial connector

- COM0: Computer (115200 baud, no parity, 1 stop bit)
- COM1: provision for serial Console

1 x Ethernet Connector (100 Mbit)

1 x Mains 230 VAC / 36W Power Input

SP6 also provides two leds:

- Red led, normally OFF. If ON it means that there is some error at initialization. If blinking it may mean that 12V power supply is faulty.
- Green led: normally shows the SP6 activity blinking at different speeds

3.4.1.1 Roller / Brake Front1, Front2, Rear1, Rear2 Connectors

1 - 5V
2 - GND
3 - Start / Stop Switch (active LOW)
4 - Brake output (PWM 0 to 5 volt, 2.4 KHz)
5 - Roller input (0 to 5 volt pulses)

3.4.1.2 Cell Front1, Front2, Rear1, Rear2 Connectors

1 - Cell (-), SP6 uses up to four 24-bit ADCs with built-in amplifier (in the HUB-4 version)
2 - GND
3 - **5V** (max 50 ma total)
4 - Cell (+)

3.4.1.3 PWS CANBUS

This connector is used for the **Power Supply Communications** (commands and feedback). It can also acquire user data (for instance from an ECU). Default speed is 250 Kbaud, it is not recommended to be changed (it will cause to lose communications with power supplies)

1 - GND
2 - CANL
3 - Shield
4 - CANH
5 - **5V** (max 100 ma)

3.4.1.4 Engine RPM Input

1 - GND
2 - Engine RPM pulses (0-5 V)
3- **5V** (max 100 ma)

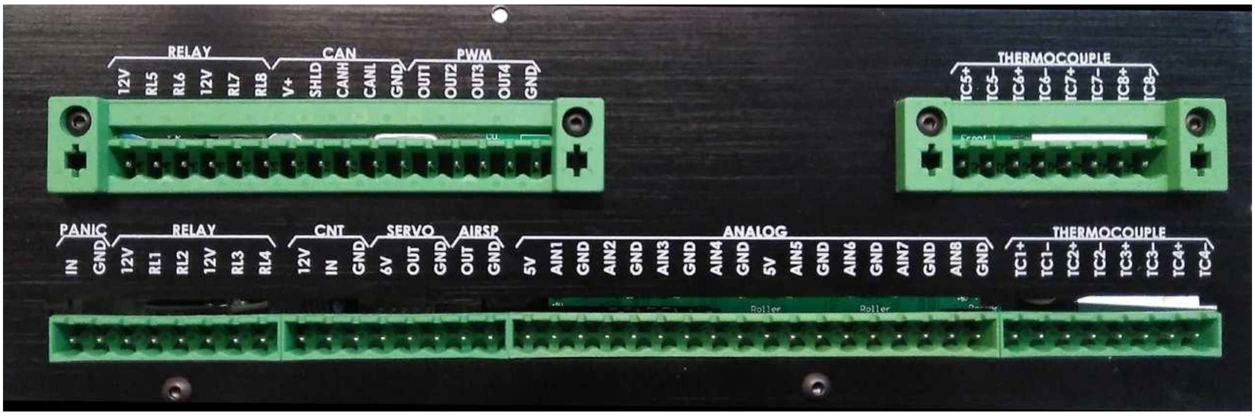
3.4.1.5 USER CANBUS

This CANBUS allows the user to acquire data from ECUs or other CAN devices at a different speed than PWS BUS (250 Kbaud). Please note that pinout does not match the PWS CANBUS pinout

1 - GND
2 - Shield
3 - CANH
4 - CANL
5 - **5V** (max 100 ma)

3.4.2 SP6 Rear Panel

Rear Panel has the following Connectors:



- 8 x Relays: Relays 1-4 at bottom row, Relays 5-8 at top row
- 1 x CANBUS (extra CANBUS for user data, default 250 Kbit, configurable)
- 4 x PWM outputs (same signal as for the front round connectors)
- 8 x Type K Thermocouples. Bottom Row: sensors 1 to 4. Top Row: sensors 5 to 8
- 1 x "Panic" Input (Emergency Stop)
- 1 x Low Speed counter CNT (typically for detonation counter)
- 1 x Servo Output: internally configurable to RC pulse (PPM) or PWM / analog
- 1 x Airspeed output: PWM 0-5 volt as a function of roller speed
- 8 x Analog inputs, 0 to 5 Volt (lambda, etc)

3.4.2.1 Relays

There are 8 Relay Outputs. Each relay output consists of an Open Collector line (-) and a 12 Volt Positive line which are intended to drive low power 12 volt relays / 100 ohm approx.
The maximum power deliverable by the SP6 is **1.5A**, this means that low consumption relays should be used, but they can be operated all at a time (while SP5 had restrictions with the max number of relays)

Normally the terminals Normally Open and Common are used on the relays for some of the following functions:

- Power the engine ECU/CDI (ignition output)
- Operate the starter Relay (the small relay operates a bigger relay, not the starter motor)
- Cooling Fans
- Other actuators such as an elevator to ease the vehicle to entering/going out from twin rollers

Function	SP6	Sequencer
IGN / Ignition	RL1	7
Starter relay	RL2	6
FAN1 (user)	RL3	5
FAN2 (user)	RL4	4
F1 / Func (user)	RL5	3
F2 / Lift	RL6	2
F3 / Bed (in)	RL7	1
F4 / Bed (out)	RL8	0

3.4.2.2 Panic Button

Panic Button / Emergency Stop is a Normally Open Switch that can be connected to the "panic" terminals. Polarity does not matter. When pressed the SP6 will apply a pre-defined brake torque to the rollers until they are stopped (switch can be released before the rollers are stopped)

3.4.2.3 PWM outputs

PWM signals are replicated at back side to ease the installation of SP6 and PWS, in order to avoid using the "T-cables" that split the signal from 5-pin connectors between hall sensor and PWS (as in SP5)

1 - OUT1 (F1)
2 - OUT (R1)
3 - OUT3 (F2)
4 - OUT4 (R2)
5 - GND

3.4.2.4 Counter Input

Low Speed counter CNT (typically for detonation counter)

1 - 12V (100 ma max)
2 - Input (0-5V, max 1000 Hz)
3 - GND

3.4.2.5 Servo Output

Servo Output is internally configurable to RC pulse (PPM) or PWM / analog

1 - 6V (4A max)
2 - Output. Configurable to PPM, PWM, analog (0-5V)
3 - GND

3.4.2.6 Air Speed

Airspeed output: PWM 0-5 volt / 2.4 KHz as a function of roller speed

1 - Output (0-5V), configurable as PWM or analog
2 - GND

3.4.2.7 Analog inputs

SP6 provides up to 8 analog inputs with a 12-bit converter

1 - 5V	10 - 5V
2 - AIN1 / LAMBDA1	11 - AIN5
3 - GND	12 - GND
4 - AIN2 / LAMBDA2	13 - AIN6
5 - GND	14 - GND
6 - AIN3	15 - AIN7
7 - GND	16 - GND
8 - AIN4	17 - AIN8
9 - GND	18 - GND

3.4.2.8 Thermocouple Inputs

SP6 includes 8 differential inputs with cold-juntion compensation to read thermocouples type K

Bottom Row	**Top Row**
1 – TC1+	1 – TC5+
2 – TC1-	2 – TC5-
3 – TC2+	3 – TC6+
4 – TC2-	4 – TC6-
5 – TC3+	5 – TC7+
6 – TC3-	6 – TC7-
7 – TC4+	7 – TC8+
8 – TC4-	8 – TC8-

3.4.2.9 Power Supply

Please refer to Power Supply Installation and setup manual.

Installation of Power Supply (all models) consists of connecting the following lines:

- **Input power lines**: 230 volt 50/60 Hz.
- **Output power lines**: 200 Vdc max, 21 / 40 Amp max (depending on models)
- **Control cable**, a "Y" split cable is provided to get the brake control signal from the **5-pin Roller Connector**. Connect this cable if CAN is not available or not being used.
- **Installation is recommended to be performed at the wall** or at other "stable" surface (no vibrations)

Power Supply can be connected through EITHER:

- **PWM signal (from each roller connector),** using the "Y" cable provided at each PWS unit, or using the rear PWM1-PWM4 pins, although this is less common. For PWS1.5 only PWM is available.

- **CAN BUS:** using the front SP6 CAN connector to all PWS. As CAN is a bus and SP6 already has the "Terminator" resistor in, the last of the PWS needs to have the Terminator Jumper set. Also, the CAN IDs need to be configured to 0x200, 0x204, 0x208 and 0x20C (check below)

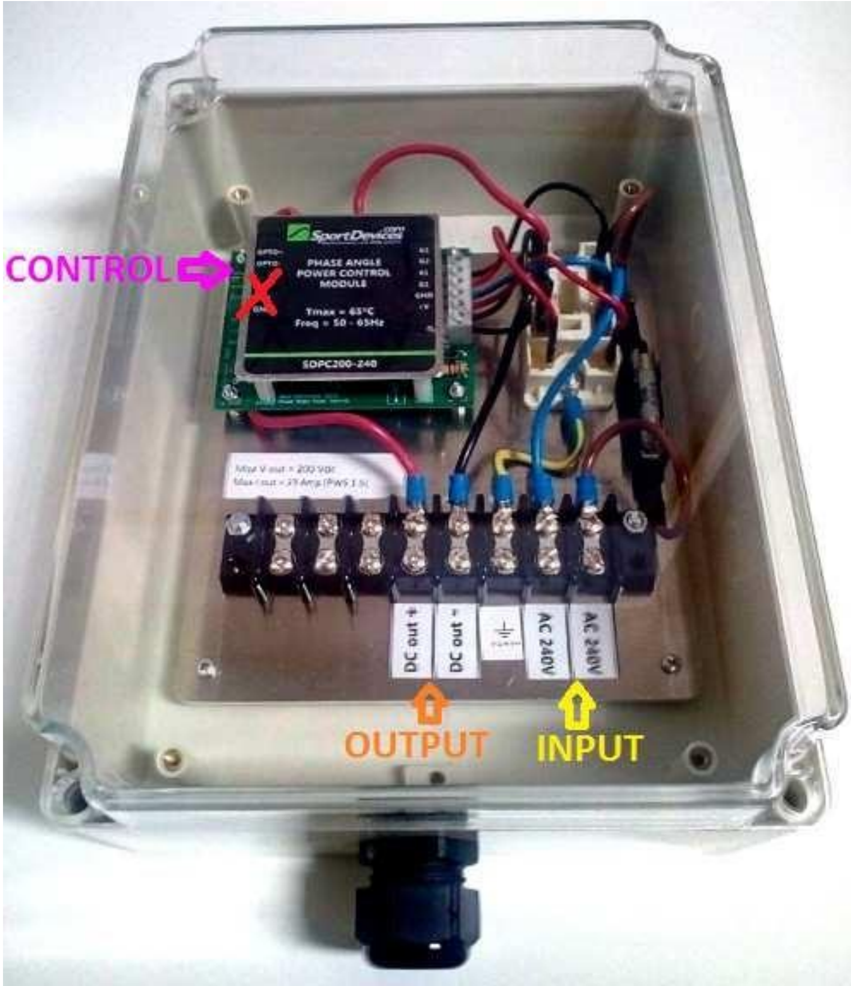
PWS3.x and HS-PWS:
Recently we have added **CANBUS** to PWS3.x and HS-PWS: connect this to SP5/SP6 PWS CANBUS. In case of several PWS (AWD dyno or HUB-4) the last PWS in the bus must have the **terminator ON**, the rest terminator OFF / jumper removed. It will **be shown a "C"** in the LCD close to the temperature value when **CAN connection is established**, for instance 25º"C" (it is not referred to Celsius degrees)

PWS	CAN ID
Front 1	0x100 & 0x200
Rear 1	0x104 & 0x204
Front 2	0x108 & 0x208
Rear 2	0x10C & 0x20C

CAN IDs. Check the PWS documentation.

PWS1.5:

IMPORTANT: Do not use 5V, I/P and GND lines, these lines are not isolated from the grid and may cause severe damage to SP6 or computer. They are only used for testing purposes (non isolated potentiometer)



4 SportDyno Quick Setup Guide

Configuration can be divided into 4 phases:

- Inertial configuration: roller(s) and pulses
- Ratio configuration, for manual modes this step may be necessary to be repeated for each vehicle, engine, or gear used.
- Load Cell configuration, this process can be performed at the end
- Speed Control Configuration

4.1 Inertial Configuration: Roller / Flywheel

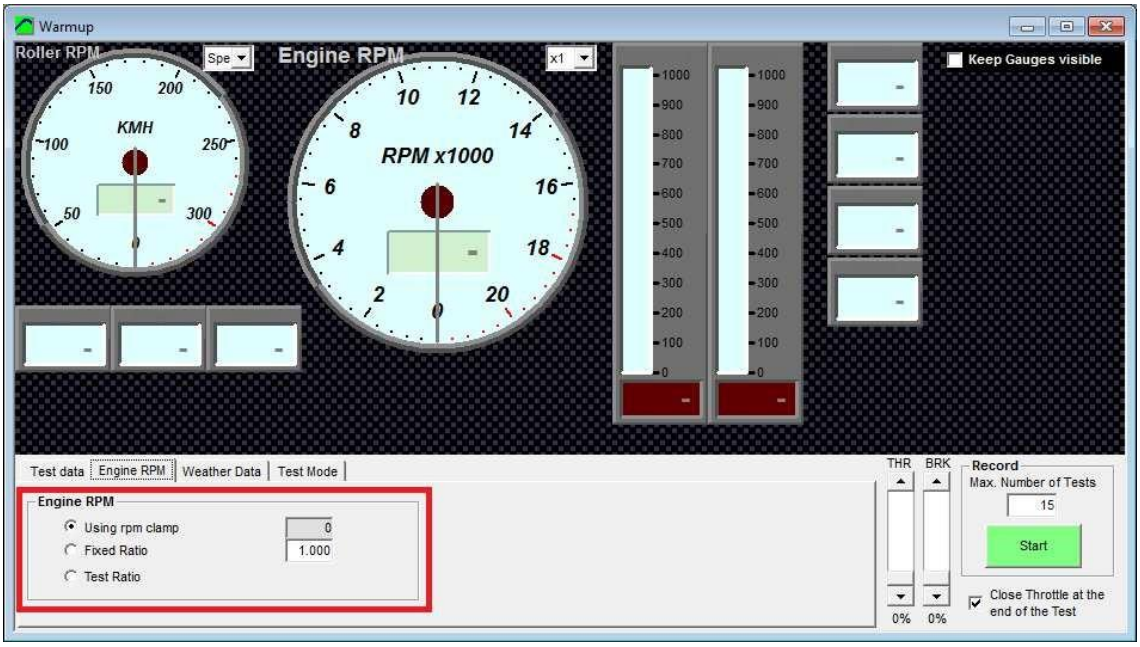
Setup all roller / dyno data at "Config / Class of Dyno" Window

- Dynamometer **type**: Vehicle Dyno or Engine testbed
- **Roller Diameter**
- **Roller Inertia**
- Number of **Teeth** for gear tooth. Note: recommended from 80 to 150 teeth
- **Prescaler**: always 1 for SP6 (please note that SP6 can internally have a HW prescaler from 1 to 16 to allow the usage of encoders)
- Set "SP6 mode" to "Only Front" by default.

4.2 Ratio Configuration

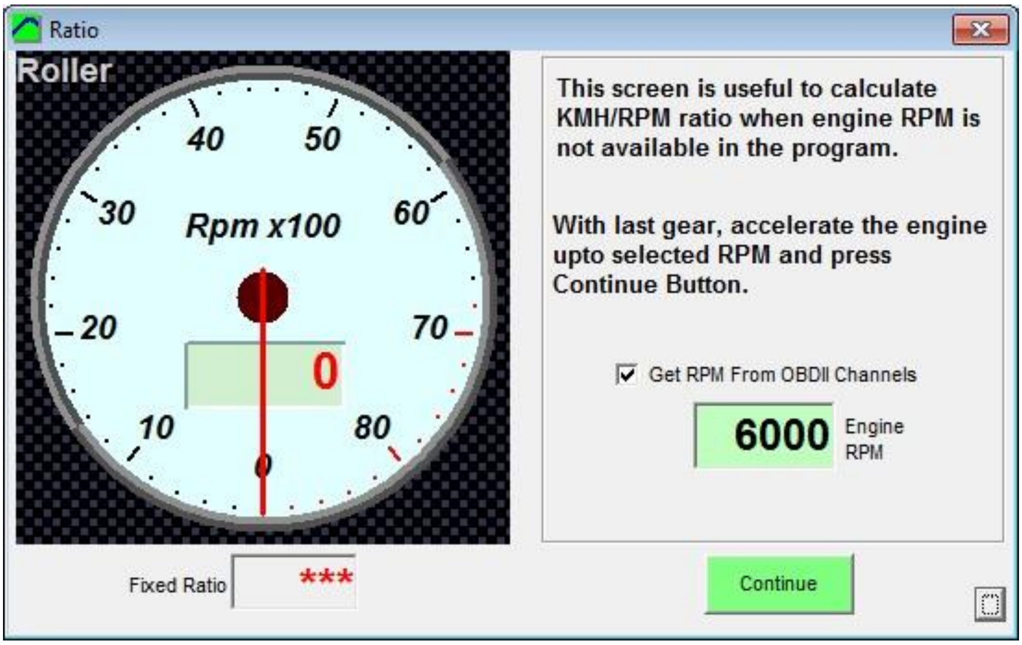
Ratio is a **key** parameter which is used on several processes of Sportdyno, and also on SP6 for speed control:

- It is used to convert Roller Torque to Engine Torque. Due to the gearbox torque conversion, normally torque at roller will be higher than at engine.
- It is used for drawing the Engine RPM axis, and as reference for the torque and power peak values.
- On SP4 and SP6, it is used to calculate an estimation of engine RPM (from roller RPM), since only roller RPM is used for speed control, but all target values are referred to engine speed.



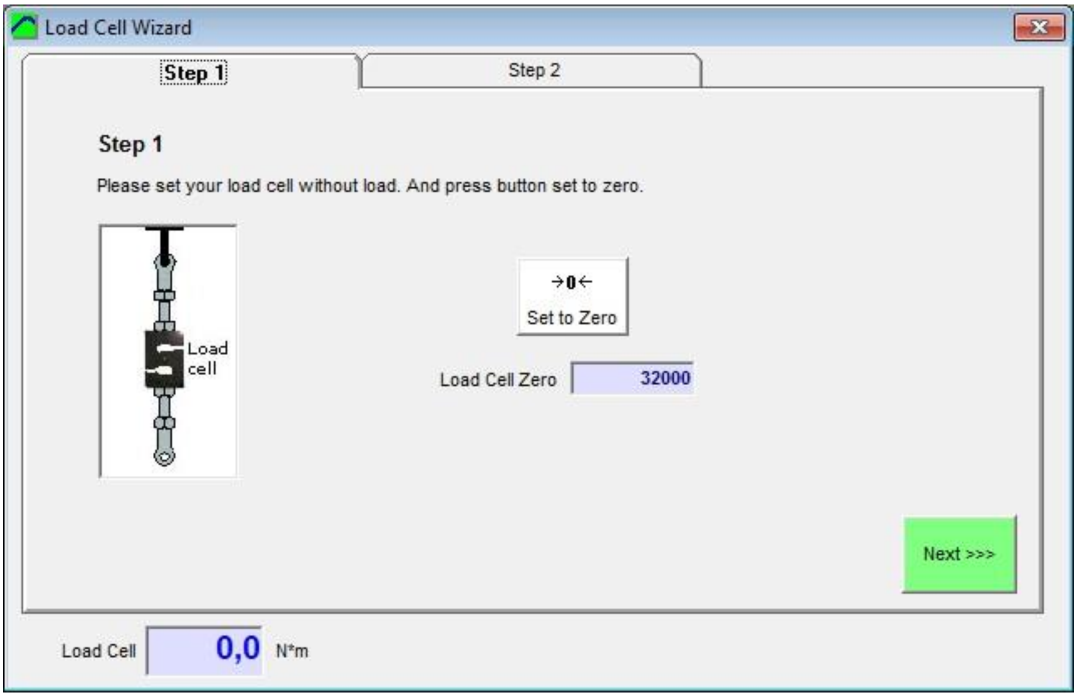
There are three ways to provide ratio to Sportdyno:

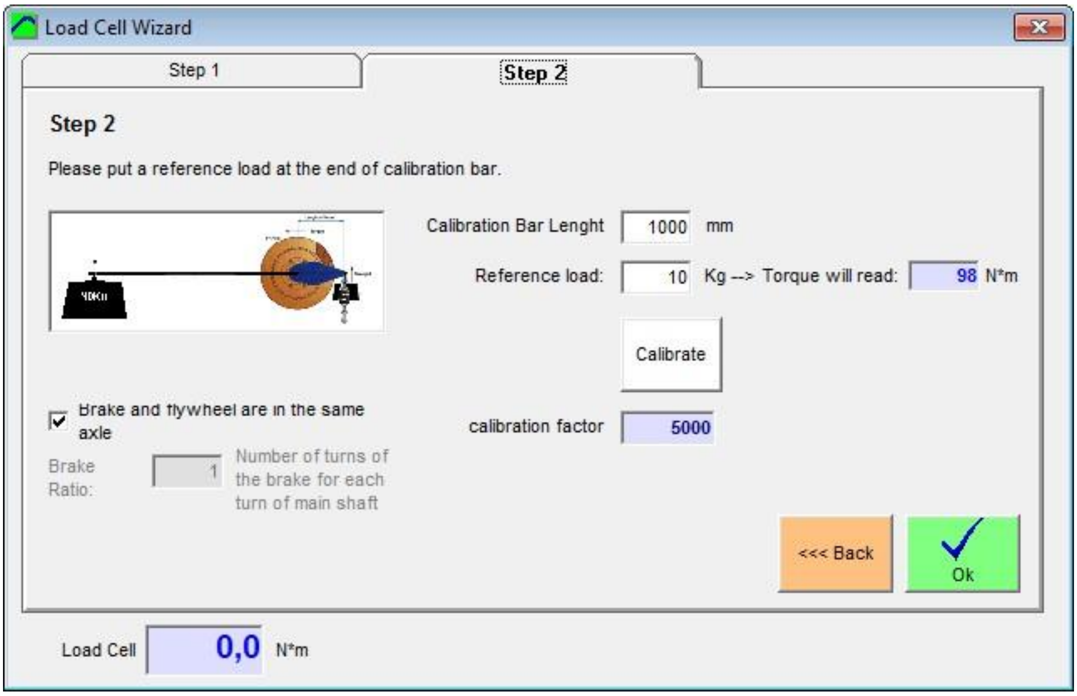
- **Using capacitive or inductive clamp:** Although Engine RPM Channel is not directly used for the three functions described below, Sportdyno will perform an histogram from engine rpm and roller rpm channels to get the Ratio value before starting the test, and (by default) after the test is finished
- **Fixed ratio**: in certain cases when Ratio value is known ratio can be setup directly (for instance engine test bed when there is a fixed transmission from engine to flywheel / brakes)
- **Test Ratio**: this option will open the "Test Ratio" window. Based on the vehicle's Engine RPM gauge this tool will determine the ratio value from Roller channel and the entered value for Engine RPM. The main disadvantage of this method is that normally all vehicle's Engine RPM gauges have an error between 10% and 20%, thus Ratio value will have this error too.
  NOTE: When using **OBDII** Interface Engine RPM can easily be acquired from the vehicle's ECU for the Ratio calculation.



4.3 Load Cell Calibration

Load cell calibration consists of applying a known weight on a calibration arm at the brake. But first of all, the cell has to be "zeroed" when it has no weight. Then the program is able to use the difference from the digital reading between the no-load condition and the loaded condition to perform the calibration.





Note: if no calibration arm is available, **calibration can be performed directly over the cell** with the following considerations:

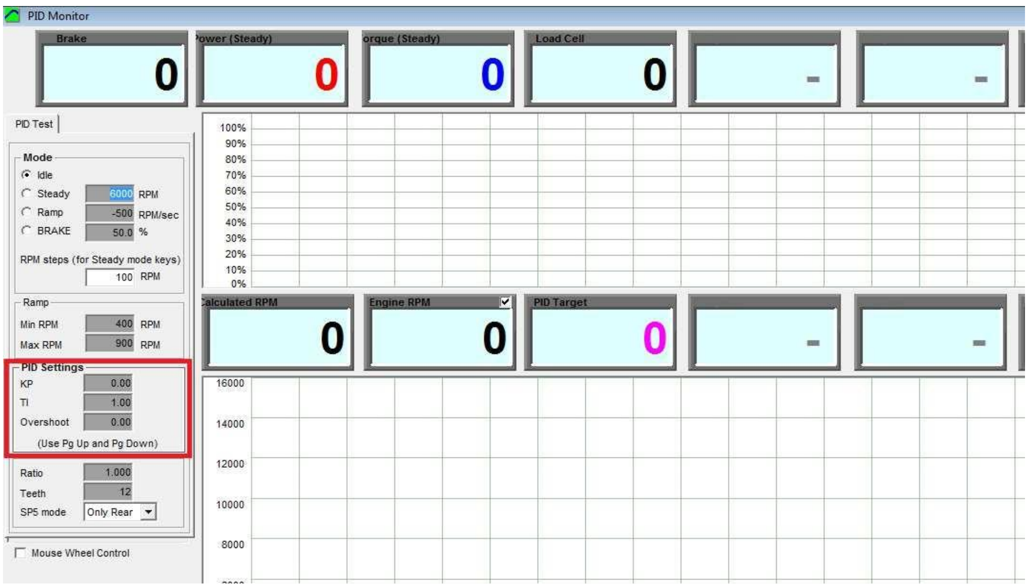
- Calibration arm length is the load cell arm length (distance from brake axle to cell)
- If cell works in pulling mode, then fill the reference load with a negative weight (for instance -20 kg for a 20 kg weight)

4.4 Speed Control Configuration (SP1+, SP4, SP5, SP6)

P.I.D. coefficients determine the brake response to the difference between the desired speed (target) and the current speed (this difference is called error).

SP6 implements a standard PID, with I constant proportionally to P (Kp) → Ti, this allows changing only Kp constant and SP6 will modify Ki to keep the same dynamic behavior. (Ki = Kp * 1 / Ti)

SP6 does not implement a Kd derivative constant, but it implements a more sophisticated overshoot control.



A good starting point for PID setup is:

Kp = 1 (1 to 2 for motorcycles, or 10-15 for car dyno, it may be higher)
Ti = 0.5-1 (max recommended 0.3 to 1.0)
Overshoot = 0 (Td / derivative control)

Kp basically controls the speed control reaction time. Control can be made faster increasing Kp, but excessively high values will cause fast oscillations on the system, thus a balance has to be found between speed response and stability
Kp by itself cannot make the speed control to reach the exact target speed, for this reason the integral control (I) is used.
Ti is (normally) modified in a narrow interval (typically 0.5 to 1.5) to get a faster approaching / drift to the target (low values), but fast approaching / drift also cause to decrease the reaction speed.

Td: With high inertia dynos, some overshoot will be present in the control operation, but normally a small overshoot is preferred as it ensures faster control than when the acceleration is so dampened so the overshoot does not happen.
Nevertheless, with lightweight dynos overshoot can be excessive and then the Overshoot coefficient has to be used to decrease overshoot to a safer value.

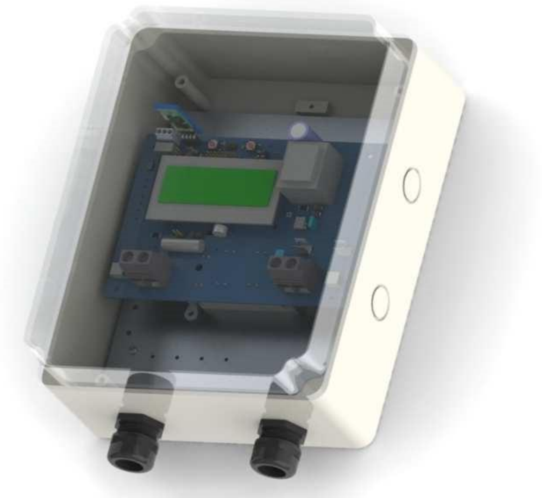
Note: **Power Supply Version 3.x (and PWS1.5)** is strongly recommended as they provide faster and more accurate response.

Document changes:

V0.92 General Review
V0.91 Software functions vs relay numbers, CAN IDs listed.
V0.9 initial Version

D.2. Manual d'usuari i instal·lació PWS

PWS3.x (SCR Based) / HS-PWS (IGBT Based) Eddy Current Power Supply with Current Control



Contents

SportDevices End User License & Warranty Disclaimer

DISCLAIMERS

Limitations of warranties and liability: This Power Supply, including its embedded firmware, is provided and licensed by SportDevices on an "as is" basis, without any other warranties or conditions, express or implied, including, but not limited to, warranties of merchantable quality, satisfactory quality, merchantability or fitness for a particular purpose or noninfringement, or those arising by law, statute, usage of trade, course of dealing or otherwise. The entire risk as to the results and performance of this product is assumed by you. To the maximum extent permitted by applicable law, neither SportDevices, its dealers or suppliers shall have any liability to you or any other person or entity for any indirect, incidental, special, or consequential damages whatsoever, including, but not limited to, loss of revenue or profit, lost or damaged data or other commercial or economic loss, even if SportDevices. has been advised of the possibility of such damages, or they are foreseeable. SportDevices is also not responsible for claims by a third party. Other possible damages INCLUDE VEHICLE OR ENGINE DAMAGES, DYNAMOMETER DAMAGES, AND PERSONAL INJURIES. The limitations set forth herein shall apply whether or not the alleged breach or default is a breach of a fundamental condition or term or a fundamental breach.

Any disputes arising between the parties over any products, services, warranties, terms, agreements, etc. shall be governed under the laws of Valencia (Spain) and in an appropriate court within its jurisdiction.

This Product License Warranty Disclaimer supersedes all prior warranty statements. Inquiries concerning this Product Warranty Disclaimer should be directed to:

SportDevices
Cami del Port 145, 46470 Catarroja, Spain

General Safety Instructions

Use the following safety guidelines to help ensure your own personal safety and to help protect your equipment and working environment from potential damage.

SAFETY: General Safety
When setting up the equipment for use:

- Place the equipment on a hard, level surface. If the equipment is installed in a closedin wall unit, ensure that there is enough ventilation.
- Avoid placing objects on top of this equipment to permit the airflow required for proper ventilation. Restricting airflow can damage the equipment.
- Keep your device away from radiators and heat sources.
- Keep your equipment away from extremely hot or cold temperatures to ensure that it is used within the specified operating range. (check technical parameters section)
- Keep your equipment away from Electromagnetic emitting devices like CDI ignition, or electric motors / VFD (Variable Frequency Drive)
- Do not push any objects into the air vents or openings of your equipment. Doing so can cause fire or electric shock by shorting out interior components.
- Ensure that nothing rests on your equipment's cables and that the cables are not located where they can be stepped on or tripped over.

When operating your equipment:

- Installation place must be dry, cool and **free of strong vibrations**.
- Ensure that ventilation is enough; if necessary drill the enclosure to ease ventilation.
- Do not use AC powered equipment during an electrical storm.
- Do not spill food or liquids on your equipment.
- Before you clean your equipment, disconnect it from the electrical outlet. Clean your device with a soft cloth dampened with water. Do not use liquids or aerosol cleaners, which may contain flammable substances.
- Clean the display with a soft, clean cloth and water. Apply the water to the cloth, then stroke the cloth across the display in one direction, moving from the top of the display to the bottom. Remove moisture from the display quickly and keep the display dry.
- Long-term exposure to moisture can damage the display. Do not use a commercial window cleaner to clean your display.

⚠ **CAUTION: Do not operate your equipment with any cover(s) removed.**

If your equipment does not operate normally - in particular, if there are any unusual sounds or smells coming from it - unplug it immediately and contact an authorized dealer or service center.

⚠ **WARNING: To prevent the spread of fire, keep open flames away from this product at all times.**

SAFETY: When Working Inside Your Device

Do not attempt to service the equipment yourself, except as explained in your documentation or in instructions otherwise provided to you by SportDevices. Always follow installation and service instructions closely.

The only user configurable parts in this device are: jumpers and wiring.

All parts in this equipment are powered to grid, even the low voltage parts as LCD, switches, jumpers, BT dongle (when present), etc, are directly connected to grid. Do not touch any of the electrical parts unless the circuit breaker it OFF.

SAFETY: General Power Safety

Voltages used in this device are capable of killing a person! Read carefully this section.

By default, if other values are not specified, all SportDevices equipment are rated for **230 VAC / 50 Hz.** (115 VAC units will have a specific label for that)

All parts in this equipment are powered to grid, even the low voltage parts as LCD, switches, jumpers, BT dongle (when present), etc, are directly connected to grid. Do not touch any of the electrical parts unless **the circuit breaker it OFF.**

Observe the following guidelines when connecting your equipment to a power source:

- Check the voltage rating before you connect the equipment to the grid to ensure that the required voltage and frequency match the available power source.
- This equipment is designed to have a permanent installation to the grid through a **circuit breaker and a differential switch.**
- Ensure both power lines (L and N) are correctly connected to the 230 V input connector, **and ground cables are correctly connected to ground screws**.
- **Brake and dynamometer must not be operated without the GND cable installed and a differential switch.**
- **All wires must be in good condition and the brake must not have leakages.** Note that some brakes from junk yard may have current leakages and **must not be used** until coils are verified and repaired.
- **Dynamometer must have its own GND cable directly to the grid, as the brake is floating over bearings and may not have enough protection in case some of the wires are in bad condition and touching the dynamometer chassis.**
- Connection can also be made through a power cord, but ensure the power cord rating is suitable for the brake application (typically 16 Amp or higher), **and ground is correctly connected from the equipment to building Ground and to brake and dynamometer**.

SAFETY: If Your Device Gets Wet

⚠ **CAUTION: Before you begin any of the procedures in this section, see the SAFETY: General Safety section of this document.**

⚠ **CAUTION: Perform this procedure only after you are certain that it is safe to do so. If the device is connected to an electrical outlet, turn off the AC power at the circuit breaker, if possible, before attempting to remove the power cables from the electrical outlet. Use the utmost caution when removing wet cables from a live power source.**

1. Disconnect the AC cord from the electrical outlet, and then, if possible, disconnect the AC cord from the device.
2. Turn off any attached external devices, then disconnect them from their power sources, and then from the device.
3. Contact SportDevices support (info@sportdevices.com)

⚠ **Limited Warranties:** warranty is limited to normal usage of the device, any fault caused by inappropriate usage or accident will not be covered

SAFETY: If You Drop or Damage Your Equipment

⚠ **CAUTION: Before you begin any of the procedures in this section, see the SAFETY: General Safety and Power Safety sections of this document.**

⚠ **CAUTION: If any internal components can be seen through damaged portions, or if smoke or unusual odors are detected, disconnect the device from the electrical outlet and contact SportDevices support** (info@sportdevices.com)

1. Save and close any open files, exit any open programs, and shut down the computer.
2. Turn off the device and disconnect from the power source, and then disconnect from the computer.
3. Turn off any attached external devices, and disconnect them from their power sources and then from the computer.
4. Connect the device to the power source and turn on the device.
5. If the device does not start, or if and smoke or unusual odors are detected, or you cannot identify the damaged components, contact SportDevices support.

Protecting Against Electrostatic Discharge

⚠ **CAUTION: Disconnect product from mains power source in accordance with product specific safety information located on the "Safety Information" section of this website.**

Electrostatic discharge (ESD) events can harm electronic components inside your device. Under certain conditions, ESD may build up on your body or an object, such as a peripheral, and then discharge into another object, such as your device. To prevent ESD damage, you should discharge static electricity from your body before you interact with any of your device's internal electronic components, like the Bluetooth plug-in.
You can protect against ESD and discharge static electricity from your body by touching a metal grounded object (such as an unpainted metal surface on your device) before you interact with anything electronic.

You can also take the following steps to prevent damage from electrostatic discharge:

- When unpacking a static-sensitive component from its shipping carton, do not remove the component from the antistatic packing material until you are ready to install the component. Just before unwrapping the antistatic package, be sure to discharge static electricity from your body.
- When transporting a sensitive component, first place it in an antistatic container or packaging.
- Handle all electrostatic sensitive components in a static-safe area. If possible, use antistatic floor pads and work bench pads.

Technical Specs

Input:

- Supply Voltage 230 Vac / 50-60 Hz. Single phase. **For PWS3.x: Max one Power Supply per phase, use different phases for AWD operation.**
- Power Consumption: 16 Amp brake: max 3.2 KW, 23 Amp brake: max 4.6 KW

Output:

- **Max Brake Voltage:** 200 VDC, 100 VDC, 70 VDC, 50 VDC
- **Max Brake Current:** up to 21A

PWS3.x

- Modulation Method: Phase Angle Control (SCRs) @ 100 Hz
- Inductive Load Control: Flywheel diode (passive discharge)

HS-PWS

- Modulation Method: PWM (IGBTs) @ 1000 Hz
- Inductive Load Control: Flywheel diode (passive discharge)

HS-PWS-Discharge

- Modulation Method: PWM (partial H-bridge topology) @ 1000 Hz
- Inductive Load Control: Regenerative discharge (-200VDC) + Overvoltage Control

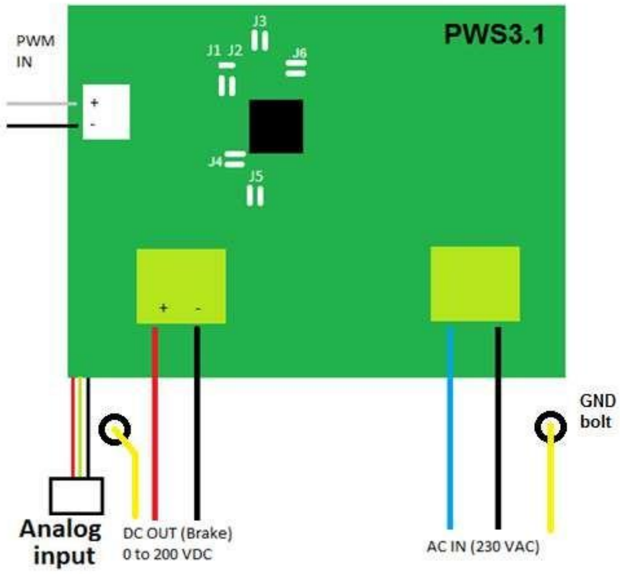
Control lines:

- **PWM input:** PWM 0 to 5 Volt, 2.4 Khz. ISOLATED:
  - \+ Brake output (SP4/SP5)
  - GND
- **Analog input (* optional):** 0 to 5 Volt. ISOLATED:
  3 pin connector
  - Pin 1: GND
  - Pin 2: Analog in
  - Pin 3: 5V (low current for potentiometer)

Other:

- Working Conditions: Temperature: -10ºC to 40ºC, humidity < 90%
- Storage Conditions: Temperature: -20ºC to 80ºC, humidity < 80%
- Current Control: P.I. regulator (Proportional Integral)

Connections for Brake Power Supply PWS3.1 (GEN 3) (FW1.11)



Note: **brake must not be operated without the GND wire**. If brake has leakages it must be repaired before using it with the Power Supply

Configuration Procedure

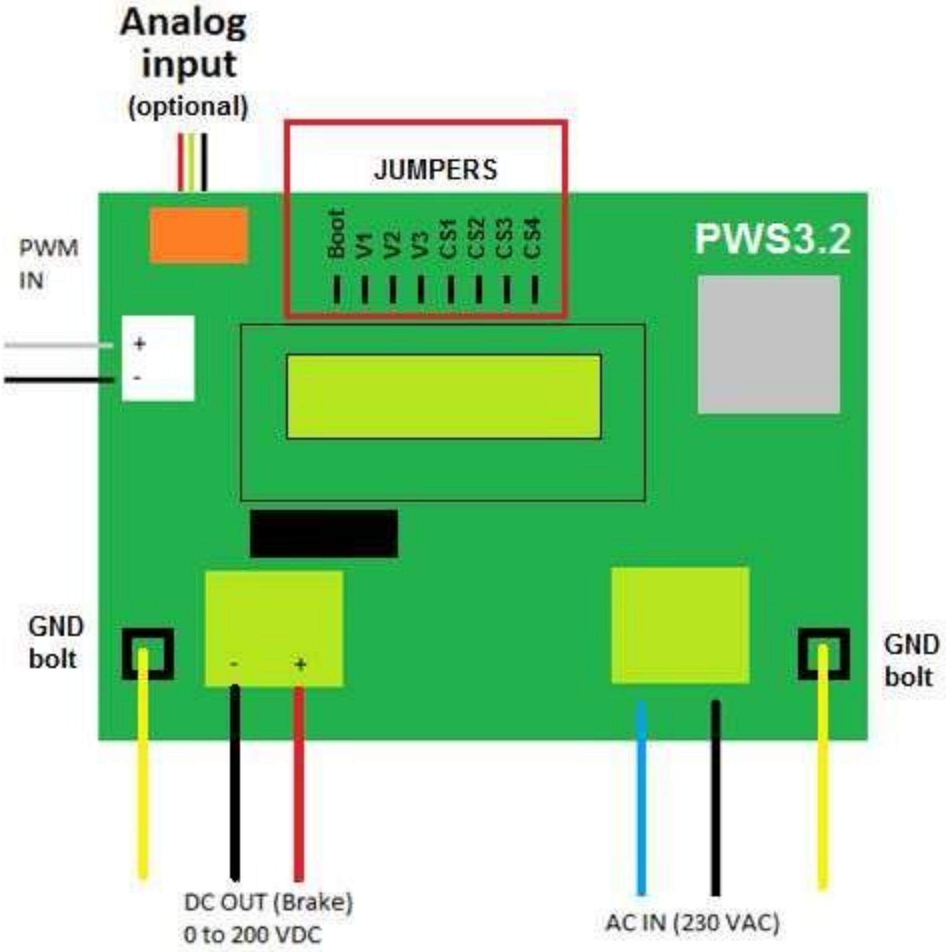
- **Disconnect PWS3.1 from grid**
- Remove Plastic box screws (4)
- Remove LCD display nuts and washers (2 + 2), and then LCD Display
- Locate solder Jumpers (J1 to J5)

Voltage	J1 (half)	J2 (half)	Current)	J3	J4	J5
200 VDC	OFF	OFF	~~29 Amp (not available)~~	~~OFF~~	~~OFF~~	~~OFF~~
100 VDC	ON	OFF	~~23 Amp~~	~~ON~~	~~OFF~~	~~OFF~~
70 VDC	OFF	ON	20 Amp	OFF	ON	OFF
50 VDC	ON	ON	16 Amp	ON	ON	OFF
			12 Amp	OFF	OFF	ON
			9 Amp	ON	OFF	ON
			7 Amp	OFF	ON	ON
			4 Amp*	ON	ON	ON

Note 1: jumpers are ON by placing a solder drop, and OFF when empty
Note 2: Table valid for FW version **1.11+**
Note 3: **modes higher than 21A are not safe,** for currents up to 25A a modification is possible, please contact us.
Note 4: *4 Amp only valid for special HW configuration (1 shunt instead 2 shunts)

- Assemble PWS3.1 again and Power It up, the starting message will show the current configuration (50, 70, 100, 200 V and selected current)

Connections for Brake Power Supply PWS3.2 (GEN 3)



Note: **brake must not be operated without the GND wire**. If brake has leakages it must be repaired before using it with the Power Supply

Note that for Firmware versions from 2.18 and 3.18 (and later) it is NO LONGER NECESSARY to use the jumpers, just keep all open (they come open by default) and use the methods 2 or 3 described below to configure your PWS for your brake

Configuration Procedure

- **Disconnect PWS3.2 from grid**
- Remove Plastic box screws (4)
- There are 3 methods to configure the power supply:
  1. Or using **Jumpers** according to the table below
  2. Using the **USB connector** (all jumpers open)
  3. **Using the brake measuring tool** (press SELECT switch) (all jumpers open)

1. Jumpers Configuration (no longer necessary from FW 2.18 and 3.18)

Note that for methods 2 and 2 (USB and measuring tool) all jumpers must be open. This work for FW versions 2.18 and 3.18

PWS3.2

Voltage	VS1	VS2	VS3	Current	CS1	CS2	CS3	CS4
200 VDC	-	OFF	OFF	**EEPROM ***	**OFF**	**OFF**	**OFF**	-
100 VDC	-	ON	OFF	~~23 Amp~~	~~ON~~	~~OFF~~	~~OFF~~	-
70 VDC	-	OFF	ON	20 Amp	OFF	ON	OFF	-
50 VDC	-	ON	ON	16 Amp	ON	ON	OFF	-
				12 Amp	OFF	OFF	ON	-
				9 Amp	ON	OFF	ON	-
				7 Amp	OFF	ON	ON	-
				~~4 Amp*~~	~~ON~~	~~ON~~	~~ON~~	-

Note 1: jumpers are ON by placing the jumper between pins, and OFF when is not set

Note 2: **For PWS3.2 modes higher than 21A are not safe!.** For currents up to 25A a modification is possible, please contact us.

Note 3: When all jumpers are OPEN the configuration is taken from the EEPROM

Note 4: *4 Amp only valid for special HW configuration (1 shunt instead 2 shunts)

- Assemble PWS3.2 again and Power It up, the starting message will show the current configuration (50, 70, 100, 200 V and selected current)

PWS3.3

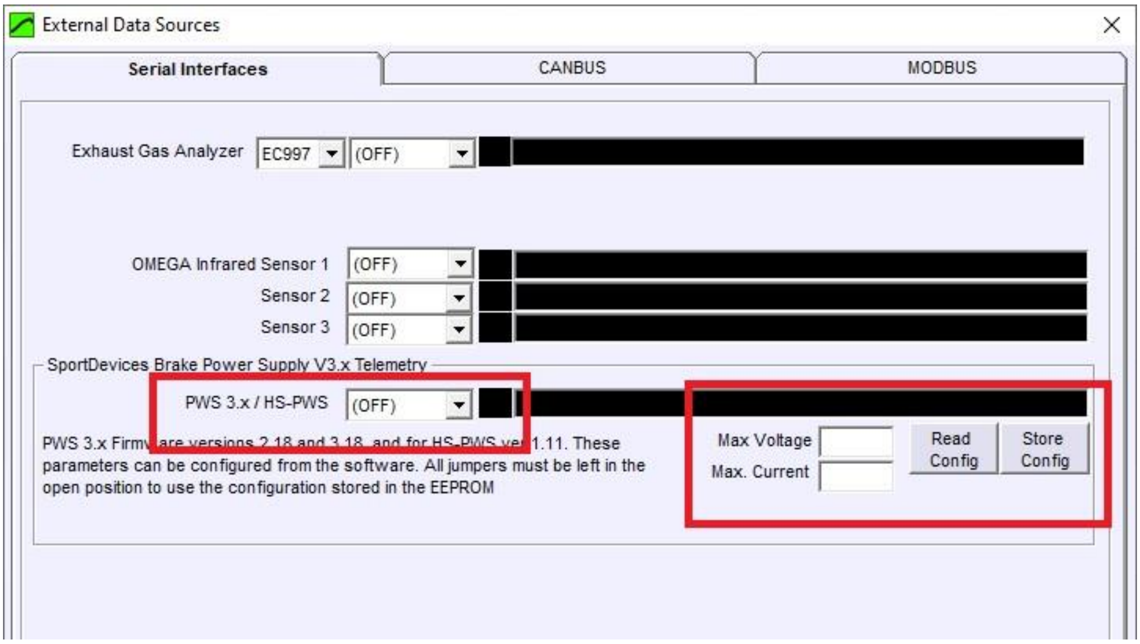
J2/40A jumper is OFF and Semikron is 28A model: same table as for PWS3.2
J2/40A jumper is ON and Semikron is 40A model

Voltage	VS1	VS2	VS3	Current	CS1	CS2	CS3
200 VDC	-	OFF	OFF	**EEPROM ***	**OFF**	**OFF**	**OFF**
100 VDC	-	ON	OFF	35 Amp	ON	OFF	OFF
70 VDC	-	OFF	ON	32 Amp	OFF	ON	OFF
50 VDC	-	ON	ON	28 Amp	ON	ON	OFF
				25 Amp	OFF	OFF	ON
				21 Amp	ON	OFF	ON
				19 Amp	OFF	ON	ON
				16 Amp	ON	ON	ON

Note: When all jumpers are OPEN the configuration is taken from the EEPROM

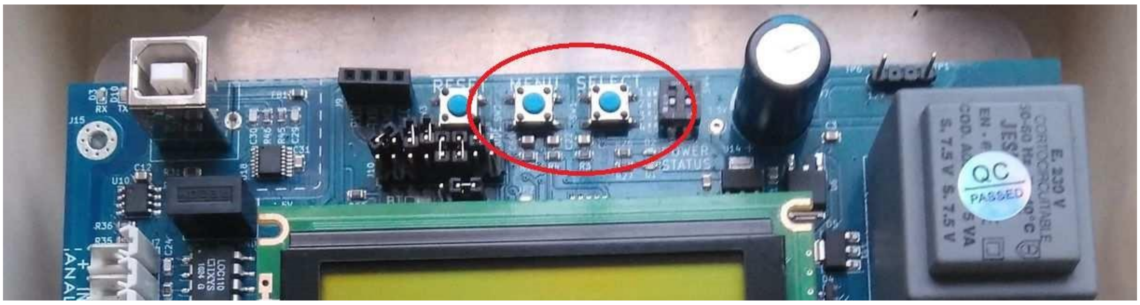
2. Configuration using USB connector

- **Note that for methods 2 and 3 (USB and Measuring Tool) all jumpers must be open. This work for FW versions 2.18 and 3.18**
- Check that the **USB / BT jumper** is in the USB position (it should be its default position)
- Connect the PWS to the computer using a **printer USB cable**
- **Open External Data Sources Window** in SportDyno (you may need to enable it at Advanced Options)
- **Choose the COM** installed when connecting the USB cable (you may need the FTDI drivers). When the connection is active it will show voltage and current in the black box
- **Read max Voltage and Max Current** values to check the communication
- **Modify max Voltage and Max Current** them according to your application and press **Store Config.** Note that despite any voltage is allowed (from 1 to 200V) for voltages below 50V the accuracy can be low.
- **Verify (read config)** that the values are correctly stored. These values will be shown in the LCD the next time the PWS is restarted

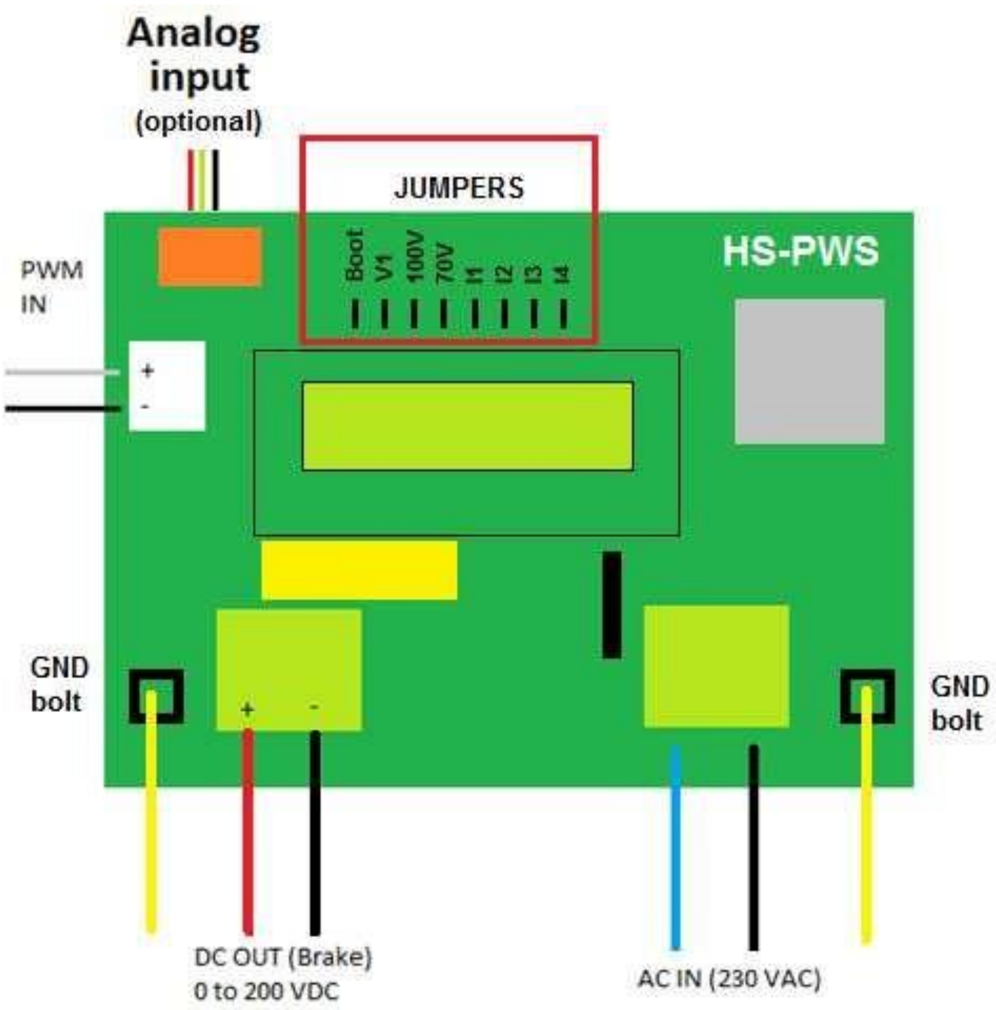


3. Configuration using the Measuring Resistance Tool

- **Note that for methods 2 and 3 (USB and Measuring Tool) all jumpers must be open. This work for FW versions 2.18 and 3.18**
- **Connect** the power and brake to the PWS as usually
- Start the PWS
- **NOTE that all switches are NOT isolated from the grid, it is better to use a plastic tool to press them.**
- When the PWS completes its startup, **press the SELECT button,** the measuring process will start, the LCD will show **"Measuring RES. "**
- The **PWS will apply approx 50V** to the brake for a few seconds. **If this voltage is not ok for your brake don't use this method**
- At the end of the measurement the PWS **will show the measured resistance,** and the recommended current for 200VDC setting. For instance for a resistance of 10.0 Ohm it will choose 200V and 20A settings:
    - **"Res = 10.0 Ohm"**
    - **"MAX 200 V, 20 A"**
- **If the resistance is below 9 Ohm it will assume that the brake is rated for 96V! . This can be a problem for CFK-550 brake models that are rated for 25A (aprox 8 ohm), in this case you should use the USB configuration manually (previous section)**
- The LCD will show **"SELECT to Store "** , if you press **SELECT** again it will store the current settings. If you wait a few seconds or press the switch **MENU** it will cancel the measurement & store process



HS-PWS High Speed Power Supply (IGBT @ 1KHz)



Note: **brake must not be operated without the GND wire**. If brake has leakages it must be repaired before using it with the Power Supply

PWS rectifies AC on a DC bus, and then DC is applied through an IGBT transistor to the eddy current brake changing duty cycle (PWM) at 1000 Hz which provides a slightly faster control than PWS3.x and less ripple on the current output.

Jumpers for HS-PWS

Note that for Firmware version from 1.11 (and later) it is NO LONGER NECESSARY to use the jumpers, just keep all open (they come open by default) and use the methods 2 or 3 (BT or Measuring Tool) as for PWS3.2 and PWS3.3 (check the previous section).

Note HS does not have USB port, it can be only connected by Bluetooth (with a preconfigured dongle).

Voltage	"100V"	"70V"	Current)	I1	I2	I3
200 VDC	OFF	OFF	**EEPROM***	OFF	OFF	OFF
100 VDC	**ON**	OFF	~~23 Amp~~	~~ON~~	~~OFF~~	~~OFF~~
70 VDC	OFF	**ON**	21 Amp	OFF	ON	OFF
50 VDC	ON	ON	16 Amp	ON	ON	OFF
			12 Amp	OFF	OFF	ON
			8 Amp	ON	OFF	ON
			6 Amp	OFF	ON	ON
			~~4 Amp~~	~~ON~~	~~ON~~	~~ON~~

Note 1: Table valid from FW version 1.05, from 1.11 the "all open" setting will access to the EEPROM values

Note 2: *4 Amp Mode is not accurate with HS-PWS due to the hysteresis of the Current Hall Sensor (does not use shunts as PWS3.x do)

Note 3: * When all jumpers are OPEN the configuration is taken from the EEPROM

Differences between PWS3.x and HS-PWS power supplies

Due to the high inductance of eddy current brakes, power supply provides a control based on current (it applies high voltages during transients to reduce the time response). **Nevertheless, a transient from 0% to 100% is always slow, as it is limited by the brake (up to 500 ms)**

Most power supplies feed the brake directly from grid using SCRs (thyristors) which actively rectify AC on DC for the brake. This topology has several advantages: robustness, simplicity, constant load on the AC grid (no current peaks). On the other hand, SCRs need to be synchronized with the grid frequency, this limits the control frequency to 100 Hz (Europe) / 120 Hz (USA), this makes control performance slightly poorer than HS-PWS.

In HS-PWS, AC is rectified to DC and then it is applied to the brake using an IGBT transistor (PWM). Our HS-PWS operates at 1000 Hz to minimize interferences. This provides a faster control than PWS3.x

HS-PWS has several advantages: More linear output, low ripple current, more accurate and faster control on transients. On the other hand HW-PWS has the following disadvantages: more heat dissipation, more electric interferences on the load cell, audible operation.

To summarize: all power supplies have an initial delay caused by the brake, but HS-PWS provides more accurate control during small transients and clean current. Nevertheless, due to the lower interferences, PWS3.x are being improved to be able replace HS-PWS.

What is HS-PWS-D (discharge)? Power supplies can charge the brake fastly, but when the discharge is required they passively discharge the brake through a flywheel diode. Although discharge is fast at the range from 100% to about 20% of brake range, **when 20% is reached discharge may become extremely slow (up to 5 seconds).** HS-PWS-D is able to regenerate the stored energy and dissipate the voltage excess using resistors. This consumes the brake energy very fast and provides an accurate control on brake de-energizing process.

When is this useful? Actually, **for most dynamometers this is almost NOT noticeable** as they normally operate in the recommended region (approx 20% to 80%) and especially on roller dynos, whose inertia minimizes the effect of the remaining brake torque. But for HUB dynos, and engine dynamometers with big brakes and small engines and low inertia, it can make a difference as the brake can operate in the 0% to 20% range and remove the remaining torque very fast.

	PWS3.x	**HS-PWS (to be discontinued)**	**HS-PWS-D (discharge) (new)**
Modulation Method	SCRs (synchronized with grid frequency)	IGBT with DC bus	IGBT, partial H-bridge
Control Frequency	100/120 Hz (Europe/USA)	1000 Hz	1000 Hz
Voltage control	Not linear (AC input)	Linear	Linear
Inductive Load Control	Flywheel diode (passive discharge)	Flywheel diode (passive discharge)	Regenerative discharge + Overvoltage Control
Interferences Emission	Low (100 Hz rectified)	Medium (1000 Hz square wave)	Medium (1000 Hz square wave)

CAN Connections and CAN ID configuration

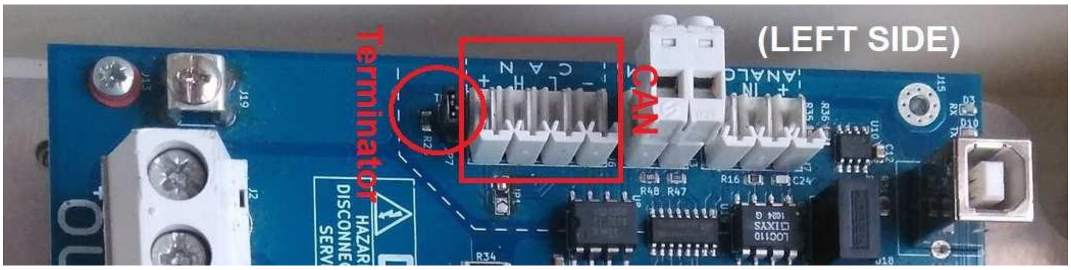
The CANBUS has a BUS topology (star net is not possible). This means that there is one first unit (SP5 / 6), zero or more intermediate units, and a last unit. Both first and last units have the "Terminator" Jumper active to avoid "echoes" in the line. SP5 / 6 have an internal fixed terminator that cannot be disabled, while the PWS have a jumper to disable all of the intermediate units, and leave only the last one

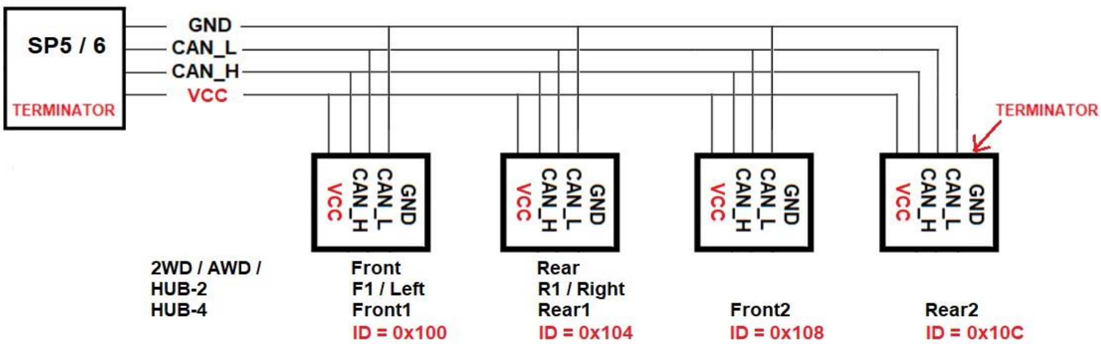
Each PWS provides a PWM cable used to command the PWS from the SP5/6 in an "analogue" way, and a CANBUS connector to command and have feedback from the PWS into the DAQ.

Until 2021 only one of those cables could be used at a time, but since 2021 we changed the strategy and allow connect both, then the priority is assigned to PWM for brake control (which is more reliable in noisy environments), and CAN is used for feedback and diagnosis. (If you have any doubt or want to update your PWS firmware please contact us)

CAN power: in order to provide a total isolation between the DAQ and the Power Grid several optocouplers are used in the Analog, PWM and CAN lines. For CAN we use a specific isolated transceiver, but this transceiver needs external power.

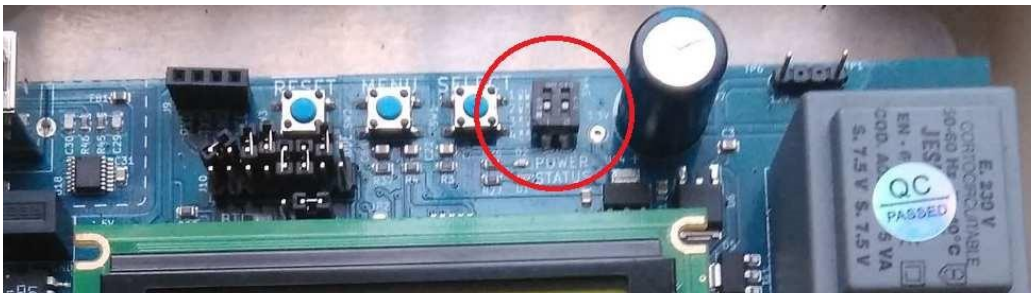
- In **PWS3.2** this power had to come from SP5/6, this makes necessary to use 4 lines for the CANBUS, and it is recommended to a shielded cable
- In **PWS3.3** power is taken from the internal DC/DC, and only the GND line. VCC line can be discarded. We recommend use GND (although in theory CAN could work with only the differential lines CAN_H and CAN_L) to avoid problems with high spikes / interferences





Can IDs:

PWS3.2b and PWS3.3 include a micro-switch block that allows to select up to 4 IDs



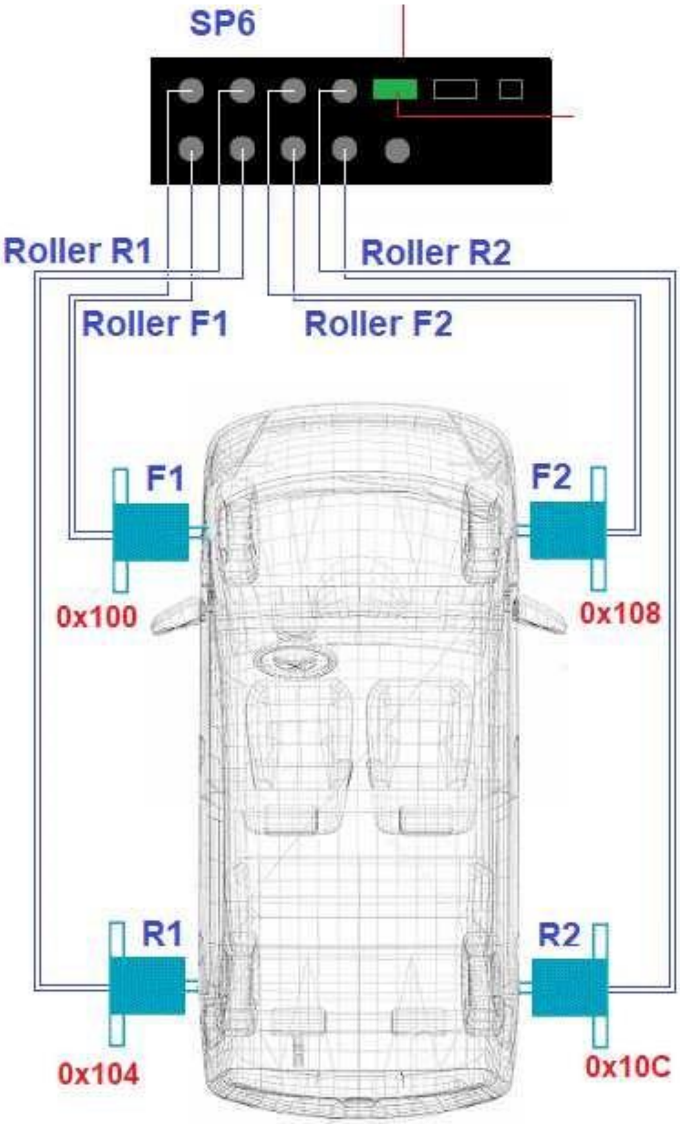
Position	ID	SP5	SP6
Low Low (default)	0x100	Front	F1
Low High	0x104	Rear	R1
High Low	0x108	–	F2
High High	0x10C	–	R2

CAN ID is shown during the startup to help to configure the system. These IDs are used by the SP5 / 6 to command the PWS, while 0x20n IDs (0x200 to 0x20C) are used for feedback.

The system allows up to 16 x PWS connected to the DAQ, all 16 PWS will share the 4 0x10n (0x100 to 0x10C) IDs, but each one will have a different **feedback ID** (0x200 to 0x23C) to allow to identify all 16 by separate. This configuration has to be stored by SportDevices with a specific tool. This process is only necessary when more than 4 PWS are necessary to be connected by CAN.

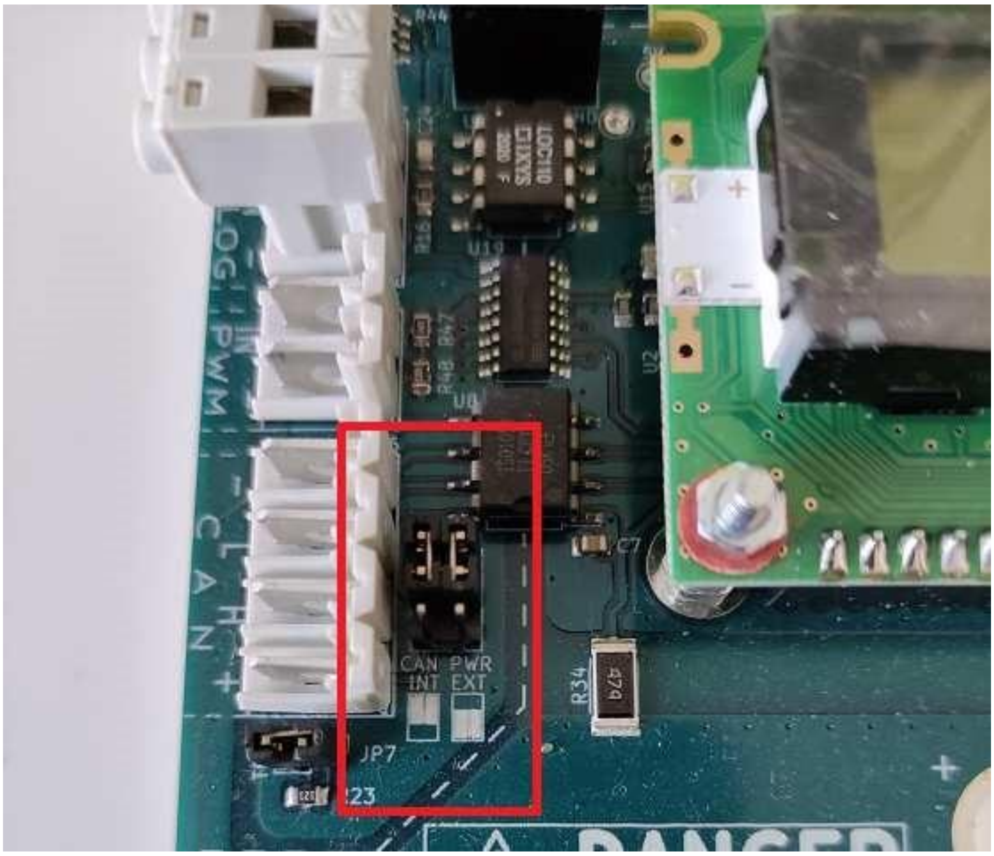
	SPx to PWS	PWS to SPx
#1	0x100	0x200
#2	0x104	0x204
#3	0x108	0x208
#4	0x10C	0x20C
#5	0x100	0x210
#6	0x104	0x214
#7	0x108	0x218
#8	0x10C	0x21C
#9	0x100	0x220
#10	0x104	0x224
#11	0x108	0x228
#12	0x10C	0x22C
#13	0x100	0x230
#14	0x104	0x234
#15	0x108	0x238
#16	0x10C	0x23C

Example for HUB-4 Configuration

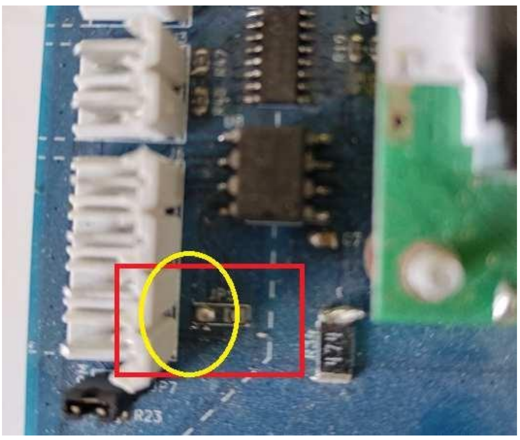

SP6
Roller R1
Roller R2
Roller F1
Roller F2
F1
F2
0x100
0x108
R1
R2
0x104
0x10C

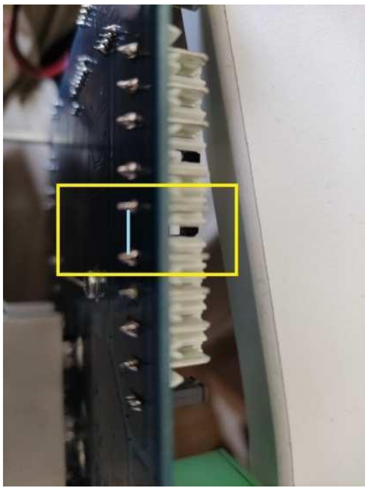
CAN Transceiver Power

PWS3.3b includes two jumpers to provide 5V to the isolated CAN transceiver. It is recommended to keep them in the upper position to get the power from the internal DC/DC instead from SP5/6 specially when there are more than 1 power supplies.



In the first **PWS3.3 units** (not PWS3.3b), the JP3 jumper should be set at the left side. And a small wire must exist between pins PWM- and GND- (it can be checked with a multimeter over those pins, without removing the PCB)





D.3. Manual d'usuari software SportDyno 4.1

SPORTDYNO V4.1

USER'S MANUAL

TABLE OF CONTENTS

1. SportDevices End User Software License & Warranty Disclaimer

DISCLAIMERS

Limitations of warranties and liability: This Software, including the embedded SPx DAQ firmware, is provided and licensed by SportDevices on an "as is" basis, without any other warranties or conditions, express or implied, including, but not limited to, warranties of merchantable quality, satisfactory quality, merchantability or fitness for a particular purpose or non-infringement, or those arising by law, statute, usage of trade, course of dealing or otherwise. The entire risk as to the results and performance of the software is assumed by you. To the maximum extent permitted by applicable law, neither SportDevices, its dealers or suppliers shall have any liability to you or any other person or entity for any indirect, incidental, special, or consequential damages whatsoever, including, but not limited to, loss of revenue or profit, lost or damaged data or other commercial or economic loss, even if SportDevices has been advised of the possibility of such damages, or they are foreseeable. SportDevices is also not responsible for claims by a third party. Other possible damages INCLUDE VEHICLE OR ENGINE DAMAGES, DYNAMOMETER DAMAGES, AND PERSONAL INJURIES. The limitations set forth herein shall apply whether or not the alleged breach or default is a breach of a fundamental condition or term or a fundamental breach.

If you are downloading this Software, the following applies:

All risk of damage to the Software during transmission and download is assumed by you.

All "Software" products, including standard and beta release versions of SportDyno Software and SportDevices's Firmware are licensed on a (non-transferable) as-is, without warranty, basis only. There are no warranties which extend beyond those stated here. The purchase price of any SPx kit (SP1, SP3, SP4, SP5) includes an implicit software license. This software license does not include any setup, training, calibration, or other consulting services.

By installing and/or using the Software you certify that you have read, understood and agreed to comply with and be bound by the following terms and conditions. If you do not agree with these terms and conditions do not install and/or use the Software.

The only exception to the above is that the "Software's media" will be replaced (if found to be unreadable) for a duration of 30-days from the original invoice ship date from SportDevices or authorized distributor. Any implied warranty determined to be applicable to the "Software's media" is limited in duration to the duration of this warranty.

In the event of a media defect in material or workmanship, SportDevices's sole responsibility is to repair (or at its option - replace or refund) the defective media. Final warranty determination will be the decision of SportDevices.

SportDevices shall not be responsible for (a) labor, transportation or other incidental charges or (b) consequential or other damages incurred by use of SportDevices Software media.
Media replacement performance will be initiated by returning the alleged defective media freight prepaid to SportDevices with dated purchase invoice.

Any disputes arising between the parties over any products, services, warranties, terms, agreements, etc. shall be governed under the laws of Valencia (Spain) and in an appropriate court within its jurisdiction.

This Software License Warranty Disclaimer supersedes all prior warranty statements. Inquiries concerning this Software License Warranty Disclaimer should be directed to:

SportDevices
Cami del Port 145, 46470 Catarroja, Spain

1.1 General Safety Instructions (SPx devices)

Use the following safety guidelines to help ensure your own personal safety and to help protect your equipment and working environment from potential damage.

SAFETY: General Safety

When setting up the equipment for use:

- Place the equipment on a hard, level surface. If the equipment is installed in a closed-in wall unit, ensure that there is enough ventilation.
- Avoid placing objects on top of this equipment to permit the airflow required for proper ventilation. Restricting airflow can damage the equipment.
- Keep your device away from radiators and heat sources.
- Keep your equipment away from extremely hot or cold temperatures to ensure that it is used within the specified operating range. (check technical parameters section at SPx manual)
- Keep your equipment away from Electromagnetic emitting devices like CDI ignition, or electric motors / VFD (Variable Frequency Drive)
- Do not push any objects into the air vents or openings of your equipment. Doing so can cause fire or electric shock by shorting out interior components.
- Ensure that nothing rests on your equipment's cables and that the cables are not located where they can be stepped on or tripped over.

When operating your equipment:

- Do not use your equipment in a wet environment, for example, in a wet basement.
- Do not use AC powered equipment during an electrical storm.
- Do not spill food or liquids on your equipment.
- Before you clean your equipment, disconnect it from the electrical outlet. Clean your device with a soft cloth dampened with water. Do not use liquids or aerosol cleaners, which may contain flammable substances.
- Clean the display with a soft, clean cloth and water. Apply the water to the cloth, then stroke the cloth across the display in one direction, moving from the top of the display to the bottom. Remove moisture from the display quickly and keep the display dry.
- Long-term exposure to moisture can damage the display. Do not use a commercial window cleaner to clean your display.

⚠ **CAUTION: Do not operate your equipment with any cover(s) removed.**

- If your equipment does not operate normally - in particular, if there are any unusual sounds or smells coming from it - unplug it immediately and contact an authorized dealer or service center.

⚠ **WARNING: To prevent the spread of fire, keep open flames away from this product at all times.**

1.2 SAFETY: When Working Inside Your Device

Do not attempt to service the equipment yourself, except as explained in your documentation or in instructions otherwise provided to you by SportDevices. Always follow installation and service instructions closely.

1.3 SAFETY: General Power Safety

By default, if other values are not specified all SportDevices equipment are rated for **230 VAC / 50 Hz.** (115 VAC units will have a specific label for that)

Observe the following guidelines when connecting your equipment to a power source:

- Check the voltage rating before you connect the equipment to an electrical outlet to ensure that the required voltage and frequency match the available power source.
- Do not plug the equipment power cables into an electrical outlet if the power cable is damaged.
- To prevent electric shock, plug the equipment power cables into properly grounded electrical outlets. If the equipment is provided with a 3-prong power cable, do not use adapter plugs that bypass the grounding feature, or remove the grounding feature from the plug or adapter.
- If you use an extension power cable, ensure that the total ampere rating of the products plugged in to the extension power cable does not exceed the ampere rating of the extension cable.
- If you must use an extension cable or power strip, ensure the extension cable or power strip is connected to a wall power outlet and not to another extension cable or power strip. The extension cable or power strip must be designed for grounded plugs and plugged into a grounded wall outlet.
- If you are using a multiple-outlet power strip, use caution when plugging the power cable into the power strip. Some power strips may allow you to insert a plug incorrectly. Incorrect insertion of the power plug could result in permanent damage to your equipment, as well as risk of electric shock and/or fire. Ensure that the ground prong of the power plug is inserted into the mating ground contact of the power strip.
- Be sure to grasp the plug, not the cable, when disconnecting equipment from an electric socket.

1.4 SAFETY: If Your Device Gets Wet

⚠ **CAUTION: Before you begin any of the procedures in this section, see the SAFETY: General Safety section of this document.**

⚠ **CAUTION: Perform this procedure only after you are certain that it is safe to do so. If the device is connected to an electrical outlet, turn off the AC power at the circuit breaker, if possible, before attempting to remove the power cables from the electrical outlet. Use the utmost caution when removing wet cables from a live power source.**

- Disconnect the AC cord from the electrical outlet, and then, if possible, disconnect the AC cord from the device.
- Turn off any attached external devices, then disconnect them from their power sources, and then from the device.
- Contact SportDevices support (info@sportdevices.com)

⚠ **Limited Warranties:** warranty is limited to normal usage of the device, any fault caused by inappropriate usage or accident will not be covered

1.5 SAFETY: If You Drop or Damage Your Equipment

⚠ **CAUTION: Before you begin any of the procedures in this section, see the SAFETY: General Safety and Power Safety sections of this document.**
4. CAUTION: If any internal components can be seen through damaged portions, or if smoke or unusual odors are detected, disconnect the device from the electrical outlet and contact SportDevices support (info@sportdevices.com)

1. Save and close any open files, exit any open programs, and shut down the computer.

2. Turn off the device and disconnect from the power source, and then disconnect from the computer.

3. Turn off any attached external devices, and disconnect them from their power sources and then from the computer.
4. Connect the device to the power source and turn on the device.
5. If the device does not start, or if and smoke or unusual odors are detected, or you cannot identify the damaged components, contact SportDevices support.

1.6 Protecting Against Electrostatic Discharge

⚠ CAUTION: Disconnect product from mains power source in accordance with product specific safety information located on the "Safety Information" section of this website.

Electrostatic discharge (ESD) events can harm electronic components inside your device. Under certain conditions, ESD may build up on your body or an object, such as a peripheral, and then discharge into another object, such as your device. To prevent ESD damage, you should discharge static electricity from your body before you interact with any of your device's internal electronic components, like the Bluetooth plug-in.

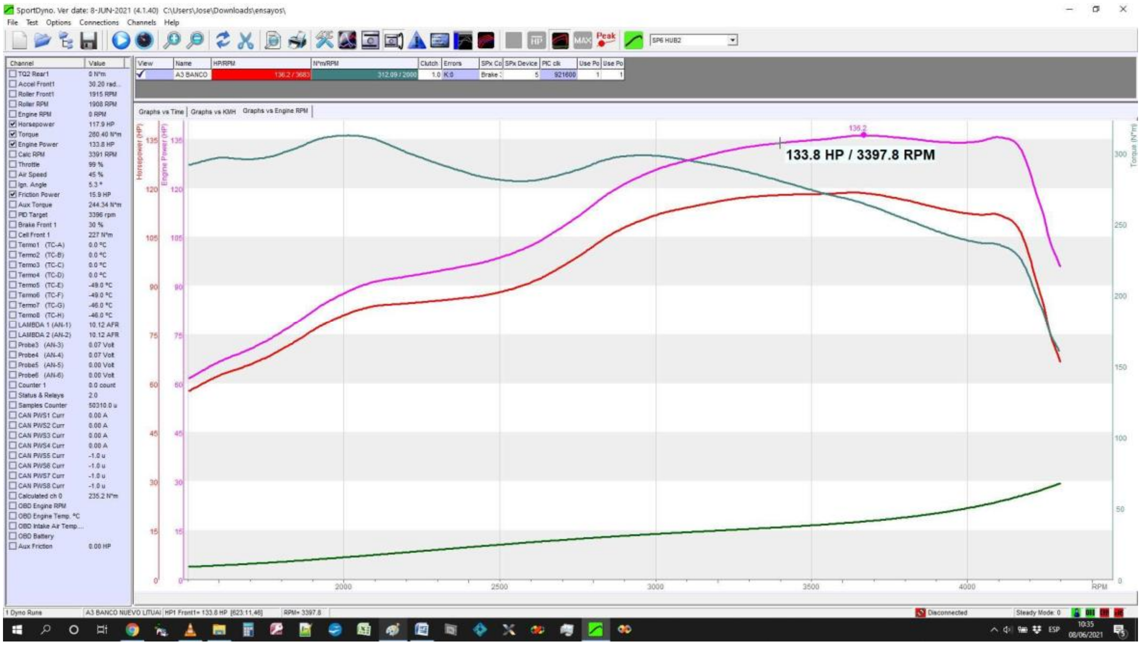
You can protect against ESD and discharge static electricity from your body by touching a metal grounded object (such as an unpainted metal surface on your device) before you interact with anything electronic.
You can also take the following steps to prevent damage from electrostatic discharge:

- When unpacking a static-sensitive component from its shipping carton, do not remove the component from the antistatic packing material until you are ready to install the component. Just before unwrapping the antistatic package, be sure to discharge static electricity from your body.
- When transporting a sensitive component, first place it in an antistatic container or packaging.
- Handle all electrostatic sensitive components in a static-safe area. If possible, use antistatic floor pads and work bench pads.

1.7 Dynamometer Important Safety Tips

- Securely fasten test vehicle using all available restraining ratchet straps. The more straps the better. Secure both front to back and side to side. Never move the steering wheel for front wheel drive vehicles while under test.
- Always inspect vehicles for fuel or oil leaks before testing as dyno electrical system can ignite fuel
- Always perform low speed test run to confirm vehicle is adequately secured and operational before doing extensive testing.
- Keep people away from the dyno test area and NEVER have people stand behind the rear of the vehicle. Debris may be stuck in the tires tread and may become projectiles during testing.
- When operating around rotating parts do not wear loose fitting clothing as they may get caught up in rotating pulleys or mechanical components
- Keep dyno area clean from all loose objects
- Keep all hands, feet, and other objects away from moving rolls during tests
- Always wear approved safety equipment such as eye protection and steel tow boots around dyno area
- The dynamometer rollers and power absorption units can become very hot during testing. Avoid contact with them as serious burns or injury can occur.
- The dynamometer power absorption units require high voltage DC current to operate.
- Contact with the high power electrical wires and boxes may be fatal. Disconnect all power to the electrical system before inspecting or servicing.
- During extended testing vehicle cooling system and engine may become very hot.
- Extreme caution is necessary when working near these components.
- Always inspect vehicle tires for wear or damage before testing and only operate with tires that are in good condition and at the proper tire pressure. FOR ALL TIRES TIRE PRESSURE SHOULD BE BETWEEN 1.8 to 2.5 bar (25-35 PSI)
- Never let untrained personal operate the vehicle during dyno testing
- Exhaust gasses are poisonous and may be fatal.

2. **MAIN SCREEN.**



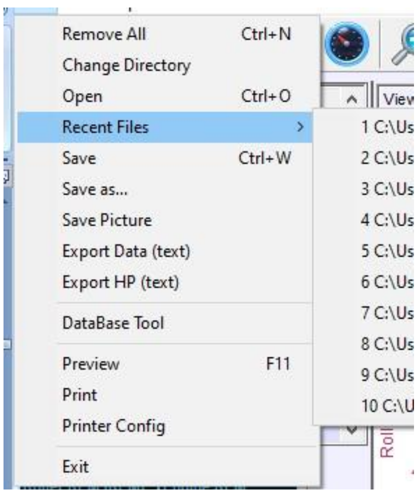
This screen is divided into several zones that are described below:

1. Menu
2. Button bar + other buttons.
3. Channel selector.
4. Options for X axis.
5. Tests list.
6. Graphs area.
7. Scroll bars
8. Status bar.

2.1 Main Menu

Below the program options are explained, there are six menus:

2.2 File Menu



2.2.1 Remove All.

It removes all tests from the memory, but not from the disk.

2.2.2 Open.

It shows a window to choose the tests to be loaded in memory. It is possible to load them one by one or several at once.

2.2.3 Recent Files

It stores a list with the 10 latest open files to ease opening them again

2.2.4 Change directory.

It allows changing the directory where tests are automatically saved.

Change Directory Window

2.2.5 Save as.

It allows saving the dyno run with a different name or in a different place.

2.2.6 Save picture.

It saves a picture with the current graphs area in BMP format. If you want to send it by email, it is better if you change it to gif later.

2.2.7 Export Data (text / raw)

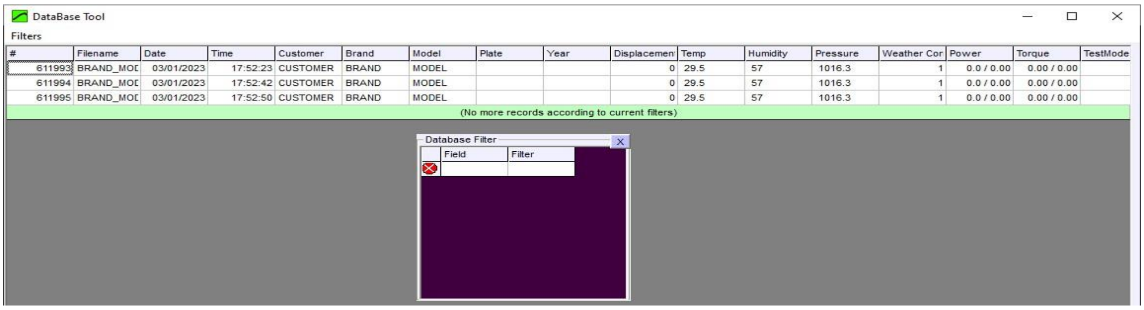
It exports all test RAW data in CSV format (Comma Separated Values), so the data can be used with other programs, for example Microsoft Excel.

2.2.8 Export HP data.

It writes a text file with data from HP and TQ in CSV format, so data can be used with other programs like Excel.

2.2.9 Database Tool

Sportdyno stores the results of all tests so a search across the different fields can be done. The user can add filters to several fields to complete the search. Using the field 'path' the user will be able to open the tests, but if the tests have been moved after they were stored, the SW will not open them.



2.2.10 Preview.

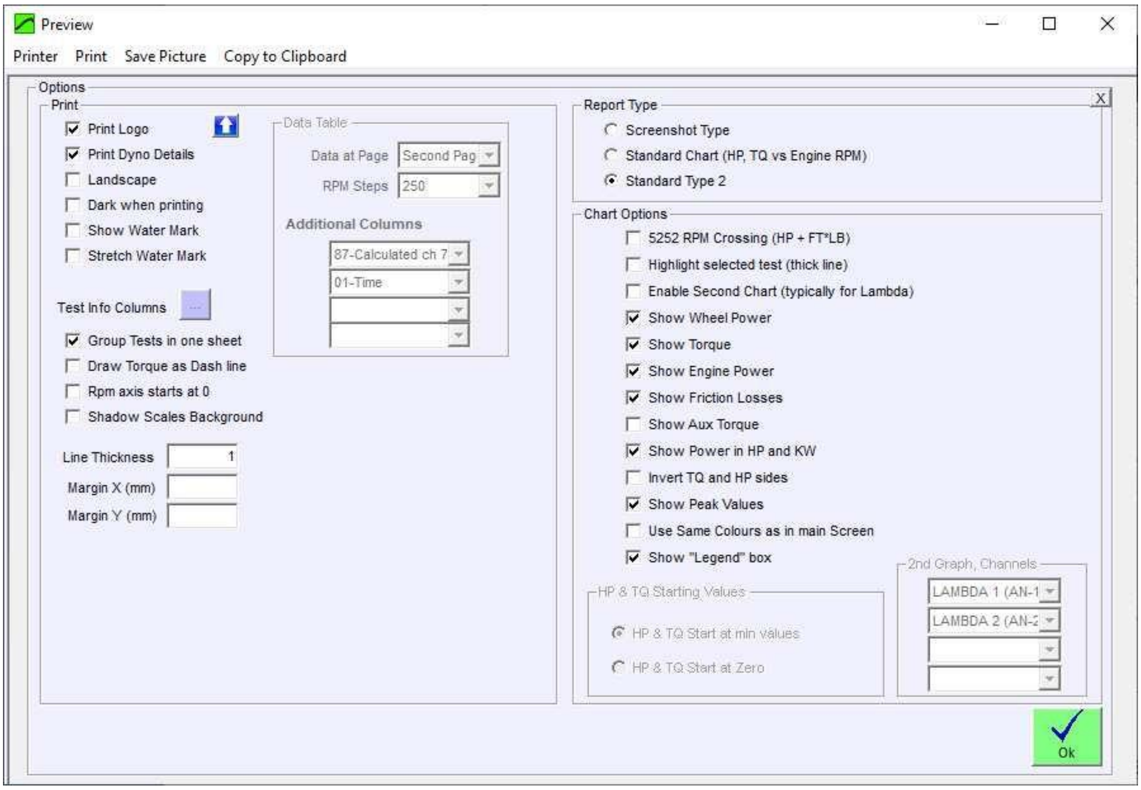
It shows a preview in the screen of the tests in the same way as they will appear in the printer. Note: in this version are three type of reports: "screenshot", "standard chart" and "type 2 chart"

2.2.11 Print.

It prints the selected tests. It shows a window so you can first choose and configure the printer. Note: in this version are three type of reports as described above.

2.2.12 Printer Config

(Note that printer configuration has been moved from the Main Configuration to this specific window)



Print Logo: user can select whether he wants to print the logo or not. There is a file named "**logo.gif"** at installation folder (C:\Program Files (x86)\Sportdevices\Sportdyno41) that can be replaced to set your own business logo. Please use a similar size file. There is also an "upload" button (the arrow up), to install your logo.

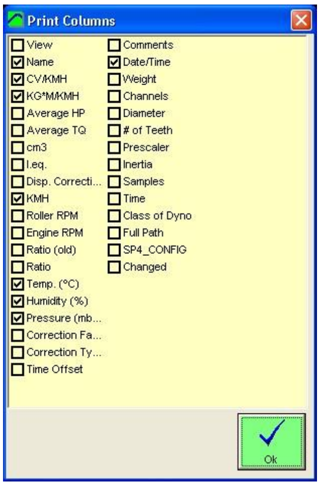
Print Dyno Details: If active, the report will show Sportdyno SW date and version, Dyno name, and Roller inertia, and active options (displacement correction, correction factor, load cell active)

Landscape: With this option dyno runs will be printed horizontally instead of vertically. In this way a bit less numeric data will fit on the paper.

Dark when printing: when printing, pure colors (red, yellow, etc) are not clearly shown over white paper. Then this option is used to dark the graphs color over the paper.

Show Watermark, Stretch Watermark

Test Info Columns Button: program will show Test Info fields selected in this window at report's header. By default: Name, Power, Torque, Temperature and a few more fields are shown per each test in the first table (on page header). User can choose which test data is to be printed on the report's header for each test (do not confuse with the test channels shown at the right table).



2.2.13 Data table

Page: None, First Page or Second Page. By default graphs and numeric table are printed in a single page. Now the user can chose to not print the data table (option=none), to print it with the graph (option=First Page) or to print it in a second page (option=Second Page)

RPM steps, when printing a dyno run the default RPM step is 250 for the data table, you can change this value to 100, 250, 500 or 1000 rpm.

Columns 4 and 5, when printing a dyno run, the first three columns of data are: RPM (or time) HP, TQ. The next column(s) can be chosen from the rest of recorded channels of dyno run.

2.2.13.1 Report Type

- **Screenshot Type:** this is the mode used in previous versions. Sportdyno draws the same graph as in main screen for the printed report.
- **Standard Chart (HP, TQ vs Engine RPM):** this mode shows the new HP chart. There are two graphs: top graph shows HP and TQ, bottom graph shows extra channels as lambda or others.
- **Standard Chart "Type 2": (default)** this is a more formatted report focused for printing one run, or for comparing two runs. It includes a foot section with detailed data from the tests.

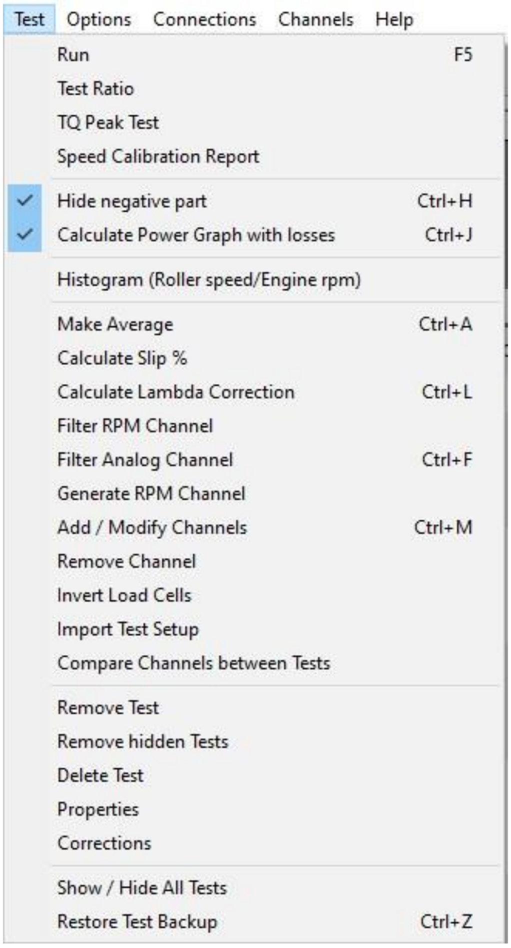
2.2.13.2 Chart Options (only at Chart mode)

- **5252 RPM crossing (HP + FT*LB),** it sets the HP and TQ units to the imperial units so the graphs cross at the known place: 5252 RPM
- **Highligh selected test (thick line):** by default the selected test will be drawn with a thicker line. This test is important because the numeric table is referred to it.
- **HP&TQ starting values:** graphs can start from 0, or from their minimum value so the curve is magnified to fit the whole graph area.
- **2nd graph channels:** In chart mode, the 2nd graph shown at bottom allows to show up to 4 channels. By default only lambda 1 is shown, but other channels can be set

2.2.14 Exit.

The program will be closed.

2.3 Test Menu.



2.3.1 Run (F5).

It opens the 'Gauges' Window. In this window you can input the data for the dyno run and the environmental conditions. Then, you can start the test by clicking over the 'Start' button in this window or the start/stop button on the dyno.

Note: in this version, test recording is guided by the software. In a typical run, SW will show:

- gauges window,
- then Ratio Window (it is not shown if fixed ratio, clamp or OBDII /xDS modes)
- then "semaphore" window (to find when the engine rpm matches the starting rpm),
- then it will record the test,
- and then if "stop when lower" option was selection it will show the "press clutch" warning

2.3.2 Test ratio (F7).

This option opens the "Ratio" Window which is used to calculate the Engine RPM / Roller RPM ratio using the vehicle's Engine RPM Gauge, when the engine RPM channel is not available.

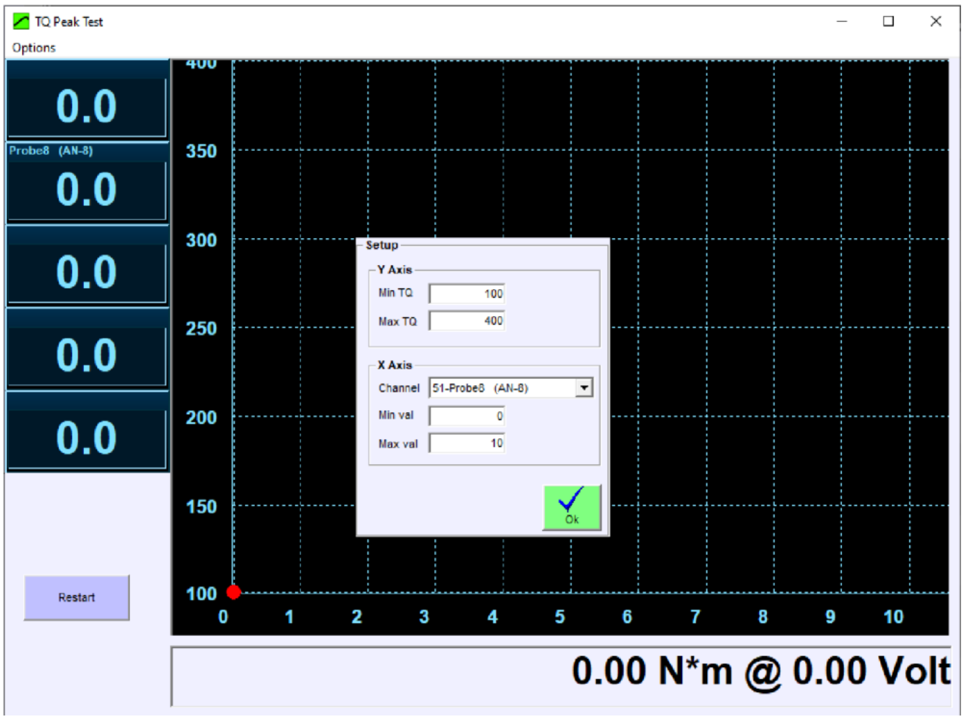
In this window the user can input the rpm value at which the calibration will be performed.

Normally this calibration is performed in the last gear (say 5th or 6th), although in some vehicles you may need the previous gear (4th or 5th). The procedure consists of accelerating the engine up to it reaches the selected RPM value, typically ½ of top engine speed (for example 6000) and then press Continue" Button (or the start/stop in the dyno).

2.3.3 TQ Peak Test

This window allows to perform a braked test to compare the Torque vs other channel (typically a channel from the ECU that shows the ignition advance) to find at which value the TQ peak is reached.

Use the Options/Setup Menu to configure the channel used for the reference (ignition advance)



2.3.4 Speed Calibration Report

This window is activated under a specific license

It is used to calibrate the vehicle speedometer (with the current status of the tires) with respect the dynamometer speed.

2.3.5 Hide Negative Part

It hides all channels during the coasting phase (ex. Lambda), in this way channels are only shown where the engine/vehicle is providing power and torque, and they are not "overwritten" when the engine RPM goes back (which normally is confusing).

2.3.6 Calculate Power Curve with Losses / Power at Engine

It calculates the addition of **wheel power** + **friction losses,** and displays the result instead of the real power curve. It is important to keep in mind that that calculation is only an estimation of the real power.

In Sportdyno 4.1 Engine Power is a different channel than Wheel / Raw power and both can be shown at same time (previous versions didn't allow this)

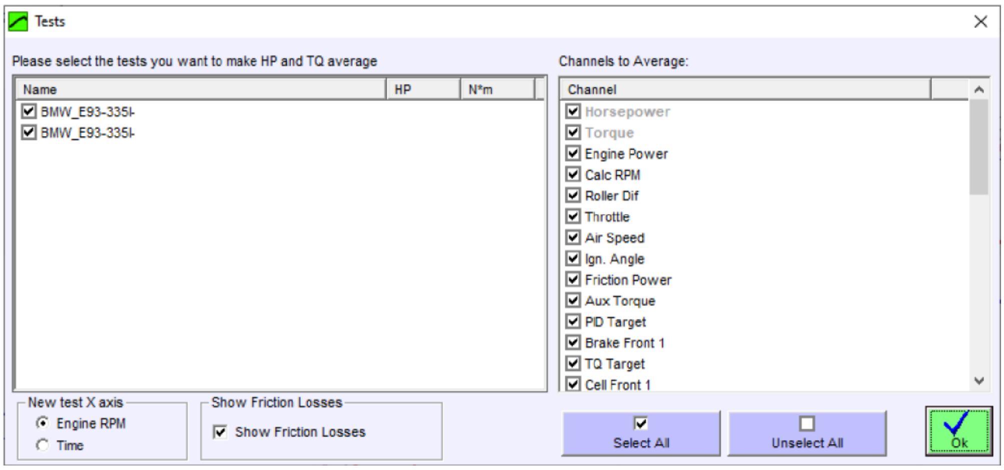
When activating "Calculate Power Curve with Losses" will also activate "Hide Negative Part", but not the opposite direction.

2.3.7 Histogram.

It performs a statistical analysis in which can be seen the predominating RPM/KMH ratio of the test. The program makes automatically a histogram after doing a dyno run when the "using rpm clamp" option has been chosen.

2.3.8 Make average.

This option is useful to make an average between tests of the same vehicle, typically consecutive tests, to get a new test with the averaged power and torque.
It shows a window to choose which tests to average, and it creates a new test from them. It is needed to have at least two tests loaded.



2.3.9 Calculate Slip %

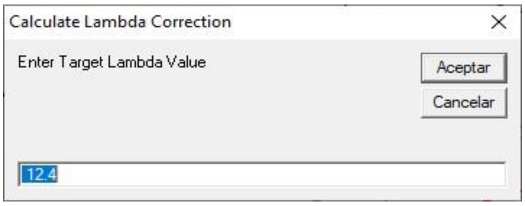
As the wheel applies torque over the roller, certain slip percentage is produced (proportional to torque). This option creates a calculated channel from roller rpm channel and engine rpm channel to see the slip percentage at each point. Actual HP could be calculated by adding the slip percentage at the maximum HP point, but it is not a reliable process to be automated by the program.

In order that the slip% calculation is accurate, the user must know the exact ratio without torque. Thus a no-acceleration test is strongly recommended in order to get the actual gearbox ratio, at steady rpm. Then, by using this ratio a normal dynorun will be performed. And slip% could be calculated from a consistent ratio that starts from slip%=0 when no torque is applied.

You can also try to compensate the current ratio with this window, but this is only an approximate way to do it:

2.3.10 Calculate Lambda Correction

For a given lambda target, the SW will create a compensation channel to show the percentage that fuel has to be corrected, either increasing current values at ECU or decreasing them.



2.3.11 Filter RPM Channel.

This option removes some "glitches" at RPM channel, but not always it can be done. Anyway, SportDyno software uses engine RPM channel in a statistic way to determine ratio between engine RPM and speed of Roller, so few glitches at the channel do not affect the Ratio, HP and TQ calculations. (Ratio is calculated only when Roller accelerates, so rpm channel is not used when the Engine decelerates)

2.3.12 Filter Analog Channel.

This option performs a low-pass filter to the selected channel to remove high-frequency noise. The size of the filter can be entered between 1 to 30.

This operation is not undo-able.

2.3.13 Generate RPM Channel.

This option recalculates the entire engine RPM channel overwriting the previous values with its calculated ones. This new values are the result of multiplying speed channel by Ratio value, thus if ratio value is wrong, resulting RPM channel will be wrong too.

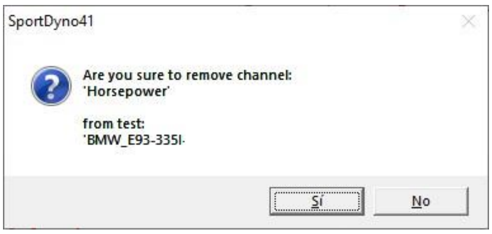
This option is only useful to generate a calculated rpm channel when it wasn't recorded, but keep in mind that this channel is fake, and could not match with the true one…

2.3.14 Add / Modify Channel.

This option adds or modifies a calculated channel to the current test. Calculated channels are selected from the total channel list, and a calculation formula is used to generate the channel. For more information please refer to section 13 (Calculated channels).

2.3.15 Remove Channel.

This option removes the current selected channel from the current test. It can be used for either removing normal channels or calculated channels. Please be careful, once a normal channel there is no "undo" option to recover it.



2.3.16 Remove Test.

It removes the selected dyno-run from memory (not from the disk).

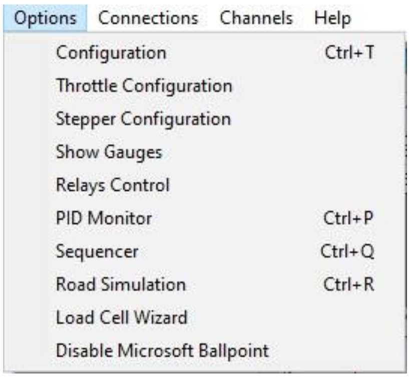
2.3.17 Delete Test.

It deletes the dyno-run from memory and from the DISK. Be careful.

2.3.18 Properties.

It shows all data from the test in a new window (the same data as in the dyno runs list). This window allows the user to change certain values (such as ratio, temp, etc) after doing a dyno run.

2.4 Options Menu

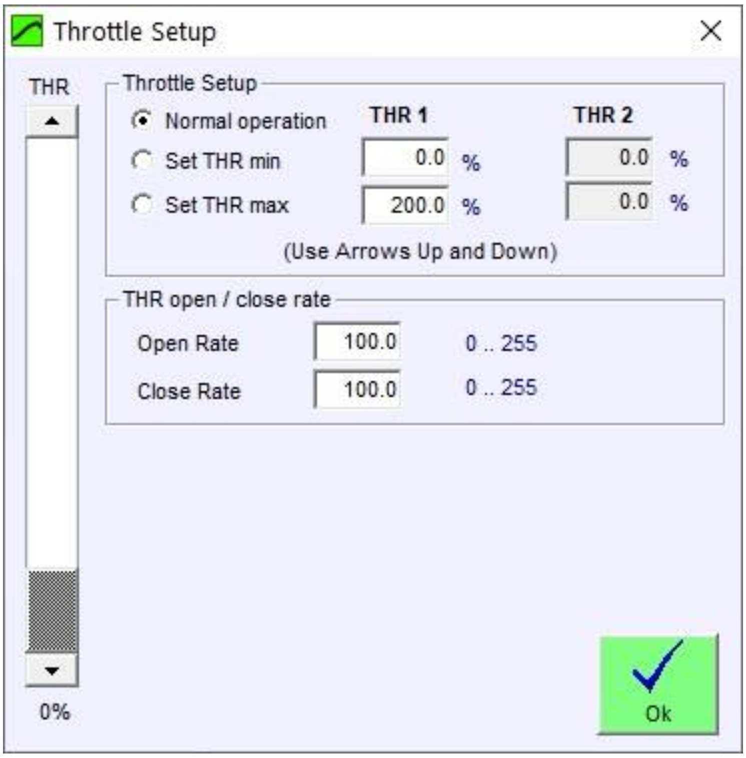


2.4.1 Configuration.

This option opens the (main) Configuration Window, it is explained below.

2.4.2 Throttle Configuration [NEW]

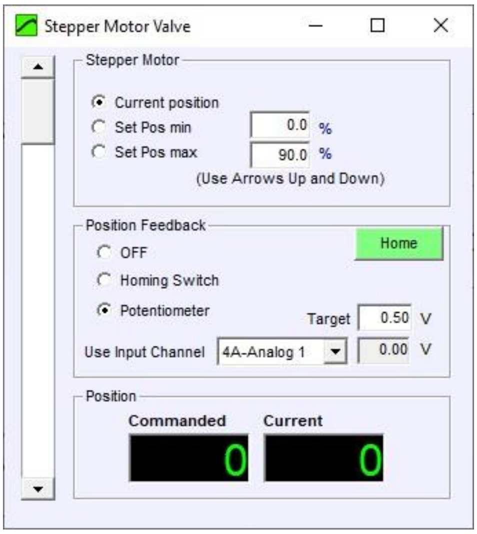
It opens the Throttle Configuration Window. Please refer section 10.



Note: **some options like this one are hidden in the initial configuration** for not creating more confusion to new users. For activating them, go to Configuration / Options / Advanced Options.

2.4.3 Stepper Configuration [NEW]

Braked DAQs (SP1+, SP5 and SP6) support controlling a stepper motor for driving a water brake valve (with a special Firmware)



2.4.4 Show Gauges

Sportdyno 4.0 and 4.1 can show 6 numeric boxes in the main window all the time, to help to supervise main channels as Roller RPM, Load Cell, Brake, Engine Temp (for instance from OBDII)

This option shows / hides these gauges

Boxes can be edited with the right mouse button.

2.4.5 Relays Control [NEW]

It shows the Relay Control panel at the Main Window. Each button can operate one relay. Button names can be changed by using the right-mouse button.

Note 1: 'Start' button is different: it only works while the mouse button is pressed. It is envisaged to use it for the starter motor.

Note 2: Relays can also be accessed using a shortcut: SHIFT + F1 to F8.

2.4.6 PID Monitor

It opens the PID monitor Window which is useful to configure and see the Speed Controller (PID) performance and to setup the PID value.

2.4.7 Sequencer.

Automated test mode, it provides a way do some automation on the test process with SP4 / SP5.

Ex: wait 2 seconds at 3000 rpm in stationary mode, and then start recording in ramp mode at 100 rpm/s rate. It is explained below.

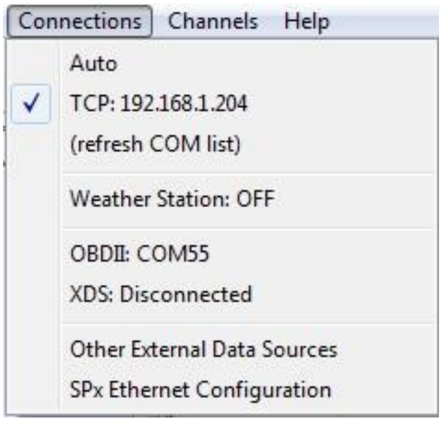
2.4.8 Load Cell Wizard.

It opens the Load Cell Wizard to ease the process of setting up the load cell.

2.4.9 Disable Ball Point Device

Windows can eventually detect the data stream from the DAQ or from the Weather Station and decide that it is a MOUSE, it will install their drivers and block the access from other applications. It is recommended to execute the Disable Serial Ballpoint procedure, **but it will only works if Sportdyno has been executed in Administrator Mode**

2.5 Connections



2.5.1 Auto Detect.

It shows the Auto-COM-search window. It is strongly recommended for USB adaptors where the COM*xxx* can be any number between COM1 and COM255.

2.5.2 COM1 - COM(n).

It selects the serial port in which the SPx module is connected. If a port fails, it will be shown grayed. If there is not any available port, it is recommended to close all programs and open SportDyno again.

Everytime the Auto Detect option is clicked, this COMs list is updated, this allows to display new COMs when a new USB adapter has been connected.

Please note that by default most FTDI adapters have a long latency that can make the realtime graphs and gauges to work "in steps" instead of having a fluid operation. To avoid this you can either configure the latency manually to 1 ms in the Hardware Manager, or using the FTDI type connection below.

2.5.3 FTDI (0xnnn) [NEW]

It performs the connection using the FTDI driver, which allows the software to configure the latency and other parameters necessary for a better performance of realtime graphs and gauges.

2.5.4 Reconnect

If this option is active, when the connection is lost, Sportdyno will re-try the connection every few seconds. This allows disconnecting and connecting USB adapters in case Windows removed the adapter driver, or in case of TCP connections, it allows to plug the Ethernet connector and Sportdyno will create the connection automatically.

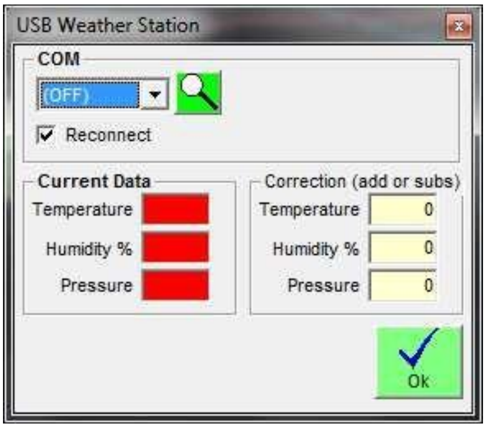
2.5.5 (Refresh COM list)

When connecting and disconnecting USB devices, the COMs list is updated automatically, but this option forces its updating in case the adapter is not shown.

2.5.6 USB Weather Station

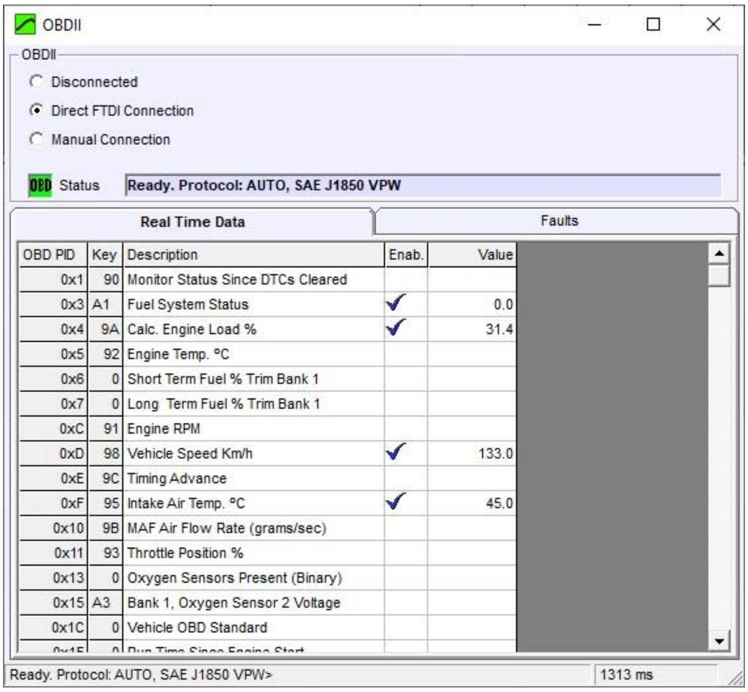
This option opens the Weather Station window. This window allows choosing the COM port for the Weather Station, and also performing an automatic search for the W.S. (magnifying glass button).

This window also allows adding correction offsets for temperature, humidity and pressure (adds or subtracts), although normally this is not necessary as Weather Station uses a high quality Bosch sensor for Temperature and Pressure.



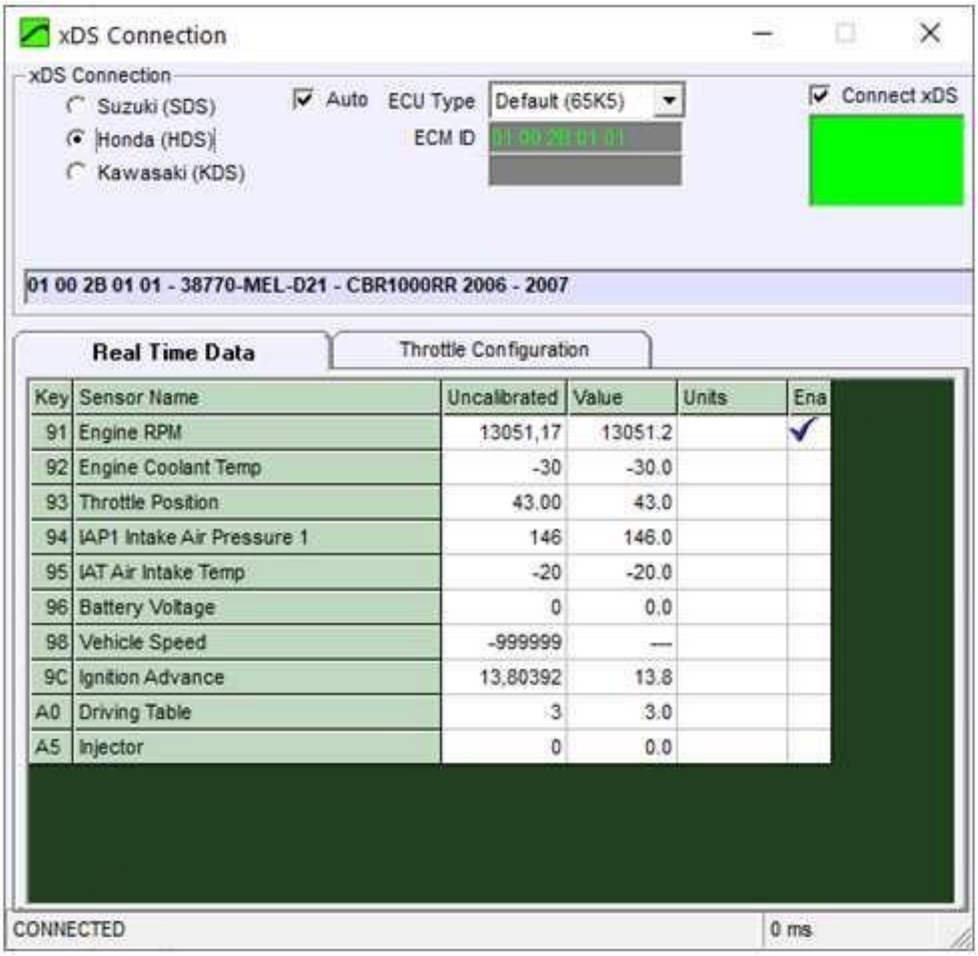
2.5.7 OBDII

This option opens the OBDII window. This window allows connecting to the OBDII device and choosing the PID channels to be acquired (note that some cars have slow protocols and only a few channels can be acquired at a reasonable speed) Please refer to section 14 (OBDII).

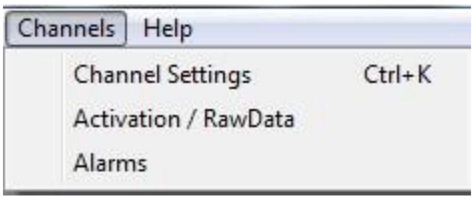


2.5.8 xDS

This option opens the xDS window (Suzuki SDS, Honda HDS, Kawa KDS). This window allows connecting to the xDS link and choosing the ECU channels to be acquired (note that some protocols are slow like KDS, and only a few channels can be acquired at a reasonable speed)
Please refer to section 15 (xDS).


xDS Connection
xDS Connection
Suzuki (SDS)
Honda (HDS)
Kawasaki (KDS)
Auto
ECU Type
Default (65K5)
ECM ID
Connect xDS
01 00 2B 01 01 - 38770-MEL-D21 - CBR1000RR 2006 - 2007
Real Time Data
Throttle Configuration
Key Sensor Name Uncalibrated Value Units Ena
91 Engine RPM 13051,17 13051.2
92 Engine Coolant Temp -30 -30.0
93 Throttle Position 43.00 43.0
94 IAP1 Intake Air Pressure 1 146 146.0
95 IAT Air Intake Temp -20 -20.0
96 Battery Voltage 0 0.0
98 Vehicle Speed -999999 ---
9C Ignition Advance 13,80392 13.8
A0 Driving Table 3 3.0
A5 Injector 0 0.0
CONNECTED
0 ms

2.6 Channels Menu.



2.6.1 Channel Settings.

It shows the channels configuration window. Channel name can be changed in this screen so the name matches to the function that channel performs in your dyno, for example: channel 0x4A (former 'J'): 'Sensor 1', could be named as 'Lambda 1'. Also, you can modify the scale data of the sensor, and decimal places.

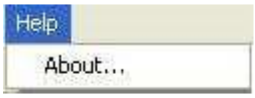
2.6.2 Activation / Raw data.

It shows a Channels Window useful to see the incoming data from the SPx box (to see if there is any fault)

2.6.3 Alarms.

It shows the Alarms configuration window. Alarms are useful to detect hazard situations especially on Engine test bed dynos that could be working for hours without the operator surveillance.

2.7 Help Menu



2.7.1 About.

It shows information about SportDevices, developer of the software and SPx module manufacturer.

2.8 Button Bar

By clicking over these buttons you can do more quickly the same actions that using the menu. Options are:

Paper sheet: New. File/new menu.

Opening folder: Open. File/open menu.

Folders tree: Change directory. File/change directory menu.

Disk: Save as. It saves the dyno run with another name or in another directory.

"Play" icon: Run. Test/run menu. (F5 key)

Gauge: Test Ratio. Test / ratio calculation menu.

Glass +: Zoom +. It magnifies the graphs area x 2.

Glass -: Zoom -. It reduces the graphs area / 2.

Round arrow: Redraw. Draws again the dyno runs, and also calculates again the scales (if not in manual mode)

Scissors: Cut-end-of-the-test. When using this option, the user will click over a certain part of the test (in graphs vs time mode) then the program will discard the final part of the test from the point where the user clicked to the end of the test. **Sheet and glass: Preview.** File/preview menu (F11 key)

Print. File/print menu (F12 key)

Tools. It opens program configuration window.

Graphs: Channels. It opens channel configuration window.

Load Cell Wizard. It shows the Load Cell Wizard window.

Invert Load Cell.

Exclamation sign: It opens the Alarms window.

Blue Label. It shows/Hides data label. This label shows certain information from the chosen channel while the user moves the cursor across the tests.

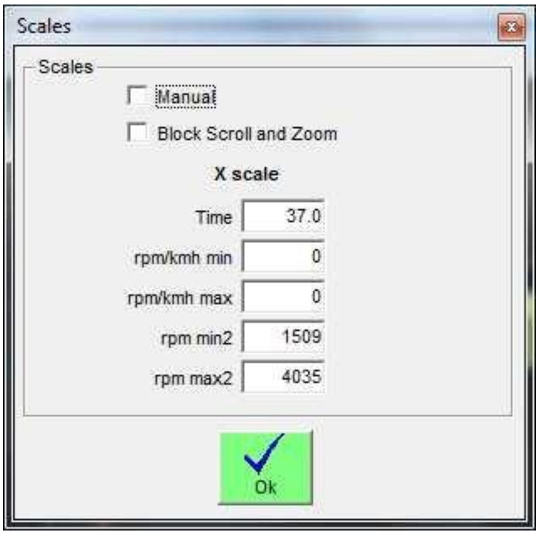
Gray and Black blocks: It changes the window arrangement: In vertical arrangement, all small frames (channels, relay buttons) are displayed at left side. In horizontal arrangement all small frames are displayed on top to allow the graphs to take the whole Window width.

Red lines: It modifies the colour grouping. In one mode all tests use the same colour for the same channel (different colours per channel), and in the other mode each test uses a different colour for all its channels.

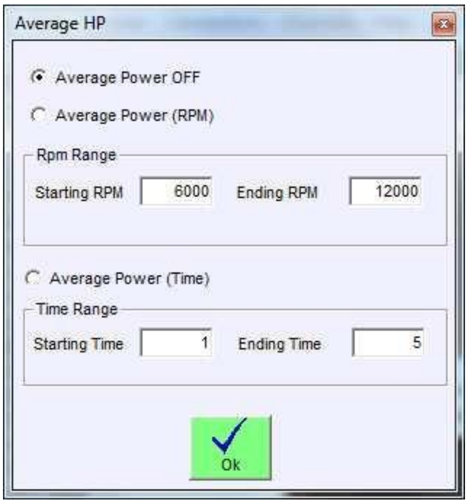
Manual. Manual mode is useful to set a fixed Time, speed (1) or Rpm (2) scales regardless of the test values. It could be useful if some strange data is present on the test and you want to force known limits. The rest of scales (HP, TQ, and the rest of channels) have been removed from this window and have been added on the channel configuration window, by using the upper bound and lower bound fields.

Manual checkbox activates the manual mode. Once activated, the button on the main window changes its colour to show you manual mode is active.

Block Scroll and Zoom checkbox disables the mouse tracking and moving over the graphs.



HP average. This option is used to calculate average power inside a rpm range or a time range. The option has been moved from main configuration to this independent window to ease its use.
It has three modes: OFF, RPM range and time range.
When activated, two small vertical lines will be displayed showing the selected range and a doted horizontal line crossing at the HP power value. This calculated value is also available in the test data area. The column is hidden by default, but the user can enable it with the right button of mouse.

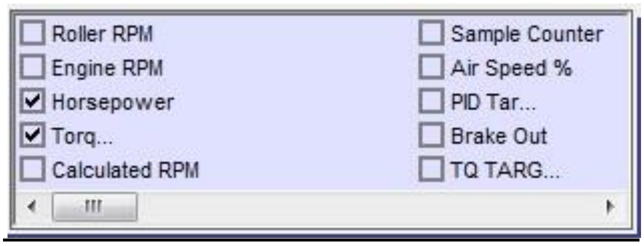


Peak dot: it will show a dot for the peak value at the current selected graph

SportDevices Icon: About. Help / About menu.

Dyno Profile Selector (combo box). Sportdyno allows to configure several dyno profiles for instance for using the same SPx DAQ box with two dynos, of for using either Front or Rear axle on an AWD dyno. Using this combo box the user can change from one configuration to another without having to enter into the Config Window.

2.9 Channel selector.

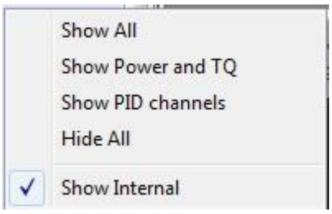


There are several channels at this box, if these channels are checked they will appear on graphs area (if they exist at the dyno run):

- **Roller RPM.** It displays roller rpm channel (when selected) **Engine RPM.** It displays engine RPM channel.
- **HorsePower.** It displays horsepower channel.
- **Torque.** It displays torque channel.
- **Calculated RPM.** With SP1 to SP4 Sportdyno generates a calculated RPM channel. With SP5 this channel is sent by the DAQ.
- **EXHAUST.** It displays thermocouple 1 channel (if available).
- **WATER.** It displays thermocouple 2 channel (if available).
- **Load cell.** It displays load cell channel (torque from brake in SP3).
- **Lambda1.** It displays lambda channel 1 (if available).
- **Lambda2.** It displays lambda channel 2 (if available).

This box dynamically loads depending on the channels available on the system. Right bar and bottom bar can be moved with the mouse to make the area bigger, if more channels are present.

With mouse right button it is shown the following window:



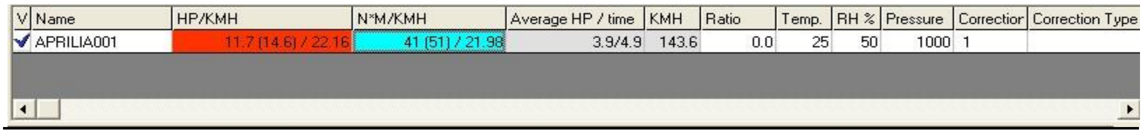
- Show All. Activates all available channels.
- Show Power And Torque. Activates only HP and TQ channels.
- Show PID Channels.
- Hide All. Hide all channels.
- Show Internal: this check box alternates between checked/unchecked. When active it will show all channels.

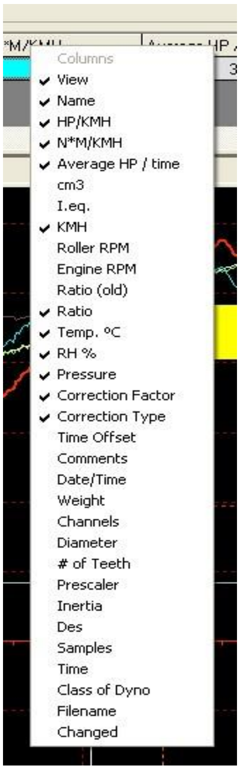
2.10 Options for X Axis.

Options in this box are:

"Graphs vs. time" It displays dyno run curves as a function of time (seconds).
"Graphs vs. KMH/MPH" (for vehicle dynos) or "Graphs vs. Roller RPM" (for engine dyno) It displays dyno run graphs as a function of roller RPM/Speed
"Graphs vs. Engine RPM" It displays test curves as a function of engine RPM. This **channel is always calculated** by using the ratio value (RPM/KMH) of dyno run, so this scale will be wrong if ratio is wrong.
Note: Automatic engines **should not be displayed Engine RPM mode**, because the gearbox ratio or CVT changes while the roller accelerates.

2.11 Dyno run List





This list contains tests loaded from the disk or tests done with the dyno.

By right-clicking over the test list, a popup window will be displayed to ease certain funcions related with the test. Behaviour of these funcions is the same as on the Test Menu.

The user can change directly most data over the list, to do this you can press key F2 or click twice over the desired cell. Note: **gray cells** cannot be edited.

If you right-click over the Titles row then a popup menu will be displayed. This menu contains all **available columns**. Here you can check / uncheck over them in order the columns will be displayed on the list or not.

Test Grid Columns:

View. By clicking over this column a check mark will appear/disappear, making the test being displayed / hidden on the main window.
Name. Name of dyno run, if name is changed and then ENTER is **pressed the file on the disk will change its name** too.
HP and TQ. These are the maximum values of power and torque, and RPM or KMH or MPH at which values was done (depending on the configuration)
If HP at engine is selected (on configuration window) it will be displayed in this way:

> HP=90 (105) / 9000:
> 90 HP at wheel, (without losses),
> 105 HP at engine, (with friction losses), read at 9000 rpm
>
> TQ=50 (65) / 7000:
> 50 N*m torque (without losses),
> 65 N*m torque (with friction losses), read at 7000 rpm

Average HP. If average option used (starting rpm and ending rpm have value) the program will show the average HP value in the selected area.
For example, if an engine has 50 HP at 5000 rpm, and 60 HP at 6000 rpm (making a straight line), the average power will be 55 HP between 5000 and 6000 rpm.

Average TQ. Same as average HP applied to TQ.

Cm3 (displacement). This field is used in "displacement correction" option (roller inertia + rolling parts of the vehicle). It can be changed after the dyno run is done (key F2 or double click)

I.eq. (Equivalent Inertia). This value is added to the inertia of roller when "displacement correction" option is checked).
There is a file: "inertia.ini" that stores all displacement and inertia values used in this option. The user can modify this file.
It can be edited.

KMH. Maximum speed of roller during the test. It can be changed to MPH in configuration window.

Roller RPM. Maximum roller speed during the test in RPM.

Engine RPM. Maximum engine speed during the test in RPM. It may be wrong if some spikes has been read from the ignition.

Ratio (RPM/KMH) (old). This field is used in the program to draw the horsepower vs. engine RPM. Its only recommended for vehicles with manual gearbox. The formula is: "engine rpm / km/h", i.e.: if vehicle with the last gear set is running at 200 km/h and its engine is at 12000 RPM, it will have a ratio of 60.
Also, ratio value can be calculated if ratio between gears and wheel are known. Usually ratio value is calculated by the program automatically, when ignition pickup is used. The program does a histogram from engine rpm/speed values and takes the most important value for the ratio.

Ratio. In current version, ratio formula is always "engine rpm / roller rpm", but the old value is maintained for compatibility.

Ratio button, when you edit the ratio value, this button is shown. By pressing it automatically does a histogram between "engine rpm / roller rpm" and it puts the calculated ratio into the ratio box. It can be used if was input a fixed value when doing the dyno run, but you are not sure about the value is right.

Temperature, Humidity, Pressure. Weather conditions are stored with the dyno run when is done. They are important because "temperature correction" option uses them. If changed after doing test, HP and TQ values will change too.

Correction factor. Depending on the chosen correction type, the program will calculate automatically this value. This value can be edited, and once you have changed it, the program won't recalculate it again. But if you want the program recalculates it, you only have to delete the number and press enter, then the program will calculate it again as a function of temperature, humidity, air pressure and correction type.

Correction Type. There are several correction formulas available:

- Blank (none)
- ISO 1585
- SAE J1349
- DIN 70020
- JIS D1001
- EC95-1
- *EWG 80/ 1269*
- FIXED

The program will use the correction type of the configuration window as default, but you can change it after the test is done

Time offset. This value has been added to the dyno run to enable comparison between tests when graphs are displayed vs. time, because the starting point of each test is not always the same. By changing this value all the test will be displaced later in time (positive values) or displaced before in time (negative values)

Comments. Comments are stored with the test. If editing the comment there will be displayed a button at the right of the box of the comment (...). By clicking the button it will show a window in which comments can be written in several lines.

Date / Time when the test was done.

Weight of vehicle. This field is only informative, but could be used for acceleration calculation purposes in future.

Channels recorded in the test. For example: 01AJ: 0-roller, 1-engine RPM, A-thermocouple, Jlambda.

Diameter (front) of the roller used on the test. The program uses it when calculating HP and TQ. It cannot be edited.

Diameter 2 (rear) of the roller used on the test. The program uses it when calculating HP and TQ. It cannot be edited.

Number of teeth (front) used on the test. The program will not use it after the test is saved. It cannot be edited.

Teeth (rear) used on the test. The program will not use it after the test is saved. It cannot be edited.

Prescaler used on the test. The program will not use it once the test is saved. It cannot be edited. For SP5 prescaler is always 1.

Inertia (front) of the roller / flywheel. The program uses it when calculating HP and TQ. It can be edited if you have entered it wrong.

Inertia 2 (rear) of the roller / flywheel. The program uses it when calculating HP and TQ. It can be edited if you have entered it wrong.

Recording (samples) taken by the SPx unit for the main channel.

Time spent on the dyno run. This **value has no relationship with the engine acceleration.** You can do a test of 5 seconds and then wait 30 seconds during coasting phase before stopping the test, and then the test will be 35 seconds long.

Full Path. Full file name and path of the test.

SW Date. Date of the software version used for recording the test.

FW Version (SP5) Firmware version number of the device used for recording the test (SP5 only)

SPx Config. Summary of all SP4 or SP5 specific configuration, including load cell, PID settings, ramp rate, etc.

SPx device. DAQ type (number) used for recording the test (1, 3, 4, 5)

Test Mode. 0 = inertial, 1 = steady, 2 = ramp, 3 = fixed brake, 4 = sequencer

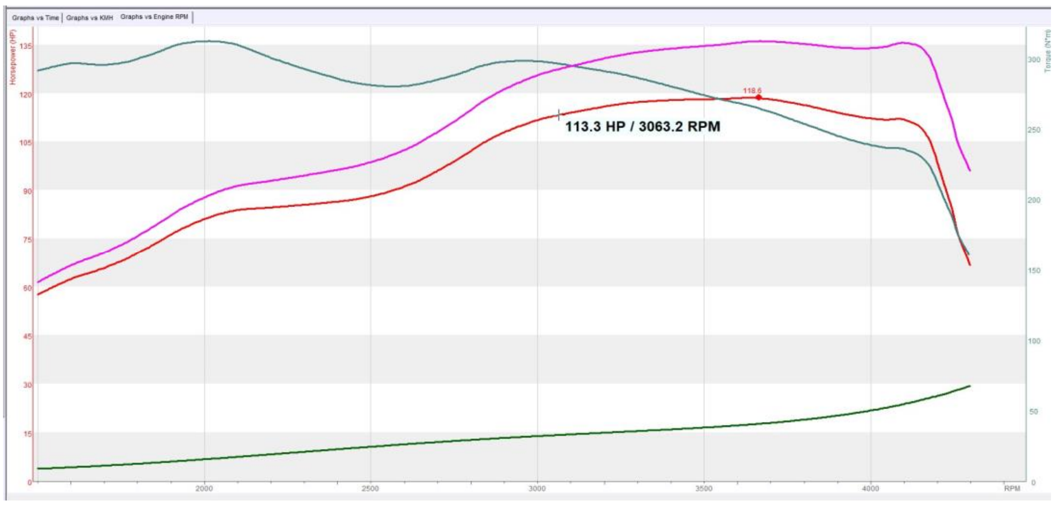
WD mode (wheel drive mode): 0 = front, 1 = rear, 2 = AWD

~~**Class of dyno** where the test was done (vehicle or engine).~~

Changed. It will be ‘*’ if the test was changed. If using “automatic saving” the test will be saved and this filed will be blank again.

2.12 Graphs Area

In this area are shown the curves from the channels of the different tests loaded in memory (power, torque and rpm).

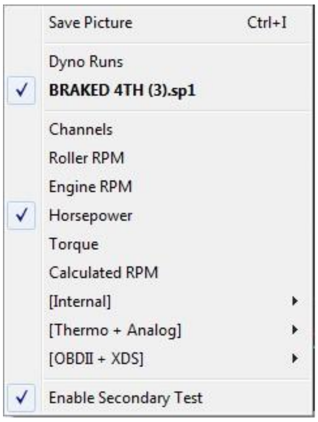


Most scales are shown at the left side graph area, but a few of them such as torque or load cell are shown at the right side. The scale showing side can be configured at channels configuration window.

X axis at the bottom shows the selected scale (time, roller RPM, km/h or engine RPM)

The scale from the **selected channel** (torque at the example) is displayed to the right side, close the graph area. Channels colour could be grouped by test (all channels same colour for each test), or by channel (all tests have same colour for each specific channel)

To show/hide any test only it is needed to click over the first column on the list of tests at the desired test.



By **right-clicking** over the **graphs area**, a list with the loaded tests is shown, this list also includes the channels from the active test. Note that in this version some special groups have been defined to hide the high amount of channels available.

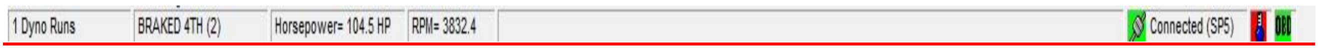
You click over a test or a channel to change the selected test or selected channel.

save picture option has been added. The same as on file menu. **Enable Secondary Test**, option has been replicated (same as on configuration / options)

2.13 Graph movig / zooming

Zoom can be controlled by using the mouse wheel, or the + and – lens in the tool bar.
The user can also change graph position by dragging the graphs area with left mouse button.

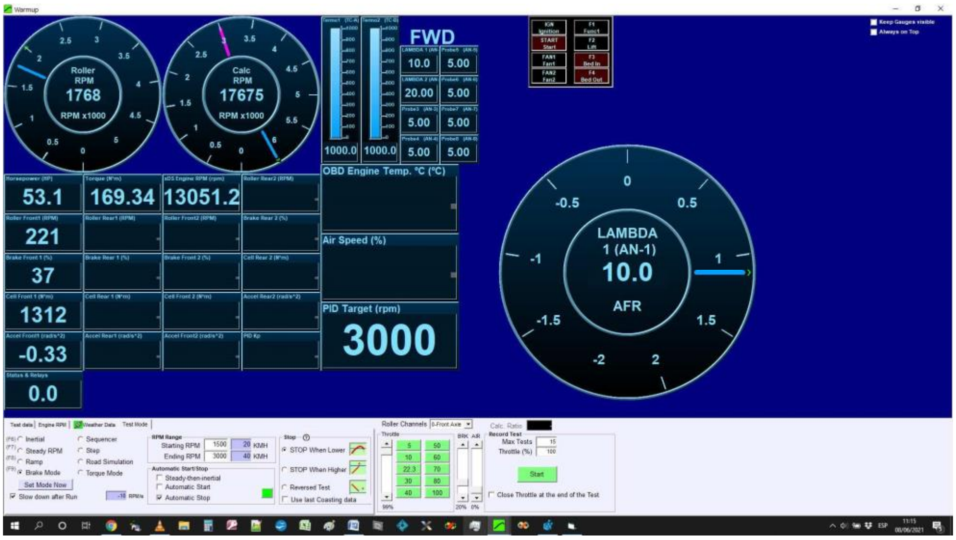
2.14 Status Bar



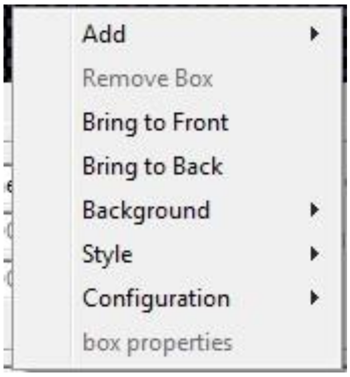
- This area shows:
- Number of loaded tests
- Name of selected test
- Name of selected channel,
- Values from selected channel, while the mouse moves over the graphs area,
- Status messages,
- Whether SPx module is connected or not.
- Weather Station Status
- OBDII Interface Status
- xDS Interface Status

3. GAUGES WINDOW

3.1 Gauges' area.



This window is user configurable. The user can add new controls: Gauges, Thermometers, Numeric boxes or Scroller type windows. If you right click over any control a popup menu will appear.



Options are:

- **Add new Control:**
  - o Gauge,
  - o Temp,
  - o Box,
  - o Scroller

  Once the control is on the screen, the user can move it to the desired position, and change its properties, and assigned channel.

- **Remove Box:** user can remove any of the current controls on the screen.
- **Bring to Front:** user can move a control over all others on the screen.
- **Bring to Back:** user can move a control behind all others on the screen.

- **Background [NEW]:**
  - **Default** (carbon fiber effect)
  - **Plain colour:** will show a colour selection window
  - **Bitmap:** allows to load a BMP file for the background

- **Style:** It changes the default colours for all controls

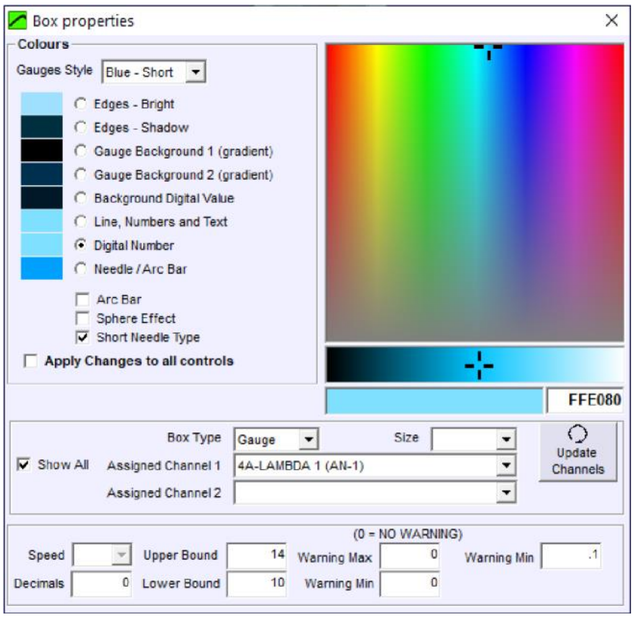
- **Cyan**
- **Yellow**
- **Blue**

- **Configuration: Open / Save.** It allows to save the current layout of Gauges window, and load it from a file

- **Show Peak.** This option will show permanently the peak values for all controls. Clicking it again will go back to the current values.

- **Reset Peak.** The peak value mark will start decay automatically after 30 seconds (configured in advanced options), but this option allows to reset the peak manually, for instance when the time is set very long.

- **Box properties:** with this option a properties window will be shown. This window lets you to change certain data from the control.



In this window user can change the control type (gauge, box, thermometer, scroller), the size of the control, the colour used for numbers, the assigned channel (1), the second channel (only for gauges and scroller), the upper lower bounds (special for gauges and scroller), decimals places.

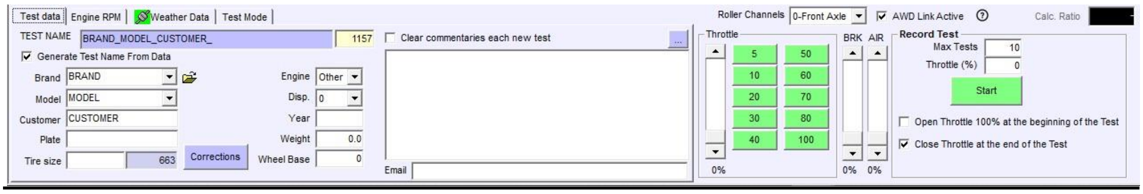
In addition controls implement a warning mechanism, if “warning max” and “warning min” fields are filled, they will detect when its channels it is out of limits and will blink in red for “warning max” and in blue for “warning min”

Note that not only SPx unit channels can be also added to Gauges Window, but also channels from: **Calculated channels, Weather Station, OBDII, xDS interface, CAN interface, etc.**

3.2 Test data area

This window is used to enter the test data and to setup the way the test will be done.
In the current version it has been splitted into four tabs to group the data by its function and to allow more data and options are available.

3.2.1 Test Data



- **Test Name,** this name will be the same that it will be saved to disk. Name will be “incremented” every new test (TEST_001, TEST_002 …)
- **Customer, Brand, Model, Plate, Year,** these are informative fields, but they can be used to **generate the filename automatically** from them, if the “**Generate Test Name From Vehicle Data**” option is active.
-  **“Folder”.** This option can be used to create a folder tree structure automatically using the brand, model, customer, plate information. One folder for each field.
- **Tire Size Tool.** This field will use the tire description (for instance **“185/55/14”**) to calculate the tyre diameter (560 mm) which is used in HUB dynamometers to overwrite the “roller diameter” fields in the test, so the calculated speed is the actual speed of this car in the road (according to the tire size). Tire size can be used to calculate the actual **Wheel Torque,** using a calculated channel.
- **Tire Diameter.** It is provided by the Tire Size Description “185/55/14” format
- **Engine Type:** It is an informative field, may be used in the future for a default setup according to the engine type, but still are many variants (petrol car, motorcycles, kart engines…)
- **Engine Displacement,** the software can use an inertia table (engine displacement vs inertia) to add some inertia to the test if this compensation is enabled. **This method was used in light dynos, but it is no longer recommended.** It is better to use the Engine Inertia field instead.
- **Equivalent Inertia,** this inertia value is added to the dyno's inertia in order to compensate the inertia from wheels, gearbox, etc.
- **Engine Inertia.** As engine has some inertia and normally runs at higher speeds than the rollers / brakes, its effect can be noticeable in some cases, especially in lightweight inertial dynos and when using short gears. For instance a motorcycle engine can have 0.05 – 0.1 kg*m2 (aprox), while a car engine can have 0.15 – 0.25 kg*m2 (or more). This is especially noticeable when comparing gears.
- **Weight,** is an informative value, it is not used on calculations.
- **Comments box:** user can fill several comment lines on this box for each test
- **Clear commentaries each new test,** the program will keep the comments from the last test by default. With this option you can clear them automatically.

- **Email.** It is an informative field, but could be used by an external tool to send each test to its customer.

3.2.2 Engine RPM

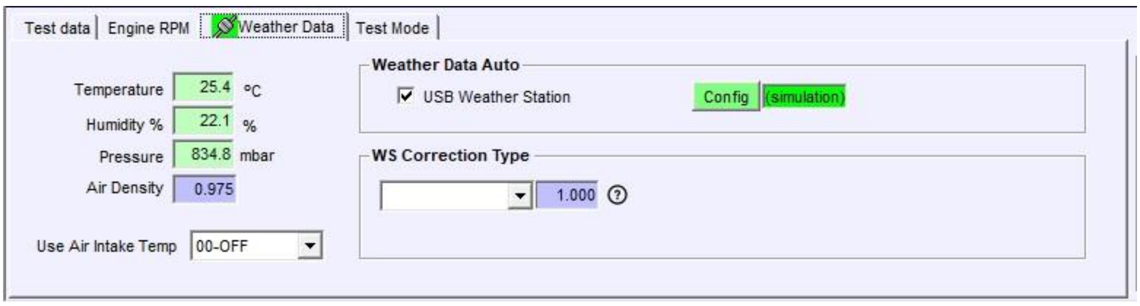
Sportdyno and SPx use the **ratio** value for the following functions:

Estimation of engine RPM in SP1+, SP4, SP5, SP6 for speed control
X-axis when drawing graphs vs engine RPM
Torque at engine calculation since torque is measured at roller but normally it is higher than at engine due to the effect of gearbox and transmission

Sportdyno provides the following methods to find out the ratio value:

- **Using RPM Clamp**: This is the most automatic way to get the ratio, but it is not recommended for braked modes. When accelerating, Sportdyno will use the Engine RPM channel to calculate automatically the Ratio value while the "update" button is enabled. With braked modes it can have potentially unexpected results, then it is better to click on the "update" button, perform a light acceleration so the ratio value and then **disable the "update" button,** so the ratio is no longer recalculated during braking.
- **Use OBDII or xDS data.** Both car ECUs through OBDII or motorcycle ECUs through xDS links (Suzuki, Honda, Kawasaki) provide accurate engine RPM data. Sportdyno can use this data to find out the ratio value. The ratio will be updated only if the **"update" button** is enabled.
- **Fixed Ratio:** Use this mode if the Ratio value is known (for instance on engine dynos using sprockets), or after determining Ratio using the Ratio calibration Window.
  - **Simulate RPM:** as most times that Fixed Ratio is used, Engine RPM channel is not available, then this option is used to display the calculated RPM, which are the same that SP1+, SP4, SP5 and SP6 use for the speed control (speed control is not performed using Engine RPM)
- **Test Ratio:** it opens the Ratio Window to determine Ratio value, and then it comes back to Gauges Window.

3.2.3 Weather Data



- **Weather conditions:** Air Temperature, Humidity and Pressure. These values are used to correct horsepower and torque.

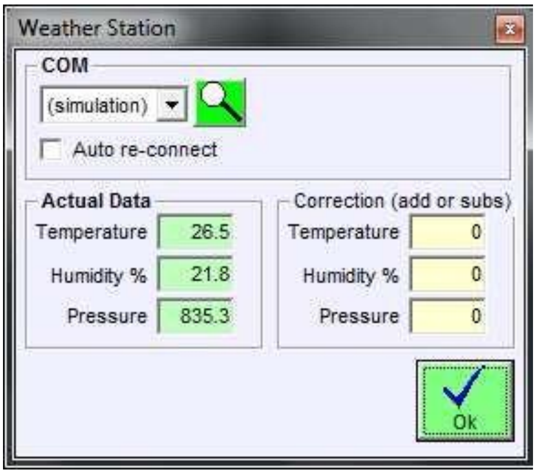
- **Air Density.** It is calculated by Sportdyno, just for information purposes.
- **Air Temp from OBDII (air intake).** If air intake PID (95h) is **available and selected** in the OBDII window, the SW will take this value to overwrite the Weather Station temperature, as normally the engine intake is at a higher temperature than the room. It also allows to choose any DAQ's analog channel (41h – 4Dh)
- **Correction type.** There are several compensation methods available:
  Blank (none)
  - ISO 1585
  - SAE J1349
  - DIN 70020
  - JIS D1001
  - EC95-1
  - *EWG 80/ 1269 (not fully implemented)*
  - FIXED (here the user can set the fixed correction factor)

By default the software will take the correction type from the configuration, after that, the user can change it for each individual test. The program shows in the grey box the current correction factor for the current weather conditions.

- **Weather Data Auto / External USB Weather Station.** This option allows automating the weather data acquisition. By default data has to be entered by hand, but by using our USB Weather Station the weather data can be acquired automatically. Data is shown in real time (if enabled)

When using USB Weather Station press Config button to open the Weather Station window and perform n automatic search for its virtual COM port.

- **Config button → Weather Station Window**



- **COM:** Virtual COM port used by the USB Weather Station, it is normally selected automatically using the **"magnifying glass" button**, but it can be changed by hand.
- **Auto Re-Connect**: The default option is that the program will reconnect automatically if the weather station is disconnected from USB port and then connected again. For compatibility reasons with old devices it may be necessary to disable it.
- **Actual data:** real time data from the Weather Station
- **Correction:** value to be add (or subtracted) to Temperature, Humidity and Pressure readings. **Keep to zero for normal operation**

3.2.4 Test Mode

3.2.4.1 Inertial (brake off)

With SP1 only inertial mode will be available (inertial mode is also available on SP4 / SP5), Inertial mode corresponds to the **Idle** mode of SP4 / SP5 (brake OFF).

3.2.4.1.1 Steady-then-inertial. [NEW]

In some cases user needs to have the engine steady and full loaded before starting an INERTIAL test, then enable this option. The SP4 / SP5 will remain in steady mode before starting the test (for instance to load the turbocharger), and when the recording is started it will perform an inertial test.
Note: as the brake is still braking for the first few instants test (or more) due to its remaining magnetic field, the test is computed as a Steady Test, and Load Cell is considered as if it was a braked test.

3.2.4.1.2 Automatic Start / Stop Mode

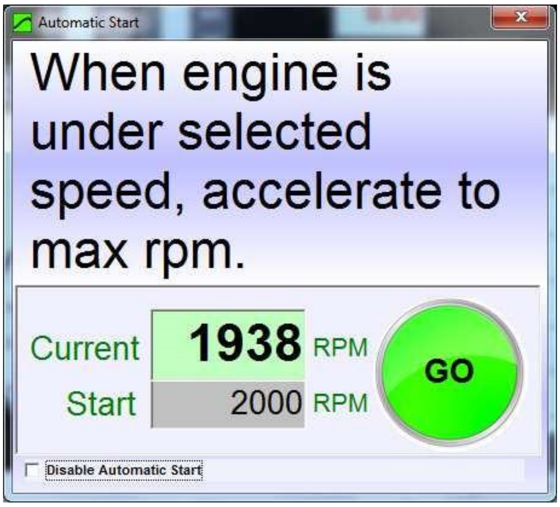
When doing inertial tests, certain automatic Start / Stop functions are available:

Speed, Engine RPM: User can enter the automatic Start value and **automatic Stop value** in **Speed units or in Engine RPM** units. But always the data is calculated from the roller rpm channel with ratio (if needed) because it is a much more accurate channel than Engine RPM channel. Thus ratio MUST be a valid value (you can use the RPM clamp or the fixed ratio modes)

3.2.4.1.3 Automatic start

If this option is selected, the dyno run will start when Engine RPM is greater than the value set at the right (ex. 2000 rpm)

Mode of operation: when button is pressed, "gauges" window will appear as usually. If you press again the button the “semaphore” window will appear (with automatic start activated). This frame give the following direction: "accelerate to max rpm".



If Engine RPM is higher than the starting rpm value the "semaphore" will be red, and dyno run won't start. When engine downs to a lower rpm, the "semaphore" will be green. Then, when you give full throttle and RPM are higher than the starting rpm value, dyno run will begin.

3.2.4.1.4 Automatic stop

Here the stop rpm value is entered. There are two possibilities to determine when to stop:

- when engine has reached the stop value, or
- when the test is in the losses / coasting stage and engine reaches down the stop value.

3.2.4.1.5 Stop Mode

In vehicle dynamometers, when doing a dyno run, user has to accelerate the engine near its maximum rpm, then clutch is pressed to leave the roller decelerate slowly (coasting phase), and when roller speed is lower than the "ending rpm" value (applying ratio) the test will stop automatically. Here user will use "stop when lower" stop mode.
In engine dynamometers (if no clutch is available), when accelerating the engine near its maximum rpm, user will finish the test as soon as the selected max rpm value is reached. Here user will use "Stop When Higher" stop mode.

These modes are provided here regardless the type of dynamometer so you can choose the mode you need for the tests you are doing.

3.2.4.2 Steady

This mode is only available with SP4/SP5 units.

When starting the test, it will enter automatically the SP4 / SP5 in Steady mode (not when choosing the option), and will update the RPM Target when changing the "Target RPM" box, or when using the page up and page down keys.
When a test is recorded in this mode, target rpm remains constant for the whole test.

Manual Step Test: It is possible to use keys PG DN and PG UP to change target RPM during the recording of a steady test, but (automatic) Step Test is recommended over this manual way.

3.2.4.3 Ramp

This mode is only available with SP4 / SP5 unit.

When test is started, it will enter automatically the SP4 / SP5 in **Steady Mode**, and will update the RPM Target when changing the "Min RPM" box, or when using the Page Up and Page Down keys. This lets you to get the engine steady and full loaded **before** starting the recording. The user should set the Ending RPM and Test Time before starting the test (Accel Slope is calculated from these 3 values).

Do not hold at Max RPM. For most cases, the ending RPM only tells the software where the ramp ends, but it is preferable not to hold the engine at that value to avoid strange measurements when load changes from partial torque (during ramp) to full torque (during holding). Only for certain engines in which exceeding the max rpm can cause a damage it can be interesting to hold the engine at the max value.

Time / Acceleration setting. Ramp mode is based in an acceleration slope, this slope can be defined as a time (from starting rpm to ending rpm), or as a slope rpm / sec.

Slow Down at the End of the Test. This option uses some braking action (percentage) to decrease the roller speed until it reaches the starting Min RPM. It is useful on Engine Test bed specially when there is a clutch between engine and brake (typically with 2 strokes), but also on heavy car dynos, because braking the car (with the car's brakes) can make it move backwards due to the inertia of the rollers.

"Stop when lower" and "Stop when higher" work in the same way as on inertial mode. **After** the test starts, the program will enter automatically the braked DAQs (SP1+ to SP6) in **Ramp** (Sweep) Mode in order to start to increase the Target RPM as the engine accelerates.

Use Last Coasting Data [NEW]. Specially in hub dynos, in which the coasting phase is difficult to get correctly (due to the parasitistic torque when the brakes disconnect after the clutch disengagement, and also due to the low inertia which cause a sudden loss of speed, and thus the coasting graph is often half of the whole range), this option allows to perform an initial "inertial" test (brakes OFF) with a clean coasting graph (even if the power section is not useful due to the lack of load), and then the data obtained from the **Coasting Polynom** can be used in the consecutive tests even if they have no coasting phase.
In the rest of the cases (rolling road dynos, or engine dynos) it is not recommended to use this option.
The way to use is is as follows:

1. Enable "Coasting Polynom" filter
2. **Disable** "keep last coasting data"
3. Do a normal "inertial" test: acceleration + coasting (even if the power graph is not useful due to the lack of load)
4. **Enable** "keep last coasting data"
5. Do ramp tests as usual, even if they have coasting, the SW will use the coasting formula from the first test ("3.596254; 3.200022E-03 format")

3.2.5 Common area

Throttle slide bar [NEW], this allows to control the throttle while preparing the test (envisaged for Engine Test bed dynos)

Brake slide bar [NEW], this allows to control the brake either after a dyno run (to slow down the roller), before a new run, or just to test the brake.

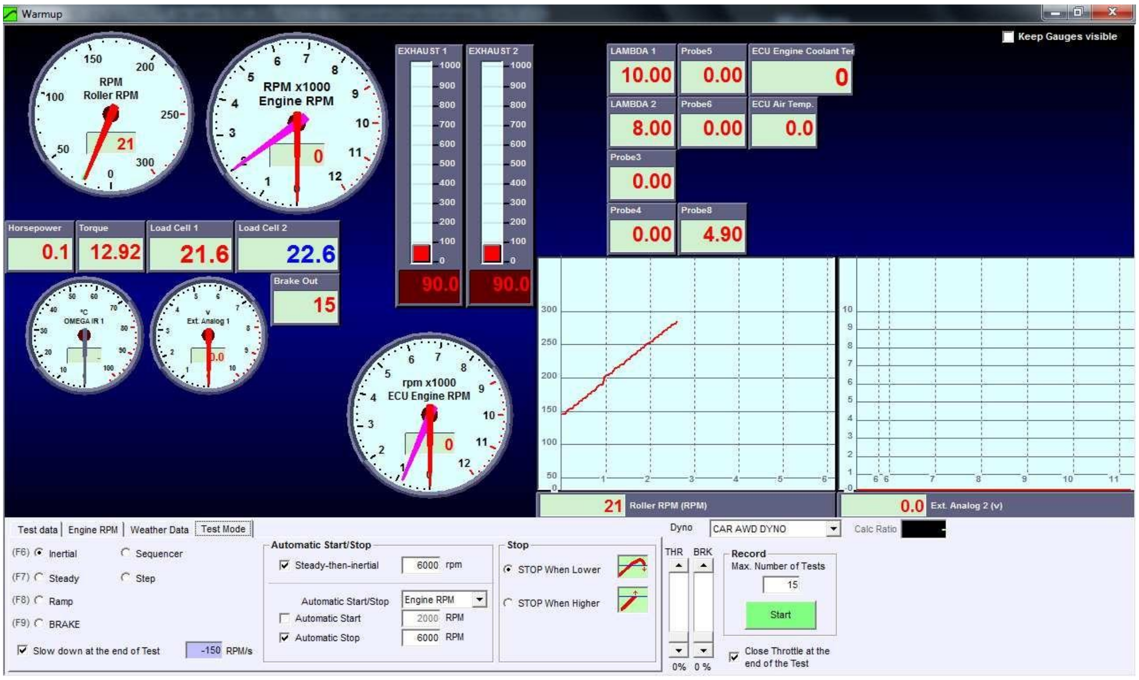
Max number of tests, (in older versions: "remove last tests"), this box (at the bottom-right side), indicates to the program the maximum number of dyno runs loaded at memory each time a new dyno run is done, it will remove the older tests if there are more. It is useful when a lot of test are being done, for example to allow one alone person to use the dyno. It prevents to accumulate a big quantity of curves at screen.

Start Button, it will start a new test (see next section 4 "How to do a dyno run")

Close Throttle after the end of the Test bar [NEW]. This option automatically closes the throttle when the test recording ends. It is envisaged for Engine Test bed dynos.

Calc Ratio. For "using clamp" and "use OBDII / xDS" modes, this box will show the real time calculated ratio value.

4. HOW TO DO A DYNO RUN?



F5 key has the same effect as the start/stop switch provided with some kits

Test phases are as follows:

4.1 Gauges Window

By pressing F5 key or the Start/Stop switch, Sportdyno will show the Gauges Window. This window shows all channels in real time: roller speed, engine rpm, thermocouples, analog channels, and also all external data sources (OBDII, xDS, CAN, EGA, Infrared sensors, etc).

This window is used to enter:

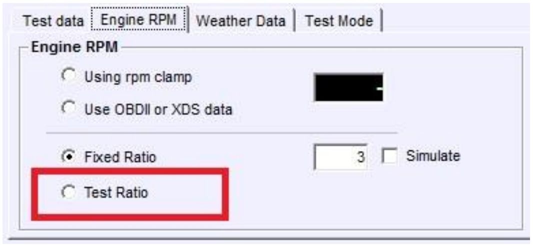
- Test name and vehicle data
- Engine RPM and engine capturing options (clamp, OBDII, etc)
- Weather conditions / Weather station
- Test mode: inertial, steady, ramp, fixed brake, step test, sequencer, etc

All these options have been described at section 3.2 (Test Data Area)

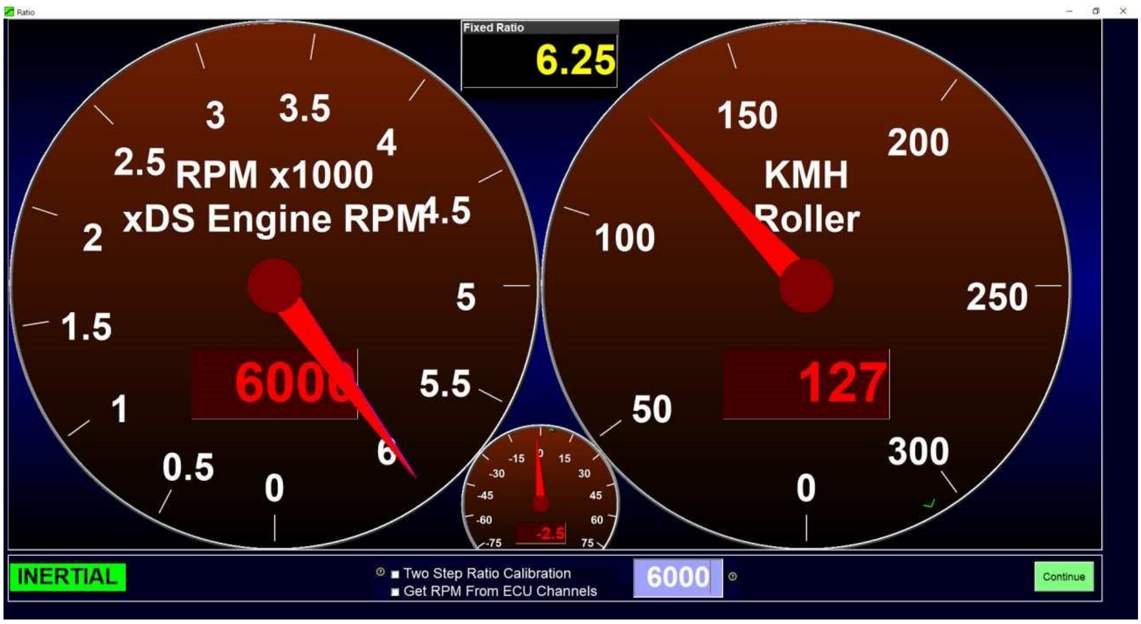
Once the user has filled all test data, F5 key or Start/Stop switch has to be pressed to go to the next phase, which depending on the ratio mode will be the Ratio Window, Semaphore Window or directly the test recording.

Note 1: activating the option **"Keep Gauges Visible"** will keep this window when the test is started
Note 2: In this version, for ramp mode, the user **does not have to accelerate** to keep the engine steady during Gauge Window stage (as for older versions)

4.2 Ratio Calibration Window



When "Test Ratio" is selected (or by pressing F7 key at Main Window) Sportdyno will show this window after the Gauges Window to start a process to determine the ratio value on a given vehicle when Engine RPM channel is not available.



Ratio is the relationship between Engine RPM / Roller RPM. This value is used for several functions in Sportdyno:

- Speed control (referenced to engine RPM)
- Graphs X-axis in "graphs vs Engine RPM" mode
- Torque at engine calculation (torque is actually measured at roller)

When ratio value is unknown for a vehicle, Engine RPM channel is not available or difficult to record (for example diesel engines), or it is noisy and inaccurate, or OBDII data is not available, then it is better to approximate ratio value with this method based on the observation of the vehicle's tachometer.
Test Ratio Window can also use OBDII data (or xDS data) to determine the ratio at a certain RPM value, in a more deterministic way than if using OBDII or xDS in real time mode, but both ways are valid.

The procedure for determining the ratio consists on setting a certain reference RPM value on this window (say 2000 rpm for cars) and drive the engine to the same value using the tachometer as a reference.

> Note about gear selection: in general it is recommended to use last gear or last gear -1 for recording the test and thus for determining the ratio, but normally in car dynamometers it is recommended to use 4th gear for 5 and 6 gearboxes.

When vehicle tachometer matches the reference RPM, the roller will run at a certain speed (for example 600 rpm), and ratio value will be **= fixed rpm / roller rpm** (2000 / 600 = 3.33 on the example). Then, when pressing "continue" or "start/stop" button, this value will stored to be used for the test recording.

Get RPM from OBDII Channels. This option allows using the Engine RPM PID from **OBDII** or from xDS link (Suzuki, Honda, Kawasaki) to get the actual Engine RPM value, instead of using the Vehicle's Engine RPM gauge. This provides more accuracy in the ratio calculation, but it is still recommended to keep a steady speed on the vehicle, as OBDII has a small delay that can be translated to a small error in ratio if both speed and engine RPM are changing.

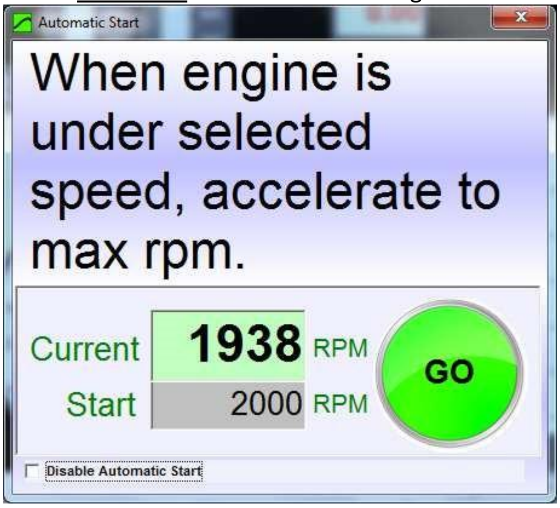
Two Step Ratio Calibration:

- **Step 1: calibration under no load.** It is performed as usual, the dyno will be in inertial mode (brakes OFF) and the ratio will correspond to the gearbox ratio * wheel vs roller diameter ratio. The software will give the suitable instructions when going to the step 2.
- **Step 2: Calibration under load.** The software will command the steady mode at the reference speed (say 3000 RPM), then the operator will accelerate. If the rollers cause some deformation in the tires, the apparent diameter will be lower and the wheels (and engine) will reach a higher speed than in no load condition. This new (higher) ratio value is useful to make the X-axle match the actual engine RPM channel. It is a common issue that twin roller dynos show less calculated engine speed than the actual value due to this tire deformation.

Finally the software will give instructions to **release the throttle before removing the steady mode** (to avoid an uncontrolled acceleration)

4.3 Semaphore Window

In both cases: when using automatic start in inertial mode or ramp mode Sportdyno will show the semaphore window. This window shows current calculated RPM and the starting RPM value.



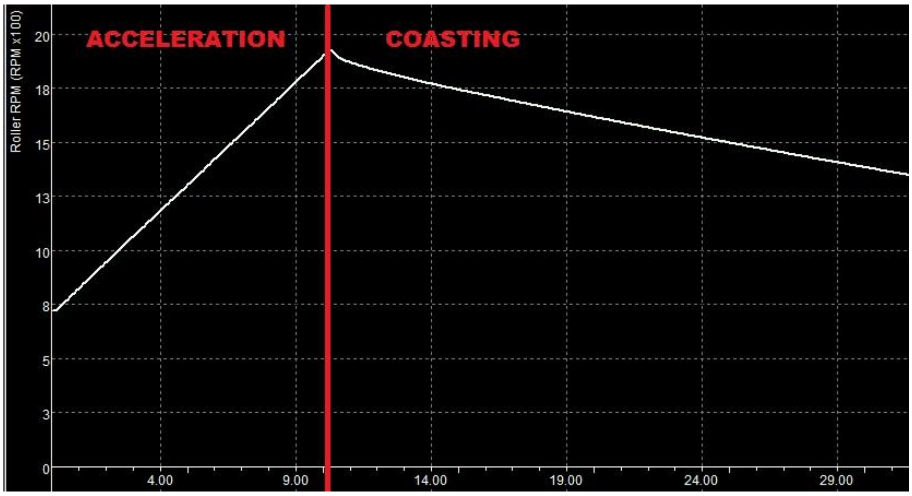
- In Inertial mode + automatic Start, the starting value determines when the test is going to start. Thus as soon as the engine RPM changes from "lower than starting value" to "higher than starting value" the test recording will start. Note that if the initial engine rpm is higher than the starting value the semaphore will be red.
- In ramp mode, the Semaphore Window also sets the steady mode to reach a steady condition in the engine at the starting RPM before starting the test recording. This was done in previous versions at Gauges Window, but now it has changed to this stage.

4.4 Test Recording

At this stage Sportdyno will start recording of test. Test normally consists of two phases controlled by the dyno operator:

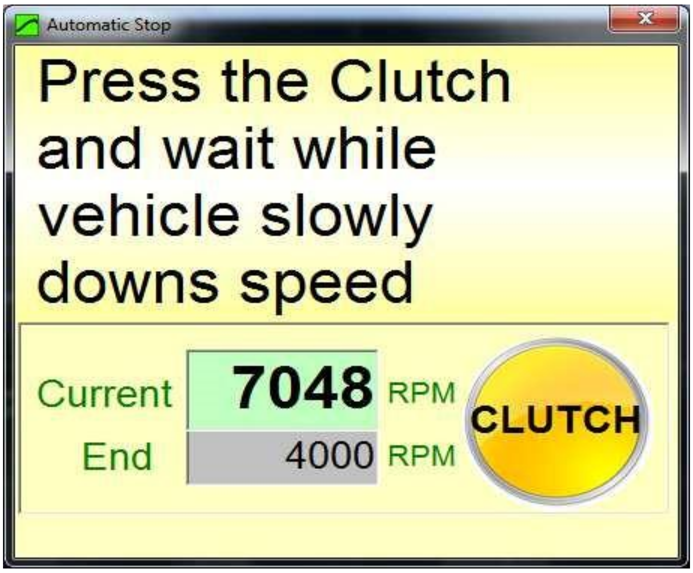
- **Acceleration**: recording the maximum performance of the vehicle until its maximum RPM (or close to max RPM) at full throttle

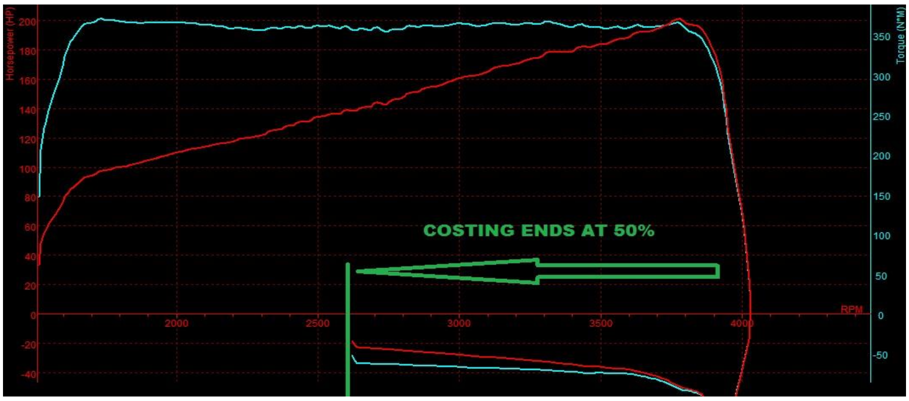
- **Coasting:** if clutch or N gear are available, when engine reaches its maximum speed (or close to it), dyno operator has to press the clutch and leave the vehicle run free while losses speed slowly.



- In **inertial mode + automatic stop** or **ramp mode,** when the ending RPM is overpassed, Sportdyno will show a warning message to tell the operator to activate the clutch.

Test recording will automatically stop at the 50% value between starting speed and ending speed. This 50% value can be changed at configuration.

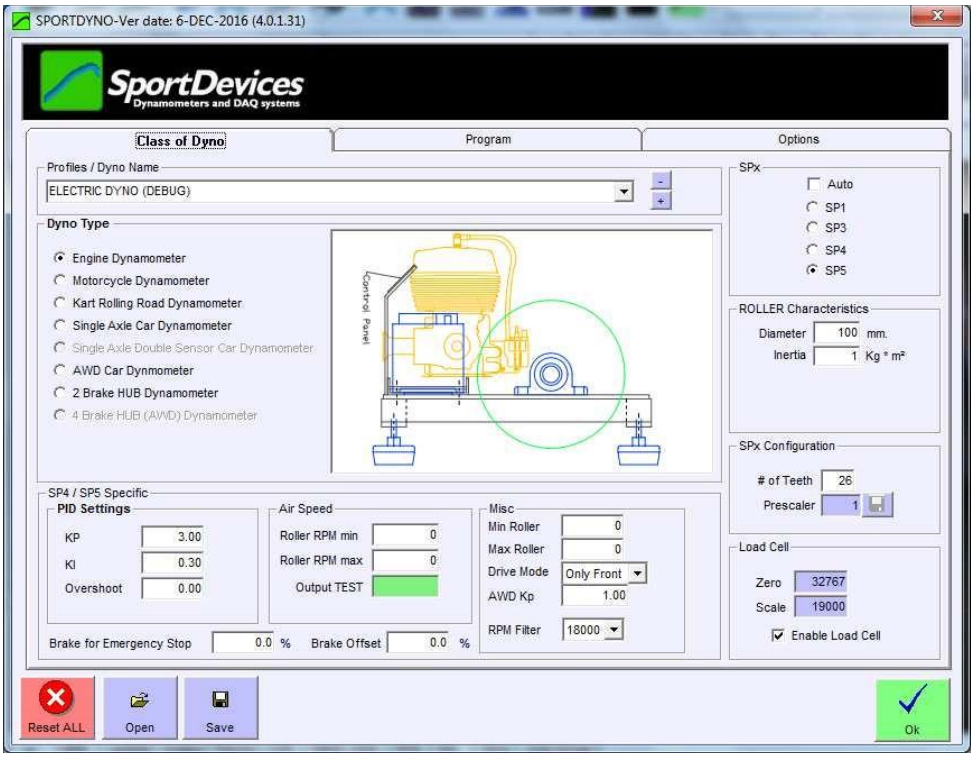




5. CONFIGURATION

At main menu options / configuration the program will show this window. There are three sections (tabs):

5.1 Class of Dyno



5.1.1 Profiles / Dyno Name

This box allows setting the dynamometer name. It also enables using **several profiles** within the same program and electronic unit.

There are two buttons: **'+'** and **'-'**, in order to add a new profile to the list, and to remove the current one.

5.1.2 Dyno Type

Current supported dynos are listed in this area. Some of them are equivalent (motorcycle = single axel car dyno), but are listed for coherence.

Vehicle dynos can use the "displacement correction". Also, losses on transmission are calculated.

5.1.3 SPx Device.

By default "**Auto Detect**" option is active, and then Sportdyno identifies the SPx device type. Nevertheless, user can select one specific SPx unit.

5.1.4 Roller Characteristics

Diameter and inertia, these data are fixed for each dyno, user normally sets it once, and does not change it afterwards. Roller diameter affects to speed measurement, and Inertia affects to Horsepower and Torque measurements (in a linear way).

For AWD operation two inertia values and two diameters have to be set. Current version needs that all rollers have the same diameter.

5.1.5 SPx Configuration

We recommend using a gear tooth between 8 and 150 teeth.

Number of teeth: number of teeth/pulses used on roller or flywheel. This gear could also be used for the starter motor.

Prescaler (SP1, SP3, SP4): this feature adapts the digital input (up to 15 KHz) to the capacity of **SP1 to SP4** units (up to 1 KHz). Depending on the number of teeth, gear tooth will generate a different frequency at the hall sensor, and then a different prescaler has to be configured (the program will chose on by default)

Configuration	*Minimum teeth*	*Maximum teeth*	*Frequency range*
Prescaler 1	1 teeth (60.000 RPM)	8 teeth (7.500 RPM)	0 to 1000 Hz
Prescaler 4	2 teeth (120.000 RPM)	60 teeth (4000 RPM)	0 to 4000 Hz
Prescaler 16	61 teeth (14.754 RPM)	160 teeth (5.625 RPM)	0 to 15000 Hz

SP1+, SP5 and SP6 have always Prescaler = 1.
From SP5 PCB v2.2, it includes a hardware prescaler to allow the usage of Encoders (up to 2000 pulses per rev). But then the number of pulses have to be divided, for instance for 500 PPR encoder, set prescaler 4:1 (at PCB), and pulses=125 (500/4) at Sportdyno.

5.1.6 Load Cell Zero and Scale fields.

These values are a copy from the ones at Load Cell Wizard. They are repeated here just to show how each Dyno Profile selector updates load cell data.

5.1.7 SP4 / SP5 Specific

Please refer to section 10.

5.1.8 Lower Buttons

RESET ALL (button). This option will erase all program configuration. This is useful when there is something that does not work and the user wants to go back to a safe configuration. Keep in mind that all different versions (changes on major number: 3.5, 3.6, 3.7, 3.8) have a different set of configuration at Window Registry, but between intermediate versions (3.8.27.10, 3.8.28.3, etc) configuration is shared

Open. This option will load a text file with the program's configuration.

Save. This option will save a text file with current program's configuration.

5.2 Test Options.

5.2.1 Tests

Max. Length: maximum time for data recording, in minutes.

Y axis position: percentage of area used for the positive part of the graphs. If you are using an Engine Dyno without clutch you may find interesting to use 90 or 95% of the graph for positive area (because you will not record losses at negative area), but if you are using a vehicle dyno, it is better using 70% to allocate the losses graphs. Default value is 70%.

Max Speed: This value is used for Roller RPM gauges, when in Speed mode. The program will set the maximum for all Roller gauges to this value (if more than one)

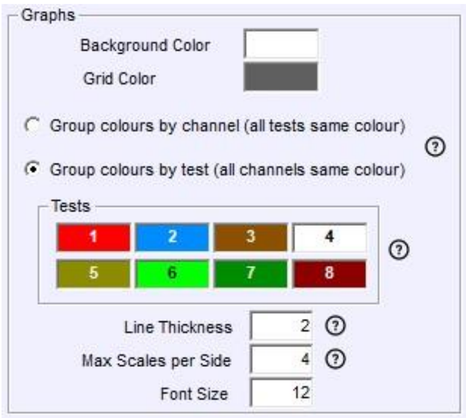
Max Roller RPM: This value is used for Roller RPM gauges, when in RPM mode. The program will set the maximum for all Roller gauges to this value (if more than one)

Max Engine RPM: This value is used for Engine RPM gauge. The program will set the maximum for all Engine and Calculated Engine gauges to this value (if more than one)

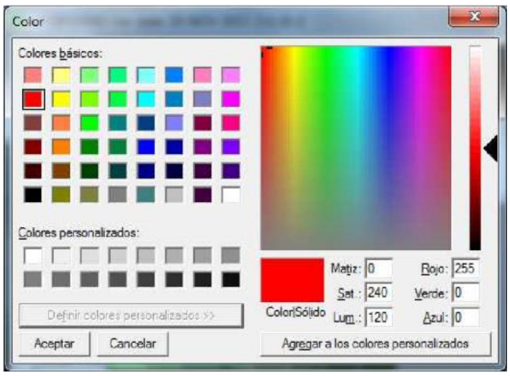
Auto saving: By default the program always save the dyno runs to the disk when a test is done. But it can be disabled. Later, the program will ask the user if he wants to save it to the disk (at program closing or when removing tests).

Create Backup Files: By default the program creates a backup file when a new file is being modified. It will rename the file to .spx_bak extension and will record the modified file with the modifications.

5.2.2 Graphs and Colors



Background Color, defines the background color in the main window. It can be edited by double-clicking over it and then a colour selection window will appear. Select a colour and press OK button.



Grid Color, defines the color used for the grid in the main window

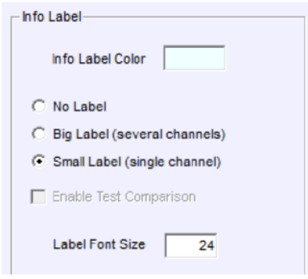
Color Group Mode:

- Group colors by channel: Each channel has a different colour, defined at channels window. And all tests use the same colours for the same channel.
- Group colors by test: Each test has a different colour, but all channels of each test have the same color. This mode is normally used to compare tests, and when only a few channels are active.

User can also modify the colors that will be used for each test.

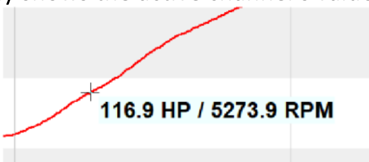
Line Thickness. Thickness used for the graphs at main window
Max Scales per side. By default the SW will show only 2 scales at each side, but it can be increased (although it will make the graph more confusing)
Font Size. Font used for the numbers and channel names in the main window.

5.2.3 Info label



Info Label Color: color for the label background
Type: The software provides two types of "tracking" over the graphs when moving the mouse pointer over them.

- None: no label
- Big Label: it is the same label as in 3.x and 4.0 versions. It is big and full of numbers. It is useful to check several channels at a time or for comparing between two tests
- Small Label: this new label only shows the active channel's value. It is smaller and cleaner.



Enable Test Comparison. When using the "Big Label" it will show the values for the active channels from the latest tests at a time and the difference between them

Label Font Size. Font size used in the label

5.2.4 Language

Language: current available languages are: **English, Dutch, French, German, Italian, Russian, Polish, Russian and Spanish.** These languages are stored on text files (*.lan) that can be edited by the user easily (with Notepad for instance). When language is changed, the changes will take effect when closing the configuration window.

Font: the user can change the Font used in the program, this is mainly interesting for languages that need a special charset as Russian Language.

Size: font size can be changed, but keep in mind that the space reserved for texts will be the same, so eventually the texts will not fit at their places.

5.2.5 Aux Torque. Torque Calculation

From this version, torque is always calculated at engine. The software calculates this channel from the torque measured at Roller, and uses the Ratio value to do this. Keep in mind that torque at engine **depends on the ratio value.** If Ratio is wrong for the dyno run, torque at Engine will be wrong too.

Torque at Engine normally is lower than torque at wheel due to gearbox, transmission and tire size, because torque is increased as RPM is decreased.
Torque at engine cannot be calculated on automatic transmissions.

Auxiliary torque channel:

- **None:** no aux channel is added
- **Torque at roller:** Sportdyno measures torque at roller (inertial and load cell). This mode is normally only useful to compare total torque with load cell torque.
- **Thrust:** It is a variant of torque at Roller; it provides the linear thrust or vehicle force over the roller. It could be used to calculate the capacity climbing capacity of the vehicle on a slope. It does not depend on ratio.
- **Uncorrected TQ.** As the default Torque is calculated at engine (ratio calculation and friction corrections), it cannot be compared with the Wheel Power anymore, then the uncorrected TQ (which only includes the ratio calculation, but not the friction) can be compared with WHP. This is typically used for the "magic" 5252 RPM crossing point.

5.2.6 Units

Power units. User can chose between HP mechanical (745 W), KW (1000 W) or HP metric (736 W) for power.
Torque: N*m, Ft*Lb (1 Ft*Lb = 1.355 N*m), Kg*m (1 Kg*m =9.8 N*m)

Speed: KMH, MPH (1 mile = 1.609 kilometers)

Temperature:

- Celsius, Fahrenheit (1 Fahrenheit degree= 1.8 celsius, Fahrenheit starts at 32º for Celsius=0º)

Pressure:

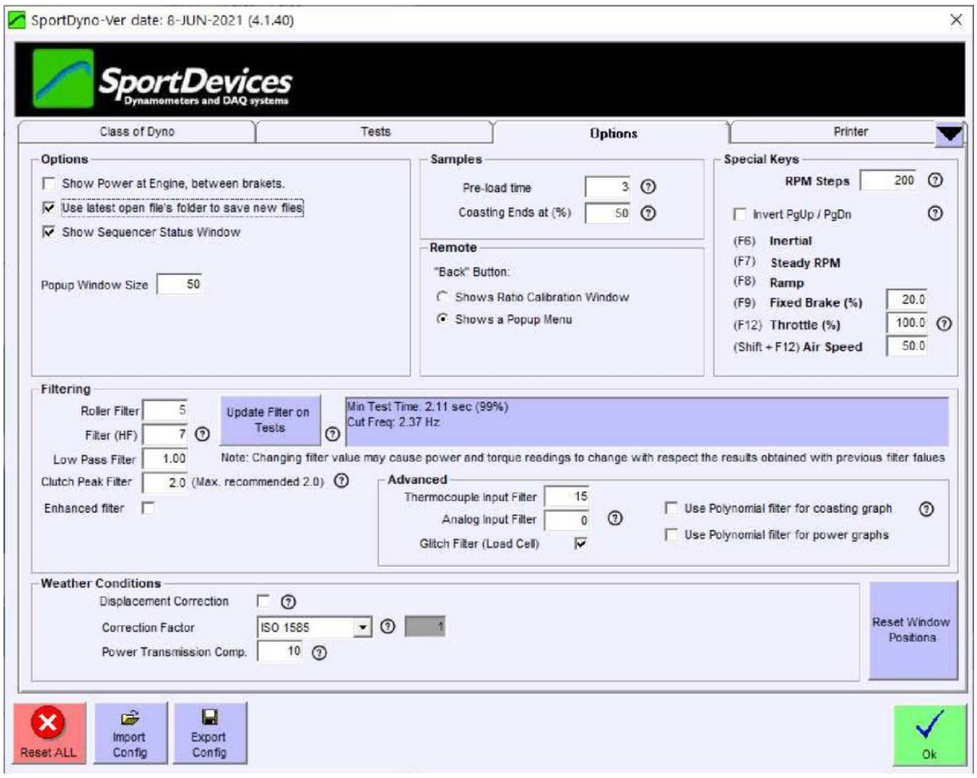
- Mbar / inHg (1 mercury inch = 33.8638 mbar)

Torque at Right Side: By default, the SW will show HP at left side and TQ at right side

5252 RPM button: this option configures the following options to allow that HP and TQ cross at the "magic" point of 5252 RPM:

- Units are set as HP for power, and Ft*Lb for Torque. Keep in mind that 5252 RPM crossing only happens with imperial units, with other units the crossing point changes
- HP and TQ channels are set to use the "Group 1". Channels using the same group share the same scale instead of that each channel has its own scale (depending on the channels peak value). If Power has its peak at 100 HP, then Torque channel will also use 100 Ft*Lb as maximum for its scale.

Options Tab



5.2.7 Options

Show “Power at Engine”, between brackets. If checked, the program will show the wheel power value, and power + losses between brackets. The same is applied to torque. Example: HP = 55.4 (67.9) / 9000

Use “Sum” method for losses calculation. There are two methods to calculate power at engine:

- **Peak Method:** Calculating the Wheel’s Power Peak value (for instance 100 HP at 5000 RPM), and then adding the losses for the same RPM point (for instance 20 HP at 5000 RPM)
- **Sum Method:** First adding power and losses sections, and then calculating the peak for the sum. For instance at some point wheels power is 99 HP, but losses is 22 HP, then peak for sum is 101 HP.

Both methods normally will **not** give the same result. This option is provided to use always the “sum” method, regardless of whether the graphs are displayed with the negative section, or are added in the screen.

Use latest open file’s folder to save new tests. This option when active changes the internal file path to the latest folder in which the user open some file. If not active path is not changed, and can be kept the same during all program execution.

Show Sequencer Status Window. During a sequencer controlled test (SEQ files) and a race-track simulation test (CSV files) a status window is shown at bottom-right corner. This option allows disabling it.

Popup Window Size. After the dyno run a popup window will be shown. This field allows to change its size (% with respect the main screen)

5.2.8 Samples / Recording

5.2.9 Special Keys

RPM Step. In Gauges and PID monitor windows, when the cursor is at Target RPM, the user can use Page UP and Page DN keys to quickly make this value to go up and down. This field determines the amount to increase/decrease the Target Value.

Invert PgUp / PgDn. With some keyboards it may be more intuitive use these keys in the opposite way.

F6- Inertial, F7- Steady, F8- Ramp, F9- Brake key (Informative) These keys can be used as a shortcut to enter each control mode at in main window, at gauges window, at PID monitor and during test recording.

F12-Throttle%. Throttle can also be set to a predefined value (say 80%) and 0%.

Advanced options. See section **5.4** (advanced options).

5.2.10 Filtering

Roller Filter. This filter can be used when the Roller signal is not stable and due to vibrations or imperfections in the gear tooth, then the speed signal has ups and downs. These oscillations will cause that in graph vs speed modes (Speed and Engine RPM) small loops will be shown in the graph caused by these changes on speed up and down. This filter only affects to graphs and speed/RPM calculations, it is not used for power calculation.

Filter (HF). This filter is applied to Power and Torque graphs in order to remove high frequency noise and low frequency mechanical oscillations. On large dynos (car), or dynos with high vibrations it can be also necessary to use the "Low Pass Filter" option.
Note that the program shows an informative window that explains for each filter setting what is the minimum recommended test duration (acceleration phase) in order to not lose information about power and torque. For instance for a filter of 19 (and Low Pass = 0) minimum acceleration time should be 3.47 seconds. If acceleration duration is below this time, then accuracy is not warranted to have less than 1% error (nominal accuracy)

Filter (Low Pass). This option is used for large dynos (car) or with high vibrations. And normally it is not necessary to be used on inertial dynos (as tests are shorter). It applies a second filter stage after the HF filter. Low pass filter works better for low frequencies (mechanical) vibrations. It requires longer tests. This makes it recommended only on braked dynos, and makes that minimum recommended test time is 10 seconds (for Ramp mode). As a general rule, the LPF filter shouldn't be higher than 1/10 of acceleration duration.

Update Filter on Tests. Tests hold the filter settings that were active when the test was recorded, these values should not be changed to preserve the original HP and TQ readings, but user can force the tests to be updated using this button.

Thermocouple input Filter. This value is used to filter the thermocouple inputs (8) with a low-pass filter at the input. Data will be recorded after the filter. The higher the value, the higher the filtering.

Analog input Filter. This value is used to filter the analog inputs (8) with a low-pass filter in the input. Data will be recorded after the filter. The higher the value, the higher the filtering.

Glitch Filter. This option will filter short glitches (spikes) in the **load cell channel.**

5.2.11 Corrections

Displacement correction. This is a correction based on the whole inertia of the vehicle and dyno (roller + wheel + transmission + gearbox) as a function of the engine displacement. If activated, this correction will be applied to all loaded tests. This option is not stored with the test, but with the program. There is a file **(inertia.ini)** that the user can edit to customize this assignation.

Correction type. There are several correction formulas available:

- Blank (none)
- ISO 1585
- SAE J1349
- DIN 70020
- JIS D1001
- EC95-1
- *EWG 80/ 1269 (not fully implemented)*
- FIXED (here the user can set the fixed correction factor)

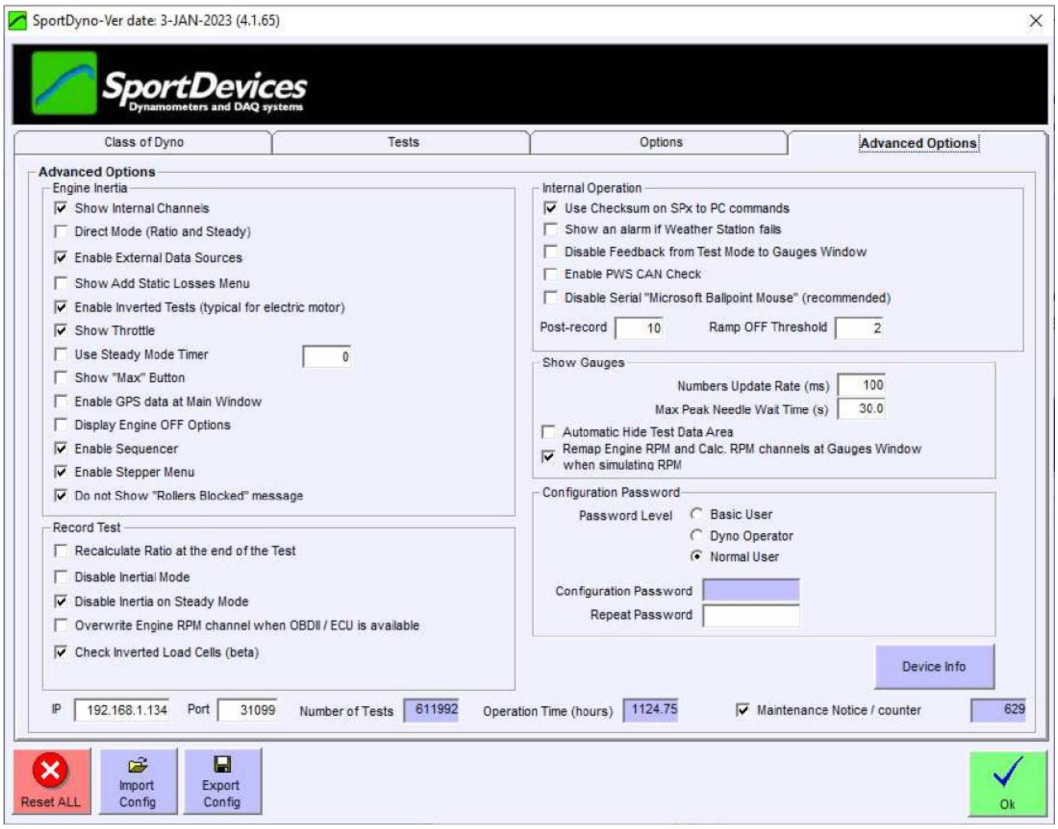
If changed on the configuration, the program will ask you if you want to change to all loaded tests.

5.3 Printer Options

Printer options have been moved to the main Menu, at File section

5.4 Advanced Options

Normally user does not need to modify these options. Nevertheless, they are provided in case of special needs, or systems that need to force special conditions on the software.



<u>Menu enables:</u>

Show Internal Channels. Some channels as brake output, PID target, etc, are disabled by default to not confuse new users. They can be enabled afterwards (they are always recorded)

Direct Mode (Ratio and Steady). From version 4.0 the guided mode is used to perform the tests, in which it is giving instructions to the user so each step is performed in the correct order. This guided mode can be disabled and return to the former direct mode (when this option is active) as in old versions.

Enable External Data Sources. Sportdyno 4.x implements many new digital data sources (data which is acquired directly to PC, not through the SPx unit): OBDII, xDS, CAN, EGA, Infrared sensors, etc.
These data sources are explained at section 16 (External Data Sources).

Show Add Static Losses Menu. "Add Static Losses Menu" is disabled by default to not add to simplify the program operation for new users.

Enable inverted tests (electric motor). This option is hidden by default to simplify the program operation for new users. Inverted tests are typical with electric motors which used to be tested from max RPM increasing brake load until the engine stalls.

Show Throttle Menu. This menu is disabled by default to not add to simplify the program operation for new users. Throttle menu allows calibrating throttle min position and throttle max position. See section 2.4.2. It also makes throttle slider visible at Gauges Window.

Use Steady Timer. This is an experimental feature to time the recording time during steady test. It is disabled by default.

Show Max Button.

Enable GPS data at main Window.

Display Engine OFF options

Enable Sequencer

<u>Recording</u>

Use interpolation of samples to increase accuracy. From version 3.0 of software, it was added an interpolation algorithm to increase accuracy when there are a few pulses per rev (for example one tooth per rev), and when acceleration is very fast. This option is enabled by default, but it can be disabled for test purposes.

Recalculate Ratio at the end of Test. By default Ratio is calculated while the program is at Gauges Window, and also after the dyno run has been performed. Normally Ratio value is not exactly the same during the dyno run, than before starting. This is caused by the little slippage caused by the wheel applying torque to the roller (vehicle dynos). This slippage is lower or does not exist before starting the test.

Record Weather Station data during the test. By default this option is enabled, and it causes that the program record the Weather Station data (temperature, humidity and pressure) within the test for later reference. Normally these values will not change during the test, but a high variation on one of them (for instance room temperature), may reveal a problem in the dyno room (insufficient ventilation, small room, etc)

Interpolate OBDII Data. OBDII channels, even with CAN protocols, are slower (2 to 10 samples per second) than SP1, SP3, SP4, SP5 channels (50 samples per second). This causes that OBDII channels generate step-like patterns. To improve this shape the program performs a 3^{rd} grade interpolation to create a smooth shape.

Post-record. Filters generate delays depending on its size. This parameter is used to record a few samples more after the test is committed to stop to feed the filters provide accurate graphs at the latest samples.

Coasting ends at %. By default coasting will end at the 50% value between starting RPM value and ending RPM value. For instance for a test between 2000 and 6000 RPM, recording will stop when coasting reaches the speed equivalent to 4000 RPM. This percentage can be changed.

Pre-load time. In ramp test, at the semaphore window the engine has to last at least this time in the steady condition before the ramp and the recording start. By default it is set to two seconds, but it can be modified.

<u>Internal Operation:</u>

Use Checksum on SPx to PC commands. Depending on Firmware version, some SP4s send configuration data to PC without a checksum, and others do use checksum.
With SP1+, SP5 and SP6, all FW versions use checksum on both directions. Actually this option is something that Sportdyno configures by its own.

Show an Alarm if Weather Station fails. By default the SW will show an alarm if the Weather Station has an assigned port and the communication is lost.

Disable Feedback from Test Mode on Gauges Window,

By default all changes on DAQ are sent to Sportdyno to update the status. Nevertheless, feedback for **Test Mode** status can have non deterministic effects at Gauges Window. For this reason feedback is disabled by default for this specific message.

Enable PWS CAN Check. When the power supplies are connected using CAN to SP5 or SP6, this option will perform a check before starting a test to ensure that the communication works and there are no errors in the power supplies. This is especially useful in AWD, HUB-2 and HUB-4 dynamometers.

Disable Serial "Microsoft Ballpoint Mouse" Windows can eventually detect the data stream from the DAQ or from the Weather Station and decide that it is a MOUSE, it will install their drivers and block the access from other applications. It is recommended to execute the Disable Serial Ballpoint procedure, but it will only work if Sportdyno has been executed in **Administrator Mode**

Gauges

Numbers. Update Rate (ms) for all numbers present at gauges, update rate can be configured. By default it is set to 100 ms to allow enough time to read each change of numbers, but some users may prefer faster changes that look like more fast software operation (but make more difficult to read the values)
Please note that most times a slow updating frequency in both gauges and graphs can be caused by the latency setting in the FTDI-COM configuration (check section 2.5.2)

Max Peak Needle Wait Time (s) new gauges add a peak value needle, the value will be set to the maximum value reached by its assigned channel, and **after this wait time** it will start to decay slowly to zero, to be able to register other maximum values.

Automatic Hide Test Data Area. In the gauges Window, some users may prefer having the whole area available for gauges / numbers when they are not editing the test details. This option will hide the Test Details when the mouse is not over that area.

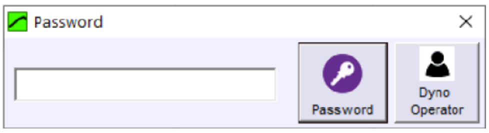
Remap Engine RPM and Calculated RPM channels at Gauges Window when simulating RPM. By default all gauges containing either "engine RPM" or "calc. RPM" will be remaped to "calc. RPM" when "simulate RPM" option is active, or to "engine RPM" when it is disabled. This automatic behaviour may cause a conflict if the user wants to have both channels available, then this option has to be disabled so the gauges are not reassigned automatically.

Configuration Password

By default the software will be run in the 'Normal User' level, nevertheless some dyno owners may need to have a "Basic User" or a "Dyno Operator" level to limit the functions that the software allow to do to 3rd users.

- **Basic User**: only has access to printer settings
- **Dyno Operator**: has access to all settings except the dyno configuration
- **Normal User**: has access to all configuration

When the access level is changed to Basic or Operator, the **software will request to fill both password fields** (with the same to ensure that the dyno owner will be able to go back to the Normal user mode)
When in Basic or Operator levels, the SW will ask for the password every time that the configuration is entered. Basic and Operator users will only be able to click in the right button to access their limited options.



Device Info

This box will show all available information about the SPx device (if available)

- Firmware version

- SPx DAQ type (SP1, SP1+, SP3, SP4, SP5, SP6)
- Firmware Subtype
- PID Type
- OV Type (overshoot control, classical derivative control)
- CMD Echo (commands are "echoed" from SP5 to PC to verify the communication)
- AWD Enable (SP5/6 allows AWD or not)
- MAC Address (SP5/6)
- Clock resolution

Bottom area
IP and port can be modified at this place. By default SP5/6 IP is assigned by the Discovery protocol when searching for a SP5/6, and port is fixed 31099, but they can be modified.

Number of Tests and Operation Time. These are informative fields about the usage of the dyno. They cannot be reseted with the "Reset All" button at Config Window. In addition they cannot be exported or imported from another computer, so new computer → count starts from zero. (They are not stored into the SPx unit)

6. CHANNEL SETTINGS.

This window is used to display and modify the Channel Settings.

A list of all existing channels is shown at the left side. The box icon means that this channel is available on your system. The standard configuration includes:

- SP1: Roller RPM, Engine RPM, 2 thermocouples and 4 analog sensors (ex. Lambda1).
- SP3 units also include load cell channel.
- SP1+, SP4, SP5 and SP6 units include 8 thermocouples, 6 or 8 Analog channels, and several internal channels (brake output, PID Target, servo output, etc)

Note: f(x) channels are internal calculated channels (ex. HP and TQ), they are not transmitted by the SPx unit.

6.1.1 Channel key

It is the internal code to identify the channel. It cannot be changed.
Note that from version 3.8 it has been changed from ASCII (A, B, C.... I, J, K) to hex numbers (41, 42, 43...49, 4A, 4B) to allow the new channels to be used, as they use an eight bit encoding and are more difficult to be represented as ASCII characters. For instance OBDII Engine RPM is 90 which does not have an associated ASCII character in most charsets.

6.1.2 Hide

Channel will be hidden in the lists and graphs. This is useful to hide certain internal channels, and to have an easy access to the channels that are being used.

6.1.3 Channel Name

It is the visible name for the channel. Some channels have specific default texts in each language. All of them can be edited by the user. This will affect to new tests which will be recorded with the new texts.

6.1.4 Colour

Channel colour can be edited directly in this window by clicking over the color. After that, depending on the grouping mode graphs will use channel colours (for group by channel) or test colours (for group by test)

6.1.5 Unit

The measuring unit name for the channel (kilograms, degrees, rpm, Newtons, etc)

6.1.6 Maximum input value
It is the maximum value for the channel. It is used as "filter" on the input. Be careful because if input is sometimes higher than this value, the program will clamp the channel at this value to void the graph to be rescaled to extreme values.

6.1.7 Upper bound, Lower bound
Those values are used in gauges and graphs as upper limit and lower limit for displaying, but they do not modify the channel data. When any of them are set, the program understands that this channel no longer uses the auto-scale method, but it uses manual scalling.
Those values are used for HP and TQ instead the "manual window" as in previous versions.

6.1.8 Decimals
Decimal places to print the numbers for this channel.

6.1.9 Raw Scale (only at properties section)
It is the scaling factor applied to digital input from the SPx unit. As data received from SPx is 16 bits integer, data has to be converted to a meaningful value for each channel.
For example: general purpose input goes from 0 to 5 volt, and its read values can be between 0 and 1023, then a factor of 5/1023=0.00488 is applied so when received 1023 value, it will recorded as 5 volt.
Normally this setting is internal and cannot be changed

6.1.10 (User) Scale (at the table and properties section)
This is the scaling factor that the user can change to convert for instance a voltage into lambda or other value depending on the sensor. Some of the sensor types / presets set this value depending on the selected sensor type.

6.1.11 Filter (HF)
This value applies a low pass filter to this channel. It is only for the graph displaying, it does not affect to internal calculationa. It is useful to display certain channels as load cell which normally have some noise.

6.1.12 Group
Normally channels are displayed using the auto-scale method, each channel has its own scaling according to the maximums and minimums detected. But sometimes it is better to group certain channels that have similar meaning using the same scale, to allow a direct comparison.
For instance when comparing the Engine RPM (or calculated Engine RPM) vs Target RPM, in order to analyze the Speed Control operation, it is strongly recommended to assign the same group to these 2 or 3 channels. For instance group "2". Group 0 means "no group", use auto-scale for this channel.

6.1.13 Time Offset
In certain systems, for instance a Gas Analyzer, some channels could be received with certain delay with respect the other channels (as roller, power or torque), then the user set this field to correct the time offset of this channel with respect the others.

6.1.14 Graph Side
Most channels will be displayed at left side (L) of the graph area, except torque and load cells which will be displayed at right side (R). This side can be edited here.

6.1.15 Real Time
This box will show the realtime converted data for the current channel. This is useful when configuring an analog channel, or when configuring a CAN channel in order to see if the CAN ID, positions and scales are correct

6.1.16 Misc
6.1.16.1 Type

Channel types are defined by the DAQ and the software. They cannot be changed.
Normally analog channels can be adjusted or mapped to be used for different sensors, that is achieved with the "User Type" in the next topic.

Example of Channel Types:

- Digital Channel, channels from 0-9 are digital and cannot be changed,
- General (0-5 V) Sensor, standard input on SPx,
- Internal
- Thermocouple
- User Calculated
- OBDII
- Weather Station

6.1.16.2 User Scale and offset

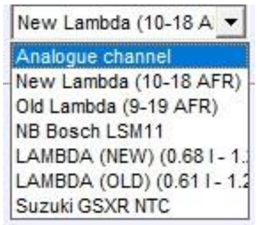
Channels can be configured either using the scale and offset, or using an interpolation table.

For instance for converting from 0-5V to 10 to 18 AFR, we need to multiply the voltage by a constant (18-10 = 8 -> 8 / 5 = 1.6) and add 10 AFR, then the user scale is 1.6 and the offset 10.

Do not use both methods: scale + offset and linearization at same time. The software would implement both.

6.1.16.3 User Type

Normally analog channels can be used for different functions. Those channels have to be configured or mapped to match the sensor or the function which is being used
The following list defines some pre-sets to configure an analog channel into some of the predefined functions. This configuration can be done also manually.



- Analogue Channel (0-5V)
- New Band Lambda (0-5V) (10-18 AFR)
- Old Band Lambda (0-5V) (9-19 **AFR)**
- NARROW Band Bosch LSM11 Lambda (0-2.5 V)
- LAMBDA New (0.68 lambda to 1.22 lambda)
- LAMBDA Old (0.61 lambda to 1.29 **lambda)**
- Suzuki GSXR Water NTC

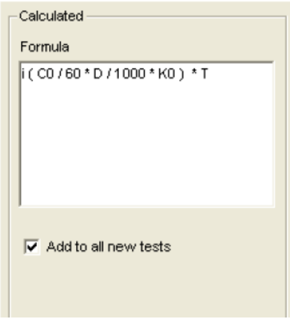
6.1.16.4 Interpolation

If checked the program will use the interpolation table instead of the scale value.
In this table you can configure any analog sensor even not lineal ones. Voltage values should be ordered from lower to higher. For each voltage it will be assigned a translated value, AFR (air fuel ratio) in the example.

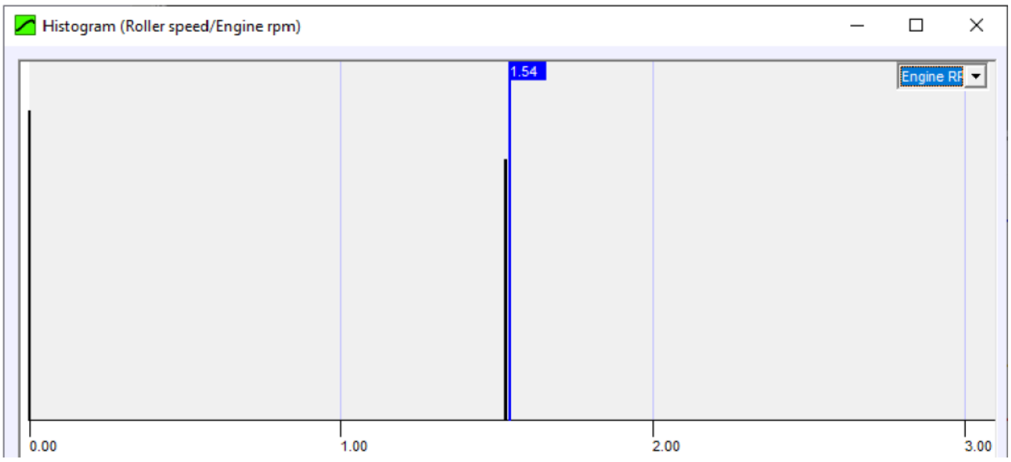
Interpolation also is possible with CAN channels

6.1.17 Default Calculated Channels

Calculated channels can be configured in this window to be added by default to all new tests. In addition its formula is entered here to be used on the new tests.



7. HISTOGRAM



After doing a dyno run (with "using rpm clamp" option activated) the program will calculate automatically the Ratio value by making a histogram of the "Engine RPM / Roller RPM" function, to find out the value that is more common during the test (only for the sections where the engine accelerates)

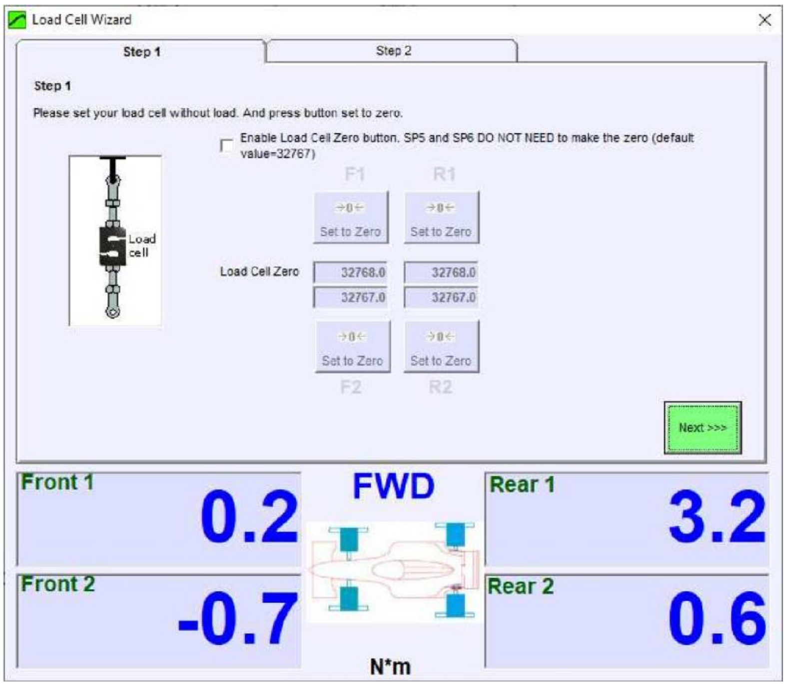
If user wants to see the histogram, it can be selected on the test menu, or by right-clicking over the desired test.

In this test all values from 0 to 3 for ratio are shown. And the amount of number of times this value was present when calculating the ratio function for each test sample. Finally the most repeated ratio value is shown with a label (1.54 in the example).

8. LOAD CELL WIZARD

This window eases the Load Cell calibration process. It is divided into two steps:

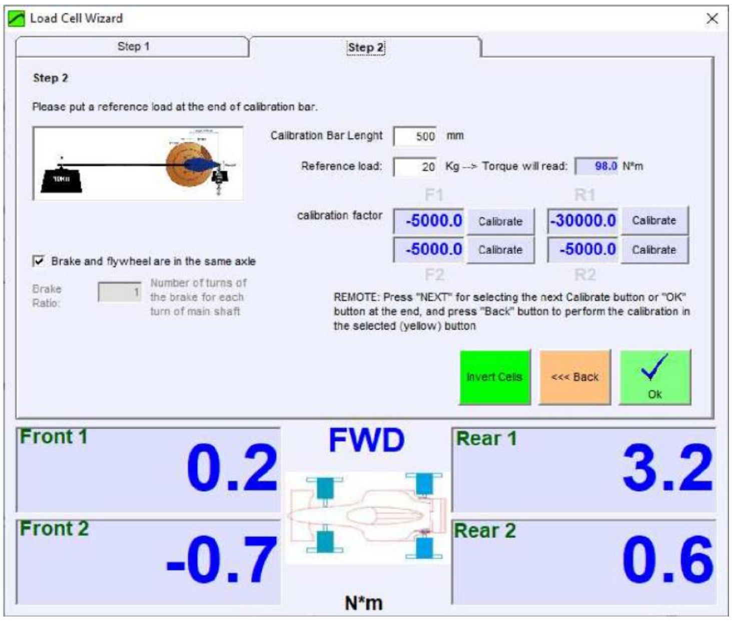
8.1 Load Cell Zeroing



Load Cell Zeroing is provided ONLY for compatibility with SP3 and SP4 which do not perform the initial zeroing process as SP1+, SP5 and SP6 do. In this case (SP3 and SP4), with the load cell free (no weight), press the "Set to Zero" button and check the "load cell zero" value is close to 32767, otherwise there may be some problem on the wiring or on the SPx unit.

For SP1+, SP5 and SP6 just restart the device and it will perform the internal self-zero calibration, and don't use these settings.

8.2 Load Cell Scale



With the load cell mounted on the brake, and the calibration bar attached to the brake, and the calibration weight set at the end of calibration bar, enter the values on the white boxes and press the "Calibrate" button. Check that the load cell reading (blue number, N*m) matches the "torque will read" number.

The DAQ should be restarted before applying the calibration weight so the calibration bar's weight is not included within the calibration process.

Finally, press **OK** button to finish the calibration process and store the results.

9. PID Monitor (SP1+, SP4, SP5, SP6)

From Sportdyno Ver 4.0 SW combines PID monitor and PID configuration windows in a single window to ease the PID (speed control) setup process.

9.1 PID Mode

9.1.1 (F6) Idle

It sets the brake output to 0. It is useful to do inertial tests.

9.1.2 (F7) Steady

It enters SP4 / SP5 in the steady mode. A RPM Target is set to keep the Engine RPM fixed when Engine tries to overpass this Target point (it does not accelerate the Engine by itself). SP4 and SP5 have a PID Controller that calculates the brake output as a function of Engine RPM input, RPM Target and PID coefficients.

9.1.3 (F8) Ramp (Sweep Test)

Once the Engine is steady, software can enter in the Ramp Mode, in which the SP4 / SP5 will increase the Target RPM at a fixed rate (Ramp Tate) until the "Max RPM" value is reached.

This mode only works when the user is accelerating, for RPM values near or higher than the current Target. If the user closes the throttle, when Engine RPM is lower than Target RPM, the SP4 / SP5 will detect that condition and will adjust the Target for the new speed in order to have a suitable starting RPM Target in case the user decides to accelerate again (although this is **not** the right way to use this mode).
Minimum RPM value that will be allowed for Ramp Mode is defined on the Ramp frame (below) in order to not stall the engine.

9.1.4 (F9) Brake

When entering this mode, a fixed value is applied to the brake. It is useful for test purposes and to stop the dyno when the test is finished (Pause key on gauges window).
Note: If the engine is not running, brake mode will disconnect the brake automatically after a few seconds in order to not overheat the coils.

9.2 Ramp Limits (Sweep)

These two values set the starting and ending point for a Ramp Test.
Please refer to section 10.2

9.3 PID Settings

Kp, Ti and Overshoot values are used to control the Engine RPM when the PID is at Steady or Ramp modes. Please refer to section 10.1 below

9.4 Misc settings

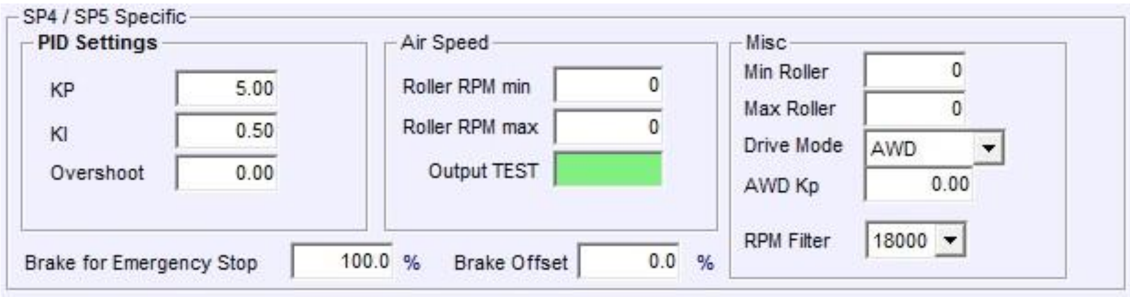
Please refer to section 10.4 below

9.5 Numeric Boxes

PID Monitor Window allocates several numeric boxes that can be used to display any channel.
To edit the channel displayed just right-click over the box to be edited.
Only channel assignment, decimal places and colour can be edited for PID monitor.

10. SP1+, SP4, SP5, SP6 Specific Settings

This section mainly describes PID settings (speed control), and other settings which are specific for SP4 and SP5. Some of them can be found at both Config Window and PID monitor Window, and others only at Config Window.



Ramp settings at Configuration window, most settings are shared with PID monitor.

10.1 PID Settings

(Configuration and PID monitor) Kp, Ti and Overshoot values are used to control the Engine RPM when the PID is at Steady or Ramp modes.

Kp: Proportional Gain Control, (the bigger Kp, the faster the control, but it will oscillate on excessive values)
Ti: Integral Time Constant. For little Ti the faster the drift/approach, but they make the system slower to changes. Normally only values inside the range from 0.3 to 1.0 should be used.
Td. Td implements a derivative control (it slows the acceleration to make the system easier to control). Normally for **chassis dynos and hub dynos it should be kept to** zero as it adds many "noise" to the brake signal. In earlier versions of SP5 a special **Overshoot** control algorithm was implemented, which was more efficient in steady tests

that only the Td (derivative) control, but it performance was a bit worse in ramp than the classical Td control, so finally it was removed.

Please read the SP4 / SP5 Setup documentation.

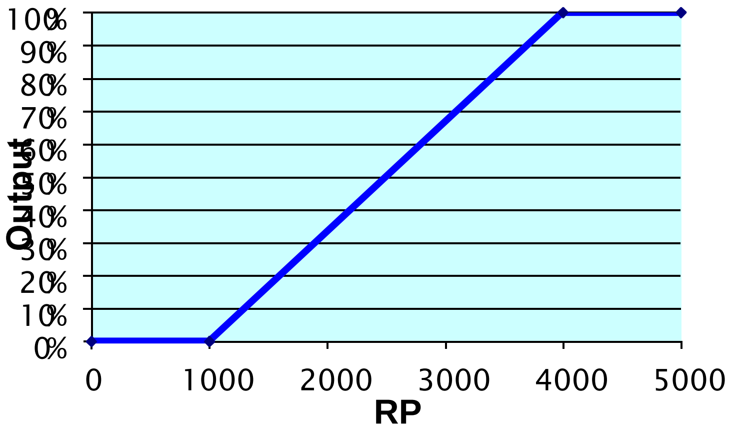
10.2 Ramp Limits (Sweep)

(Only PID Monitor) Min RPM and **Max RPM** values are used in the Ramp Mode as limits to the ramp sweep target generator (auto-increment). If the Engine decreases its speed (because throttle is closed) the system detects this condition and decreases automatically the Target RPM, this value is limited by the "Ramp MIN" value. When the Engine is accelerating, the Target value is increased automatically at the ramp rate until the "Ramp MAX" value is reached.
If any of these values are set to zero, then it has no effect (PID will not force RPM to zero!)

10.3 Air Speed

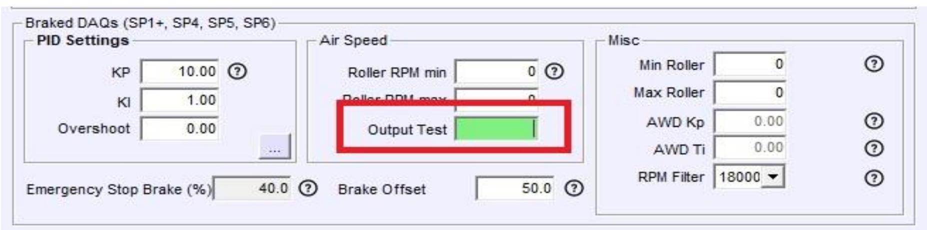
(Only PID Monitor) With certain SP4 units and all SP5 units, the servo2 output can be used to control the output signal to a VFD that powers a 3 phase motor connected to an air turbine.

- **Roller RPM min** is the speed value to start the operation for the air speed output. For instance if Roller RPM min = 1000 rpm, for all speed values between 0 and 1000 rpm, the output will be zero.
- **Roller RPM max** is the speed value in which the air speed output reaches 100%. For instance if Roller RPM max = 4000 rpm, for all speed values above 4000 rpm, the output will be 100% (5 volt)
- For all values of roller speed between **Roller RPM min** and **Roller RPM max**, the output will be a linear function proportional to the position between these two values.

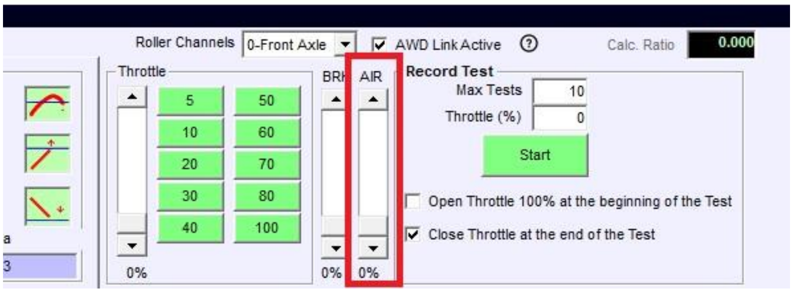


Air Speed Output Function
(min=1000, max=4000)

- **Output Test,** this field is used to perform a manual test of the air speed output when the roller is stopped.



Air speed output can also **be manually** operated from the Gauges Window. Manual control will override the roller speed command.



10.4 Misc Settings

10.4.1 Min Roller (SP5).

(Config Window) When Roller speed is below this value, PID output is zero. This allows to prevent engine to stall, or if a centrifugal clutch is used it prevents it to get damaged. Note that the setting is for Roller RPM not Engine RPM

10.4.2 Max Roller (SP5).

(Config Window) This setting fixes a maximum allowed speed for the system. If the system tries to go over this speed the brake will reach 100% its value. This may create oscillations but it is preferable this than overpassing the safety speed (if any). Note that if it is set to zero, then no max roller speed will be used.

10.4.3 Ratio.

(Config and PID monitor) This value is the relationship between Engine RPM and Roller RPM. All RPM values in the SP4 / SP5 are referred to the Engine RPM, but speed is measured at the Roller / Brake, thus Ratio value is very important as it used for the internal Calculated Engine RPM channel which is used for speed control.
On the gauges window, when using the RPM Clamp, the Ratio is calculated in real time and sent to SP4 / SP5. Once the test is started the last Ratio value calculated is kept for the whole test.

10.4.4 (Config and PID monitor) Number of Teeth (geartooth).

For suitable PID operation it is recommended to use a gear tooth of minimum 8 teeth.

10.4.5 Prescaler (SP1, SP3 and SP4).

Depending on the number of teeth, prescaler has to be set among 1, 4 and 16. Usually prescaler=1 is used for number of teeth lower than 16. Prescaler=4 for 16 to 64, and prescaler=16 for higher number of teeth.
Note that **SP1+, SP5 and SP6** always use prescaler = 1.

10.4.6 AWD Mode (SP5 / SP6).

As SP5 has dual Roller Channel set (roller speed, load cell and brake output), it allows 3 modes:

- **Only Front.** It uses the channels closer to the RS232 connector. This mode is used for engine test bed, single axle dynos, and for AWD dyno using Front axle.
- **Only Rear.** It uses the channels closer to the MAINs plug. This mode is only used for AWD dyno using Rear axle.
- **AWD.** It uses the both channels and enables the AWD synchronization.
- **Note that AWD option is not free**, not all SP5s have this option enabled.

10.5 Brake Configuration

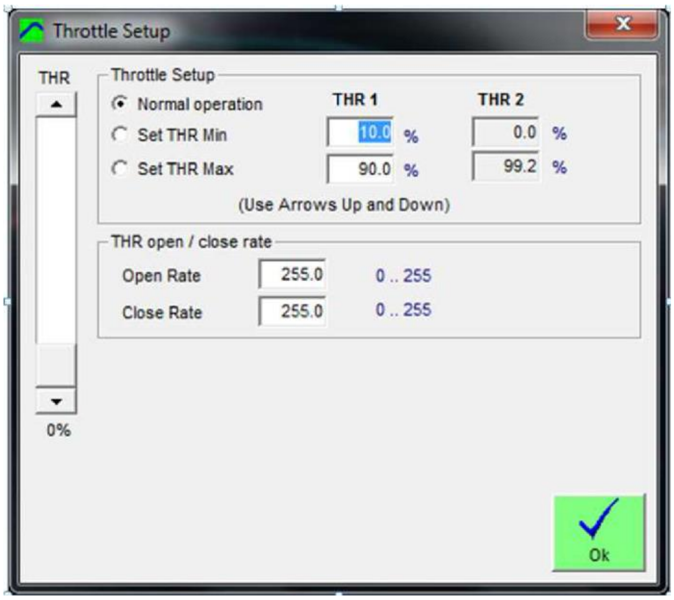
10.5.1 Brake for Emergency Stop (SP5 / SP6).

When Emergency Stop button is pressed (Panic Button), SP5 will go to Brake mode, and will apply this fixed value to the brake.

10.5.2 Brake offset.

Some Brake Power Supplies are not full linear (for instance old Semikron PWS). They start to provide current from brake values higher than 130 (13%). Note that this could change depending on the mains frequency on your country.
This offset is added to the brake action (when it is higher than 0) to get a suitable control signal over the power supply.

11. Throttle Configuration



11.1 Throttle Setup

Here servo start and ending positions are configured. It is important not to force the servo.
Min and max positions can be reversed in order the servo moves in the opposite direction.

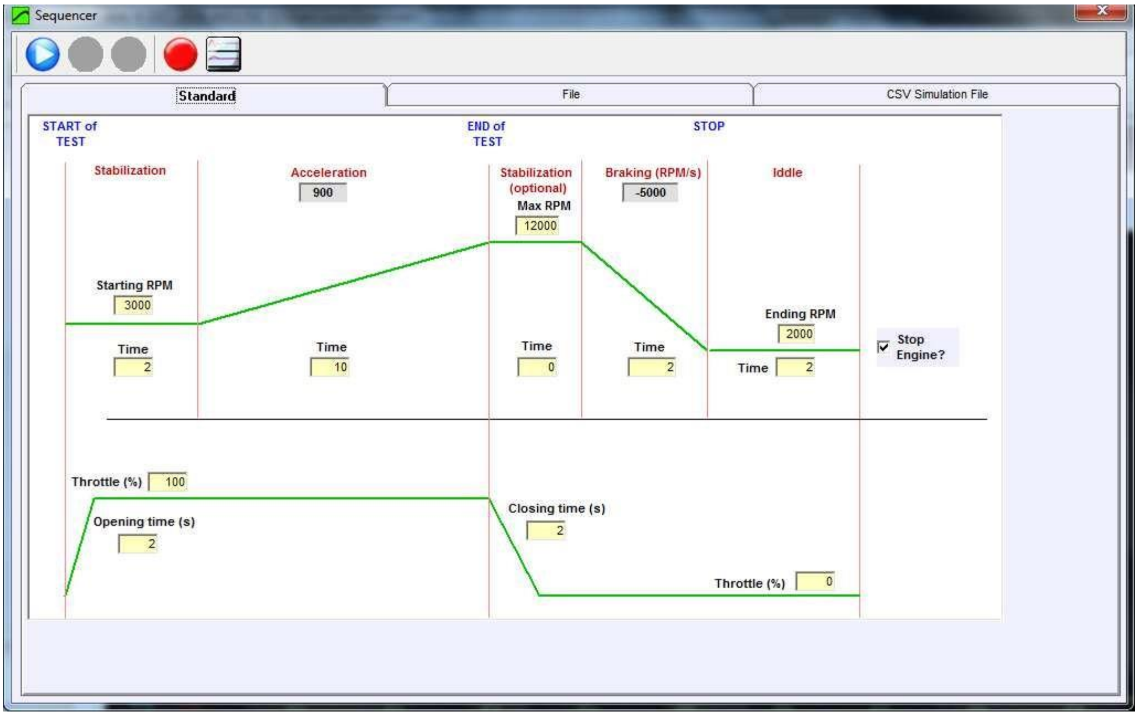
- Normal operation: the sliding bar to the left moves the servo.
- Set THR min: sets the minimum position for the servo
- Set THR max: sets the maximum position for the servo. Be careful to not force the servo against the Throttle body max allowed position.

11.2 Throttle Open / Close rate

By default, a value of 50 or higher at these values will make the servo open and close quickly, but by setting low values (1, 2, etc) it will move slowly. It is only available for servo 1 (throttle)

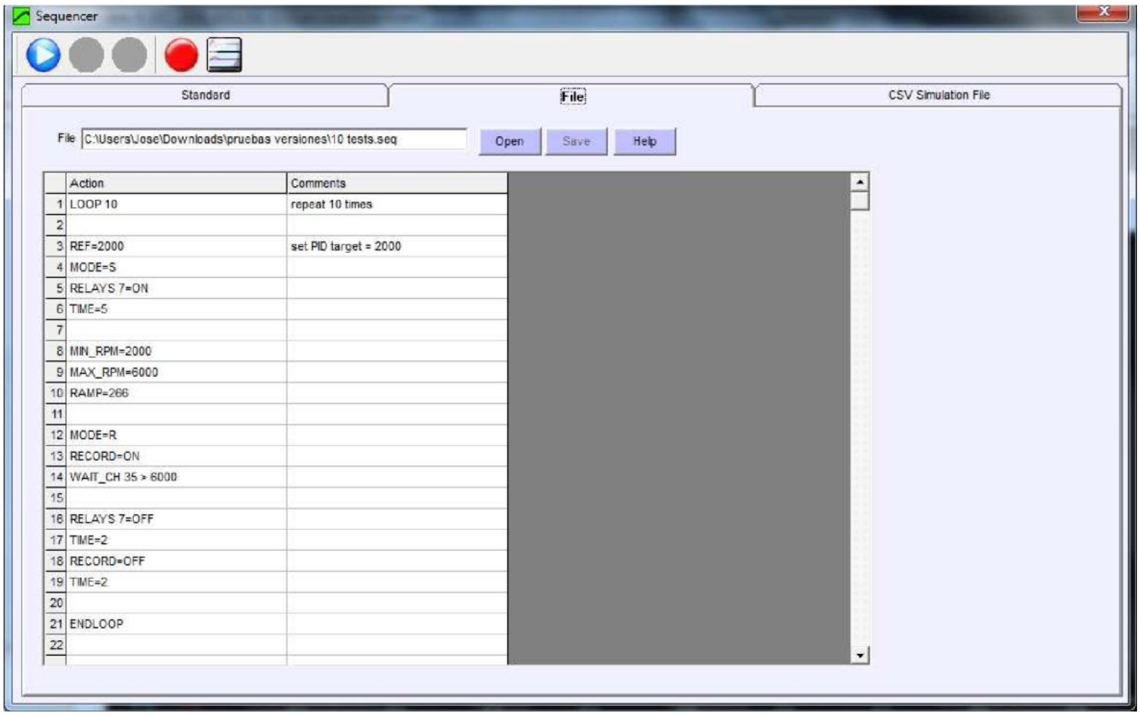
12. SEQUENCER (SP4 / SP5 / SP6)

12.1 "Standard" Sequence



This window is useful for simplified automated cycles.
The user can edit the duration of all stages and the parameters related to acceleration and starting / ending RPMs

12.2 Sequencer File



Sequencer File can be used to perform Engine Test Cycles. It can keep then engine running several hours to test its reliability. The programmed sequence is stored in a text file and automated by the program by using simple orders like THR=10, REF=3000, etc. One level loop is allowed to repeat certain program sequence a known number of times.
This version allows to edit the file directly in the grid list (older versions needed the usage of Notepad for editing the file)

Sequencer Commands [updated]

Command	Description
RELAY(n) = on | off	Turn Relay (n) ON or OFF. 7=IGNITION, 6-STARTER, 5 to 3: Fans or other user function, 2=Bed In, 1=Bed Out, 0=block/lift
MODE = I | S | R | B | T	I=IDDLE, S=STEADY, R=RAMP, B=BRAKE, T = Inertia Mult
THR = n%	Throttle 0..100%
REF = rpm	Set TARGET to rpm
RAMP = rpm / s	Set RAMP RATE to rpm/s
BRAKE = n	Set BRAKE TO n (%)
Variables	
START_PARAMS	Defines the Start of Parameters section
END_PARAMS	Defines the End of Parameters section
$Variable = nnnnn	Assigns a numeric constant to a variable. Normally at PARAM section
Key_word = $Variable	Assigns a variable to some key_word (for instance MIN_RPM = $Var1)
Test mode Control	
AUTO_START = ON | OFF	Sets auto Start mode ON or OFF
AUTO_STOP = ON | OFF	Sets auto Stop mode ON or OFF

STOP_MODE = L | H | R	Sets Stop mode to L = 'Stop when lower', H = 'Stop when higher', R = 'Reversed'
MIN_RPM = n	Sets starting value for ramp mode
MAX_RPM = n	Sets ending value for ramp mode
RATIO = n.nnn	Sets Ratio for current test
GEAR_LIST r1-r2-r3-r4	Defines the List of Gear Ratios for a specific vehicle
RAMP_CHANGE_RPM =	RPM value at which ramp slope will change
RAMP_CHANGE_SLOPE =	New Slope value when ramp changes
RAMP_TRANS_TIME =	Time to make the transition from steady to ramp smoother
Delays and Loops	
TIME= n.n Or Delay = n.n	WAITs n.n seconds
WAIT_END_OF_TEST	Returns when the recording finishes, for instance 'auto stop'
LOOP n . ENDLOOP	Repeat N times, loops cannot be nested
label:	label for GOTO
GOTO n | label	Go to line N, or go to LABEL
WAIT_CH n > val	Waits Channel N to be HIGHER than val, CH=@ is ESPACE (meters)
WAIT_CH n < val	Waits Channel N to be LOWER than val, CH=@ is ESPACE (meters)
START 0x31 > val	It activates the Starter Relay until the Engine (0x31) is higher than the value
RECORD= on | off	Start/Stop recording data

12.3 CSV Simulation File

From Version 3.8 Sportdyno can load a CSV file (Comma Separated Values) and use it for sending speed and throttle data to SP1+, SP4, SP5, SP6 and perform a simulation of a race track which was recorded with a Data Logger.

Mode of operation is simple: just load the CSV file and press "play" button.

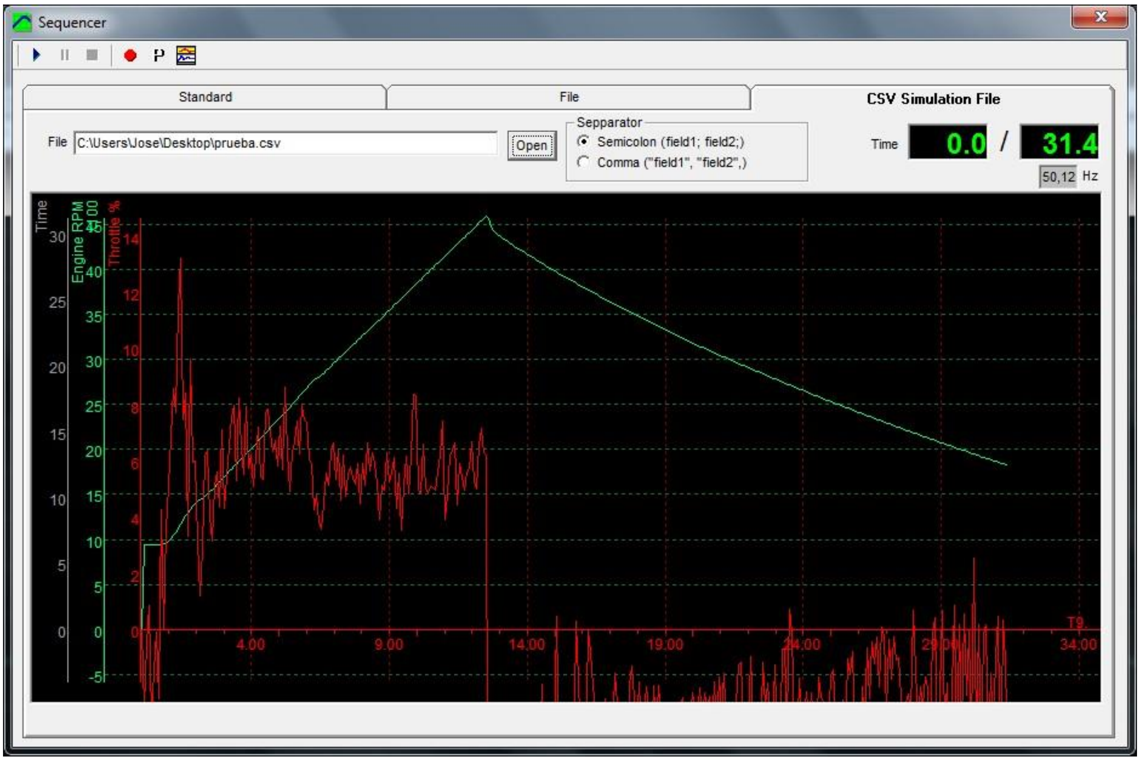
File format:

It admits two basic CSV formats, compatible with Excel (tm):

- Values separated by semicolons: 111; 222; 333....
- Values between quotation marks (" ") and separated with commas: "111", "222", "333"

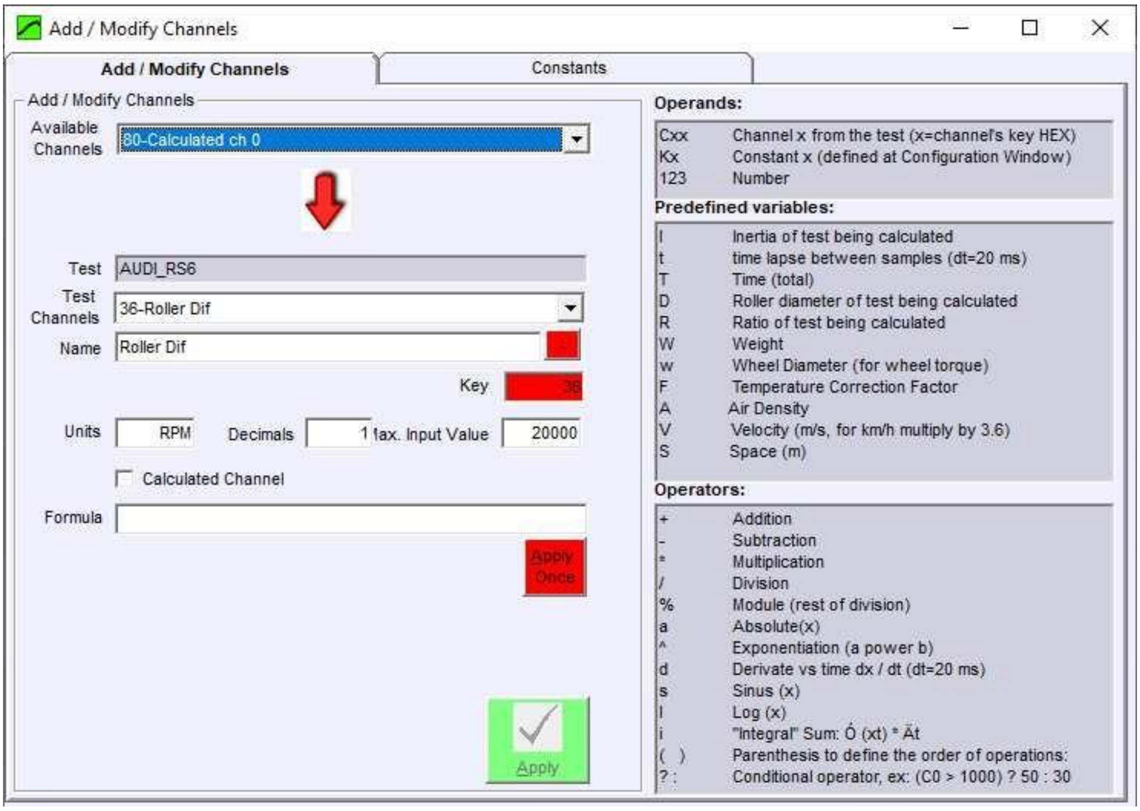
First line of the file (header) is ignored.
Only the first three columns of the CSV are used:

- First column is always Time (s)
- Second column is always Engine RPM
- Third column is always Throttle position (%)


Sequencer
Standard
File
CSV Simulation File
File C:\Users\Jose\Desktop\prueba.csv
Open
Sepparator
Semicolon (field1; field2;)
Comma ("field1", "field2",)
Time
0.0
/
31.4
50,12 Hz
Time
Engine RPM
Throttle %
4.00
9.00
14.00
19.00
24.00
29.00
34.00

13. Calculated Channels

Calculated Channels can be added to existing tests. They will take the Channel basic data (key and name) from an existing channel from the total channel list (not only SPx device channel list) and will use the specified formula to get data from other channels and perform the calculations that will provide the data for the new channel.
Calculated channels are recalculated every time that anything is changed in the test (ratio, inertia, etc)



Add / Modify Channels Window is used for adding channels to **existing** test

13.1 How to use it?

When the "Add Calculated Channel" option is selected from the main window the program will show the screen above.

Press the "+" button to automatically find the next free calculated channel, starting at 0x80. The user can also choose a different channel (including existing ones), and the program will show the default data for the channel (if it is new) or the current data for the channel (if it already exists) including the formula if it is an existing calculated channel.

Next step is giving the channel a meaning name, for instance: "calculated power", and their corresponding units (HP), decimals (1) and formula.

Note: "-" button has the same effect as "Remove Channel" in Test menu.

13.2 How to use the formula field?

Within the formula the user can combine Channels, Constant values (numbers), Constants and operators.

Prefixes to refer the items:
The formula consists of a series of 4 basic elements:

- Channels
- Program Constants
- Operators

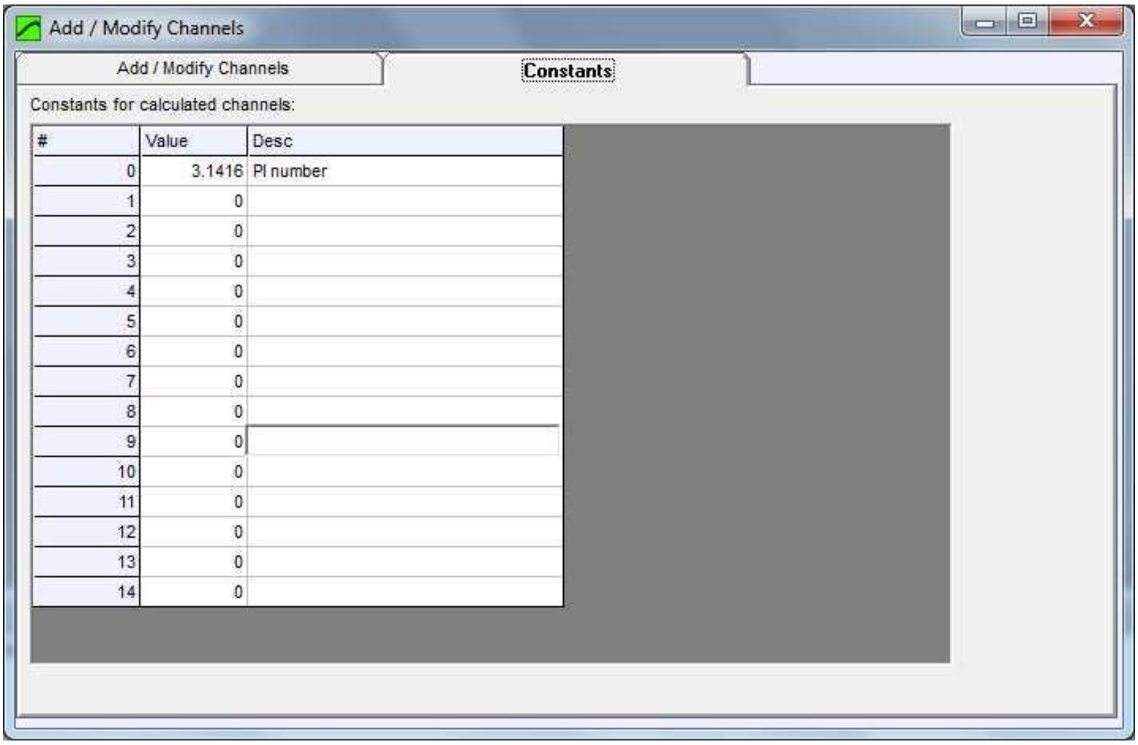
- Test Constants

13.2.1 Channels

- To access to the data of an existing channel (for that test) write Ck (k is the channel's key), for instance roller channel is C30, engine channel C31, Lambda 1 channel C4A Note: old channels nomenclature was based on ASCII chars for Formulas, now also the Hexadecimal nomenclature is available.

13.2.2 Program Constants

- Constant (internal array of constants x = 0..15). Constants can be defined at "Configuration" Window.



Constants Tab

A typical constants is:
PI = 3.1416 (3.14159265358979323846264338327950)

13.2.3 Operators

+	Addition
-	Subtraction
*	Multiplication
/	Division
%	Module (division remainder)
a	Absolute value
^	Exponentiation (a power b)
d	Derivate vs time dx / dt (dt = 20 ms = 0.02 s)
s	Sinus (x)
l	Log (x)
i	Integral (x) (sum f(x) * dx)
( )	Parenthesis to define the order of operations
?	Conditional operator, example: (C0 > 1000) ? 50 : 30

13.2.4 Test constants

I	Inertia of current test
t	(dt) Time lapse between samples (20 ms)
T	Total test time
D	Roller diameter of test being calculated
R	Ratio of current test
W	Weight
w	Wheel Diameter (for wheel torque)
F	Weather Correction Factor
A	Air Density
V	Velocity (m/s, for km/h multiply by 3.6)
S	Space (meters)

13.3 Formula examples

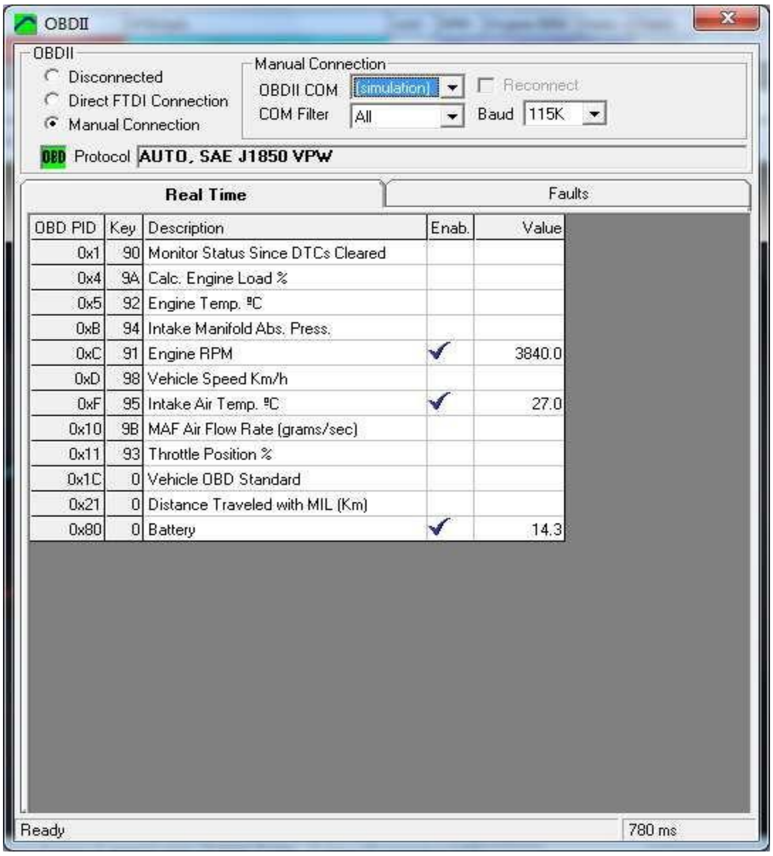
Torque (N*m): d (C30 / 60 * K0 * 2) * I * 50 + C39	Torque calculated from roller and load cell: d ("Roller rpm" / 60 * K0 * 2) * Inertia -- + "Load Cell" dt *or* acceleration (Rad/s) * "Inertia" (kg/m^2) + "Load Cell" (N*m)
Power (Watt) (d (C30 / 60 * K0 * 2) * I * 50 + C39) * C30 / 60 * K0 * 2 Is equivalent C33 * C30 / 60 * K0 * 2 Note: to convert to HP divide by 736	Torque (N * m) * Speed (Rad / s) or Torque channel (N * m) * Speed (Rad / s)
Speed (m/s) C30 / 60 * K0 * 2 * D / 1000 / 2 = C30 / 60 * K0 * D / 1000	(Roller / 60 * PI * 2) * (Diameter / 1000 / 2) or "Roller speed" (rad/s) * Diameter (m) / 2
Distance (m): i (C30 / 60 * K0 * 2 * D / 1000 / 2) * t = i (C30 / 60 * K0 * D / 1000) * t	Integral of (Roller / 60 * PI) * (Diameter / 1000) * dt or Integral of "Roller speed" (rad/s) * Diameter (m) * dt Or Integral Speed (m/s) * dt

K0 = 3.1416 (PI)

14. OBDII

Sportdyno provides support to Sportdevices OBDII interface from version 3.8. This interface is mainly provided for acquiring Engine RPM from the car (specially for diesel engines), although there are other interesting channels (PIDs) as Engine Coolant Temperature, Air Intake Temperature, Intake Manifold Abs. Pressure (turbo), Engine load, Throttle Position, etc that can be acquired.
OBDII is a set of standardized protocols. Each car normally will have only **one protocol.** Depending on the protocol the communications will be faster or slower. For instance K-Line protocols are quite slow, it is not recommended to acquire more than two channels (PIDs) per cycle. Nevertheless other protocols as CAN are faster and allow acquiring more channels per cycle.
Although OBDII is mainly used on cars, many motorcycles (for instance some Triumph) are using OBDII nowadays. Motorcycle manufacturers are committed to change to OBDII protocols to fulfill the testing requirements for official homologation process and periodic verifications.

14.1 OBDII Window / Real Time



OBDII Connection mode:

- **Disconnected.** Sportdyno will close the connection
- **Direct FTDI connection.** Most of our OBDII interfaces include a mechanism for detecting the OBDII automatically and provide authentification. Use this option by default.
- **Manual Connection.** For old OBDII devices or licenses acquired by separate user can configure a manual connection and a manual License authentication.

14.1.1 Manual Connection:

(This is not recommended connection method, try first Direct Connection)
OBDII COM: According to COM Filter, the program will load in this combo box those COMs of the specified type. Current Sportdevices OBDII uses a FTDI chip, thus Filter has to be set to "FTDI". As the connection procedure is a slow process, there is no an automated COM discovery process by now.
Note that default recommended connection is based on FTDI chip (automatic). No search is necessary.

COM Filter: As mentioned before, the filter allows loading certain COMs (as there can be several of them in the system). Current OBDII Interface is identified when setting filter="FTDI" Note that first OBDII versions used a Bluetooth link (using Windows Pairing method) thus filter="Bluetooth". Other OBDII used a dedicated Bluetooth Hardware that was identified with filter="Silabs". Also some of the first cable units use "Prolific" or "Silabs" chips.

Baud: By default, current OBDII interface always use Baud=38K. Old versions may need
Baud=115K setting (specially Bluetooth to COM USB card)

Status and Protocol: During the OBDII connection establishment, the driver will show the status of the connection (searching PIDs 00.. etc). After connection is complete, it will show the protocol name and details for that car. Normally each car has only one protocol, but there are cars with combinations of slow protocols and CAN.

PID list: Channel identifiers are called PIDs in the OBDII nomenclature.
Once the OBDII device has been identified, and the connection has been established with the car, the program will show the list of available PIDs. Each car has only some PIDs. Manufacturers are not obliged to implement all PIDs. Nevertheless most car have a fixed subset including: Engine RPM, Engine coolant Temp, Intake Air Temp, etc

Once the PIDs are listed, user should choose only a few PIDs (enable column) to be acquired, as OBDII is not very fast in general, and acquisition cycle should not be more than 500 ms (approx). On slow protocols as K-line, even only two PIDs can reach the 500 ms limit, but with CAN BUS time is about 100 ms for 3 PIDs.

These channels will be automatically acquired on both Gauges Window, and Test Recording.

14.1.2 Special connections

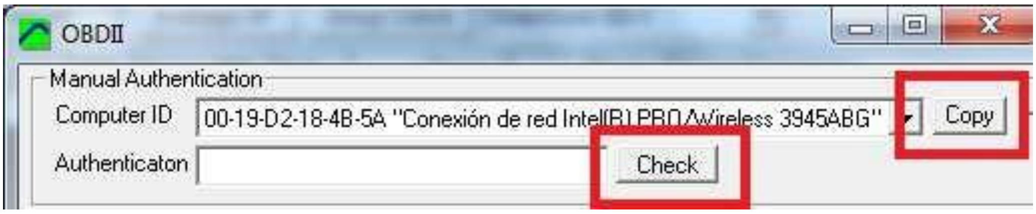
Sportdyno mainly use the OBDII protocols to connect most ECUs.

Recently **Motorcycle** manufacturers started to include OBDII protocols (normally based on
CAN) in their ECUs. Sometimes using a special adapter, but the OBDII interface still is usable

For **Electric Vehicles** as there is not a standard yet (they seem not be committed to use OBDII) they use a special implementation normally based on CAN, but can be broadcast (like Zero Motorcycles) or based on a query-response protocol (like Nissan Leaf). If you are interested please contact us: info@sportdevices.com as we are adding some EV protocols to Sportdyno.

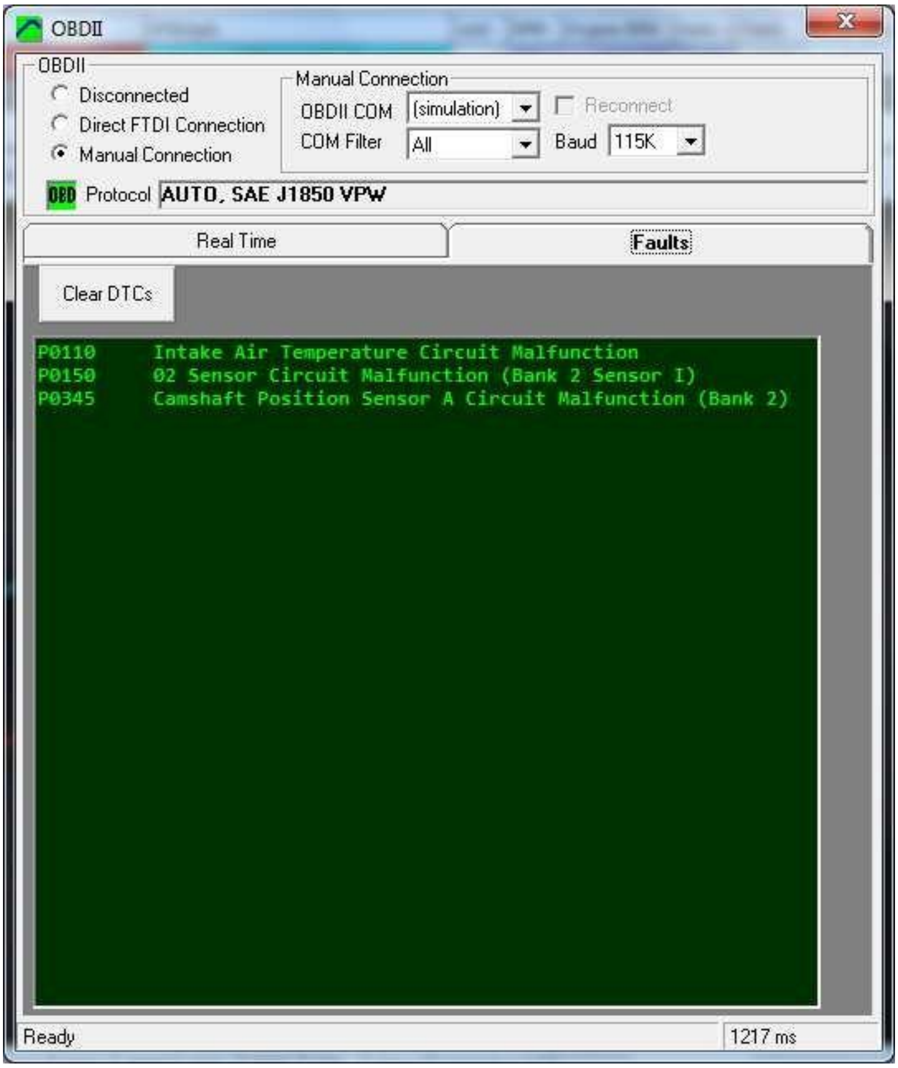
14.2 OBDII Authentication

(Only at manual connection) Sportdyno is designed to work with our OBDII interfaces. For 3rd party interfaces we can provide a license, but we cannot warranty that the performance is the same as with our units.
Some of the first OBDII units have special info recorded on them, and thus they do not need the manual authentication. Current version do not require manual authentication. User has to send us an email with the Network info that the "Copy" button provides.
Then an authentication key is sent to the user, and the user enters it on the software, and press "Check" button.
This key can only be used in one computer



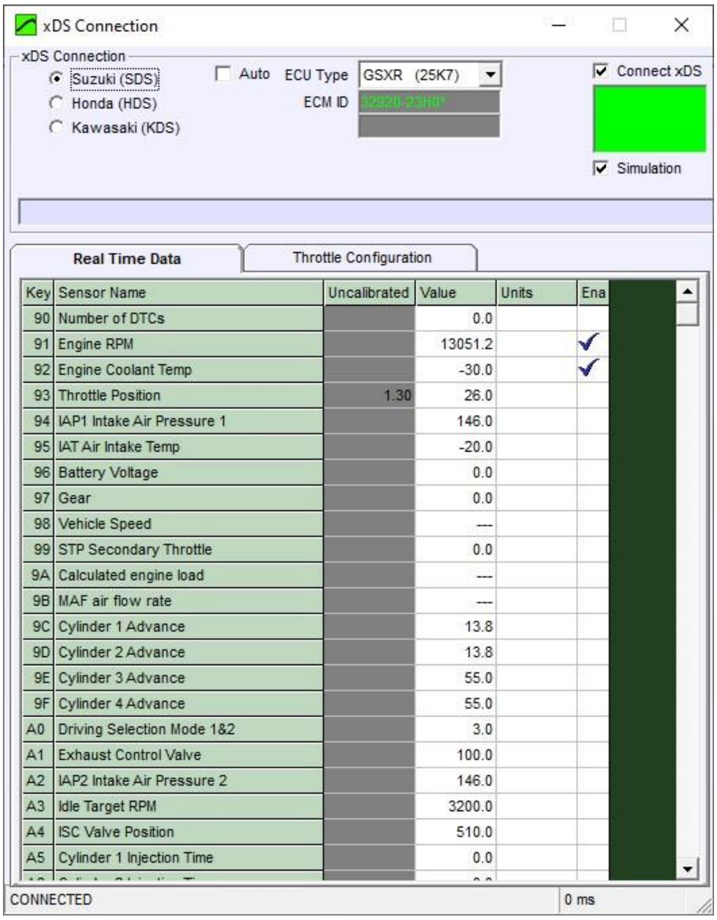
14.3 OBDII Window / Faults

OBDII interface can read ECU faults and list at the Faults Tab. There is a database of all public OBDII faults in the OBDII_DTCS.csv file.
Faults can be cleared at car ECU using the **Clear DTC** button.



15. xDS (Suzuki, Honda, Kawa)

Clicking at Connections/xDS menu or at lower-right corner on the xDS icon SportdDyno will open the xDS window (Suzuki SDS, Honda HDS, Kawa KDS). This window allows connecting Sportdyno to the xDS link and choosing the ECU channels to be acquired (note that some protocols are slow like KDS, and only a few channels can be acquired at a reasonable speed)



15.1 XDS Connection:

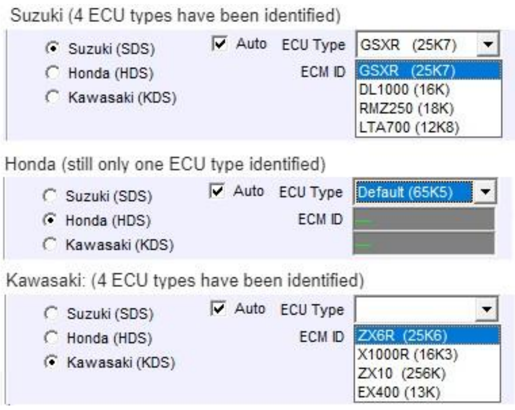
Select one of the three available protocols and enable the **Connect XDS checkbox**, and Sportdyno will enter the connection loop until it detects a valid connection.

- Suzuki SDS
- Honda HDS
- Kawasaki

Auto: After the ECM IDs are read from the ECU, the software will use them to search the ECU in a database. If not found, the user can choose one of the ECU types implemented for the selected brand.

The ECM ID, ECU type and Motorcycle model (and years) will be shown in the status box.

ECU Type. Each brand can have several ECU types with different scales for some channels like Engine RPM or Coolant temperature.
The name given in the software is only informative, there are many models that share the same type. The number close to the type name is the top RPM read when the input for RPM is 0xFFFF, for instance the "GSXR" type would read 25700 RPM if the ECU sends the 0xFFFF value. In this case the "GSXR" type is the most common in this database. Only 6 other models use the other 3 types.

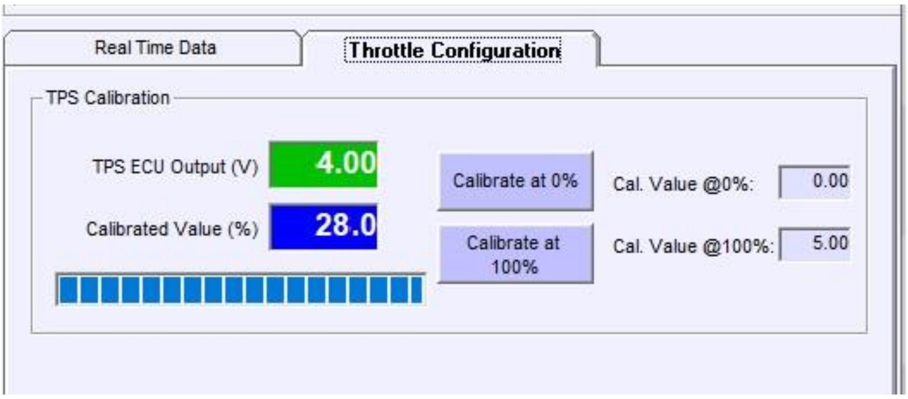


ECM IDs: Some protocols can read the ECU identifiers. If the ECM ID is in the database the software will use to choose the suitable ECU type to make RPM and Temperature show its right values.

Live Data: Sportdyno will show all available channels. User can enable or disable them by clicking over the "enable" cells, for optimizing the data transfer (for KDS protocol) and test channels usage.

15.2 Throttle Calibration:

Most ECUs send the throttle value uncalibrated (say from 23% to 106%). If the user needs that a calibrated value in the test, this window has to be used.

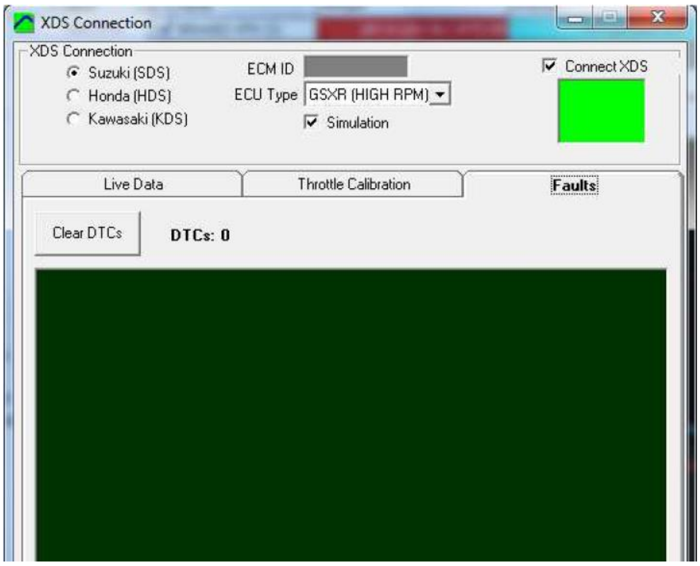


Throttle Calibration Tab

- **Green box** shows the raw value from ECU in volts (uncalibrated)
- **Blue box** shows the **value after calibration** (when it is complete)
- **Calibrate at 0**%: with throttle full closed, press this button to store the voltage for "cal value at 0%"
- **Calibrate at 100**%: with throttle full open, press this button to store the voltage "cal value at 100%". Then calibration is ready. Realtime tab will show **the calibrated value.**

15.3 Faults Tab

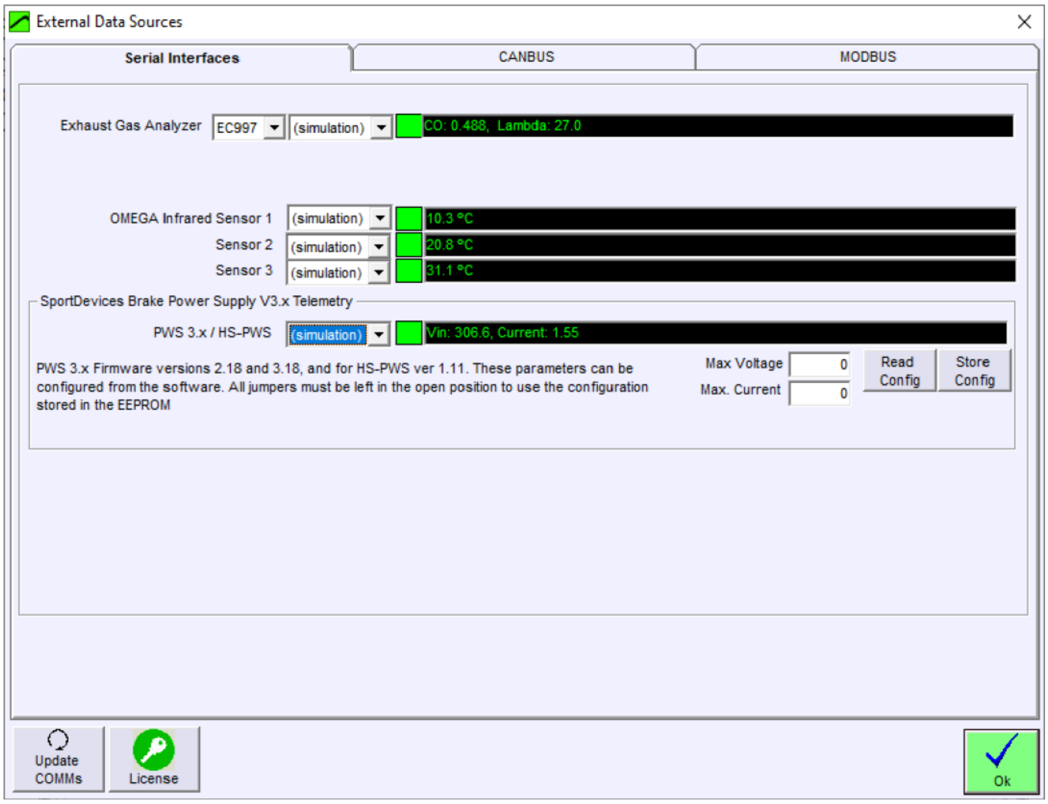
Current version of Sportdyno can read DTCs (faults) from **Suzuki SDS protocol**, and also can clear them at the ECU


XDS Connection
XDS Connection
Suzuki (SDS)
Honda (HDS)
Kawasaki (KDS)
ECM ID
ECU Type
GSXR (HIGH RPM)
Simulation
Connect XDS
Live Data
Throttle Calibration
Faults
Clear DTCs
DTCs: 0

Faults Tab

16. External Data Sources

Sportdyno 4.1 implements many new digital data links (data which is acquired directly to PC, not through the SPx unit): OBDII, xDS, CAN, EGA (Exhaust Gas Analyzer, compatible with EC997), OMEGA Infrared sensors, Power Supply Telemetry, MODBUS analog cards.



16.1 Serial interfaces

EGA (Exhaust Gas Analyzer), OMEGA Infrared sensors and Power Supply Telemetry are included in the basic Sportdyno License (they are free when purchasing the SPx unit). But CAN and MODBUS channels are not free, you have to use the License button to get your computer data and request a License to Sportdevices

16.2 CAN / MODBUS License

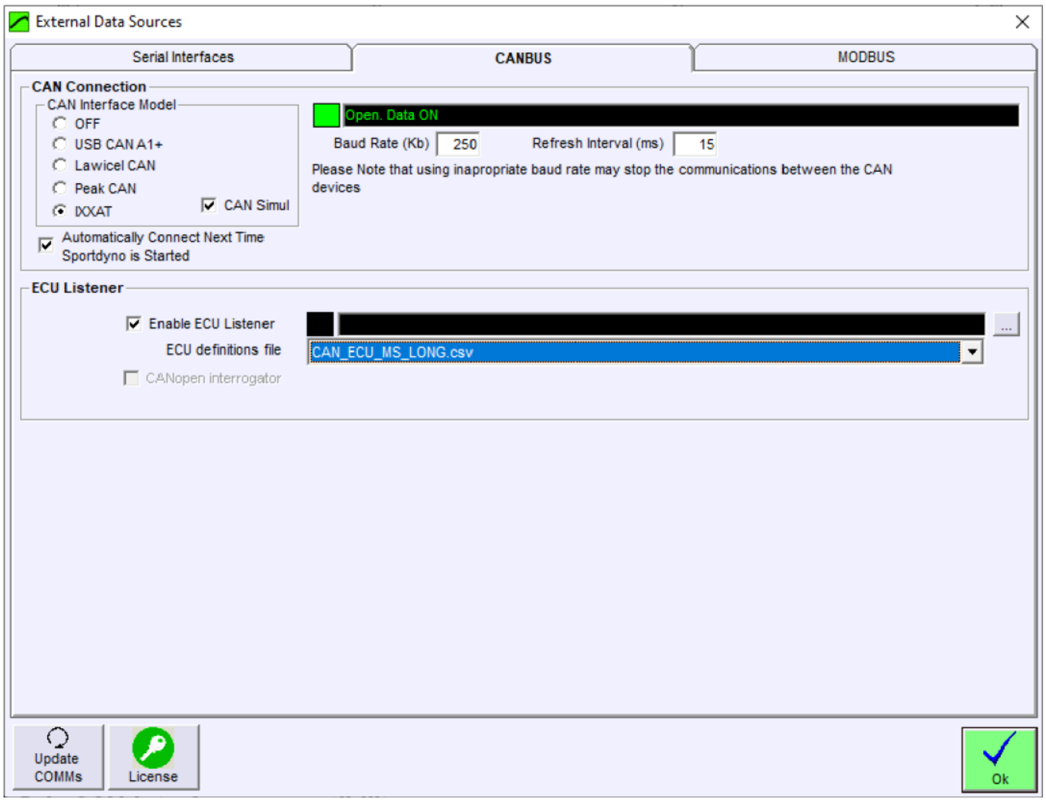
Press **copy button** to get your computer data at clipboard and send an email to info@sportdevices.com

License Key will activate both: CAN BUS and MODBUS connectivity.

CAN BUS and MODBUS open a **big range of channels expansion** for Sportdyno data acquisition capability:

- 48 channels for ECU listener
- and 32 channels for extra analog channels.

16.3 CAN BUS



16.3.1 CAN Interface compatibility

Sportdyno is compatible with 4 commercial USB-CAN interfaces:

- ~~**USB CAN A1+** (cheap interface, NO LONGER RECOMMENDED)~~
- **LAWICEL CAN** (intermediate price)
- **PEAK CAN** (most popular, less cheap)
- **IXXAT** (quite common for electric motor controller, specially with SEVCON)

Note that USB-CAN interface is not included with the CAN License (Licenses are free at the moment)

Once the CAN Interface type is selected, user can configure:

- **CAN Baudrate** (250 Kb or 500 Kb are the most common baudrates), check the device documentation
- **Refresh rate:** it depends on the device being acquired. Most devices will work fine with a refresh date of 100 ms. Allowed range is 10 ms to 100 ms

16.3.2 CAN Listeners

Sportydno CAN operation is based on that **broadcast function is active** in the device to be acquired. This is valid for CIO308 modules (analog inputs) and most ECUs, but not for OBDII CAN which has its own adapter.

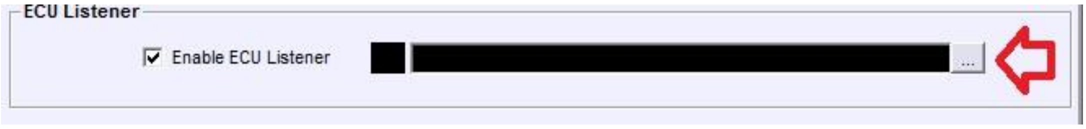
16.3.2.1 CIO308 Modules Listener.

Note: DEIF CIO308 are no longer supported

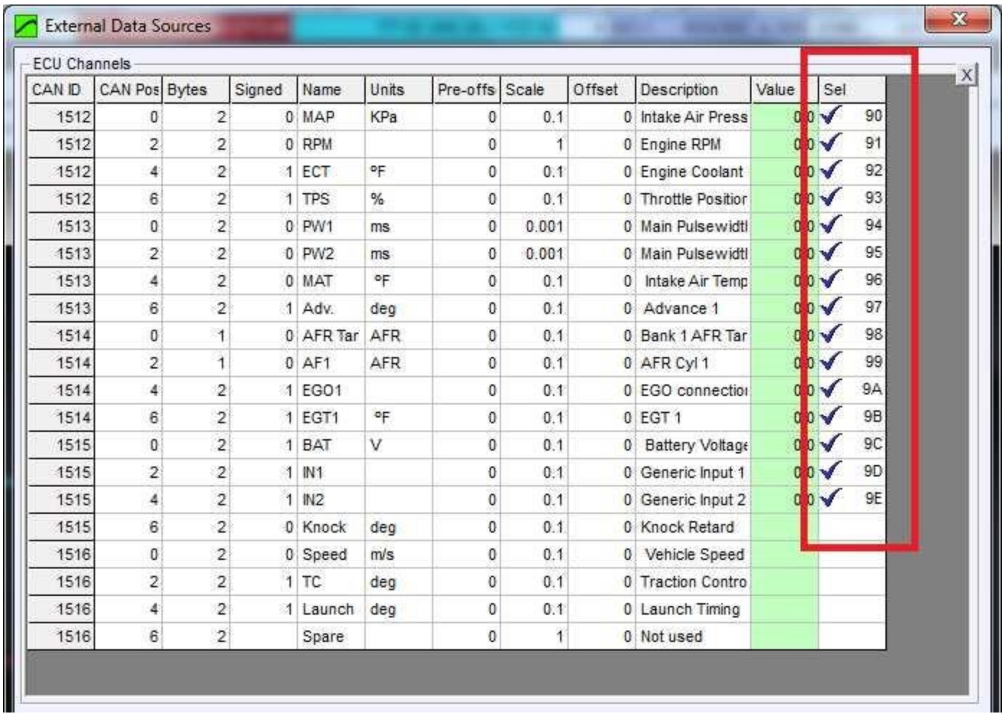
16.3.2.2 CAN ECU Listener.

ECU must have broadcast function active. By can provide ECU definition files under request.

Sportdyno allows enabling / disabling the ECU listener. It will use the channels reserved for OBDII or xDS. Keys from 0x90 to 0xBF, with a total of 48 channels.



As ECU available channels can be potentially more (about 300 in Megasquirt Long Datagram) than the allocated room by sportdyno (48), the user has to configure the active channels with the dotted button (se picture above)


External Data Sources

ECU Channels

CAN ID	CAN Pos	Bytes	Signed	Name	Units	Pre-offs	Scale	Offset	Description	Value	Sel	
1512	0	2	0	MAP	KPa	0	0.1	0	Intake Air Press	0.0	✓	90
1512	2	2	0	RPM		0	1	0	Engine RPM	0.0	✓	91
1512	4	2	1	ECT	ºF	0	0.1	0	Engine Coolant	0.0	✓	92
1512	6	2	1	TPS	%	0	0.1	0	Throttle Positior	0.0	✓	93
1513	0	2	0	PW1	ms	0	0.001	0	Main Pulsewidtl	0.0	✓	94
1513	2	2	0	PW2	ms	0	0.001	0	Main Pulsewidtl	0.0	✓	95
1513	4	2	0	MAT	ºF	0	0.1	0	Intake Air Temp	0.0	✓	96
1513	6	2	1	Adv.	deg	0	0.1	0	Advance 1	0.0	✓	97
1514	0	1	0	AFR Tar	AFR	0	0.1	0	Bank 1 AFR Tar	0.0	✓	98
1514	2	1	0	AF1	AFR	0	0.1	0	AFR Cyl 1	0.0	✓	99
1514	4	2	1	EGO1		0	0.1	0	EGO connectioi	0.0	✓	9A
1514	6	2	1	EGT1	ºF	0	0.1	0	EGT 1	0.0	✓	9B
1515	0	2	1	BAT	V	0	0.1	0	Battery Voltage	0.0	✓	9C
1515	2	2	1	IN1		0	0.1	0	Generic Input 1	0.0	✓	9D
1515	4	2	1	IN2		0	0.1	0	Generic Input 2	0.0	✓	9E
1515	6	2	0	Knock	deg	0	0.1	0	Knock Retard			
1516	0	2	0	Speed	m/s	0	0.1	0	Vehicle Speed			
1516	2	2	1	TC	deg	0	0.1	0	Traction Contro			
1516	4	2	1	Launch	deg	0	0.1	0	Launch Timing			
1516	6	2		Spare		0	1	0	Not used			

Here available ECU channels are selected to be acquired within the test.

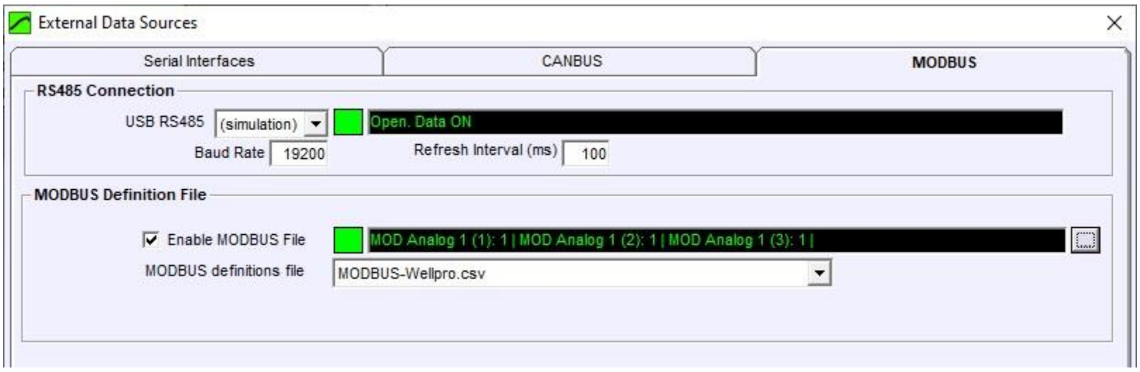
16.3.2.3 Enable CANopen Interrogator

CANopen is typically used for Electric Motor Controllers. This checkbox enables the interrogator loop.
CANopen protocol is based in a query-reply schema (instead of using a listener), this may cause some overhead in the bus and cause some collisions with other devices like the DVT Software used for SEVCON controllers. When it is possible, listener is preferred over CANopen (for instance SEVCON offers both methods for the telemetry)

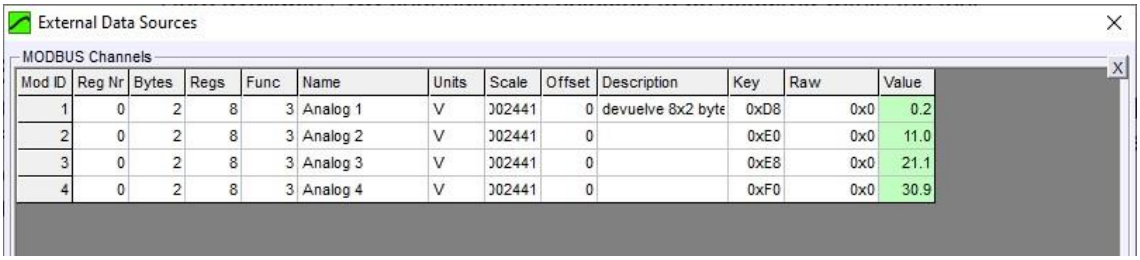
16.4 MODBUS

MODBUS is a classical bus in industrial automatization. It is based on a single link with RS485 differential lines (2 wires + GND optional). Thus an USB-RS485 adapter has to be used. There are lots of adapters compatible with Sportdyno, as long as they provide a virtual COM (same as for RS232 USB-serial adapters)

MODBUS is a protocol based on enquiry-response, not broadcast. We have implemented a full MODBUS interface based in a definition file similar to the CAN definition files.



For instance WELLPRO MODBUS devices are a cheap solution for analog acquisition, they have 8 x 0-10V inputs, no other modes are available.



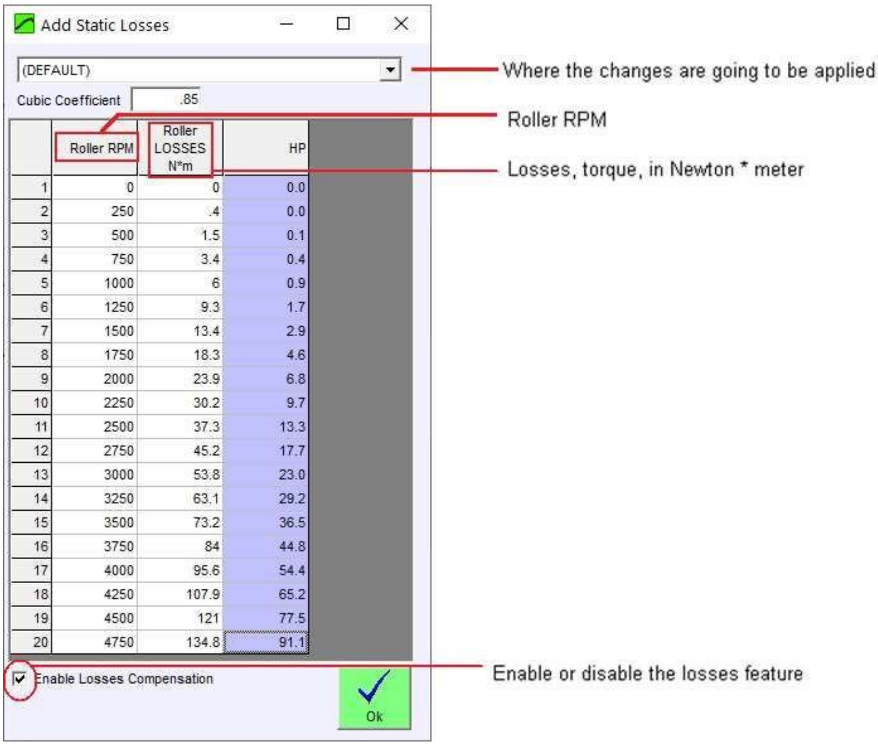
Other definition files can be provided under request. Please send an email to info@sportdevices.com to get more information about the compatible devices.

For configuring the RS485 connection, you have to find out:

- **RS485 COM**. It is assigned by Windows during the installation of the USB-RS485 adapter.
- **Device Baud Rate.** Common baud rates for MODBUS devices are 9600 and 19200 baud, but most of them can be configured with an external tool to a higher speed.
- **Refresh Interval.** Each device has a maximum allowed enquiry rate. A recommended value is 100 ms or slower.

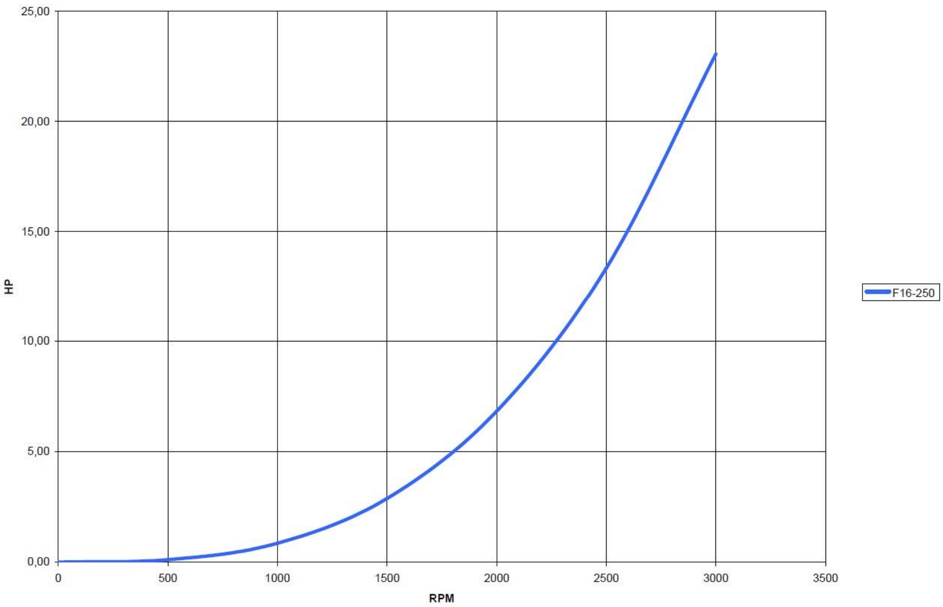
16.4.1 Add Static Brake Losses.

This option is useful for dynamometers with brake, in which the brake has losses (air friction) which cannot be measured with the load cell, and the user want to compensate these losses by using the retarder's manufacturer data, especially if the dyno has no clutch to measure the friction losses by the usual coast down method.



	Roller RPM	Roller LOSSES N*m	HP
1	0	0	0.0
2	250	.4	0.0
3	500	1.5	0.1
4	750	3.4	0.4
5	1000	6	0.9
6	1250	9.3	1.7
7	1500	13.4	2.9
8	1750	18.3	4.6
9	2000	23.9	6.8
10	2250	30.2	9.7
11	2500	37.3	13.3
12	2750	45.2	17.7
13	3000	53.8	23.0
14	3250	63.1	29.2
15	3500	73.2	36.5
16	3750	84	44.8
17	4000	95.6	54.4
18	4250	107.9	65.2
19	4500	121	77.5
20	4750	134.8	91.1

Example, Frenelsa F16-250 brake



We model the air pump losses as: **HP = ct * (rpm / 1000) ^3**

(Other losses sources may exist: bearings, belts, etc, but normally the brake is the biggest one)

In this case HP = 23 for RPM = 3000, then 23 = ct * (3000 / 1000) ^3 = ct * 3^3

➔ ct= 23 / 27 = 0.85 (used in the table above)

Appendix I. What is new in 4.1 version? (Main topics)

- New Gauges interface
- New channels arrangement (Engine HP, Wheel HP, friction HP are always available at same time)
- New Report "Type 2"
- New filters: polynomial filters
- New test modes. (braked coasting)
- New PID / Brake Maps

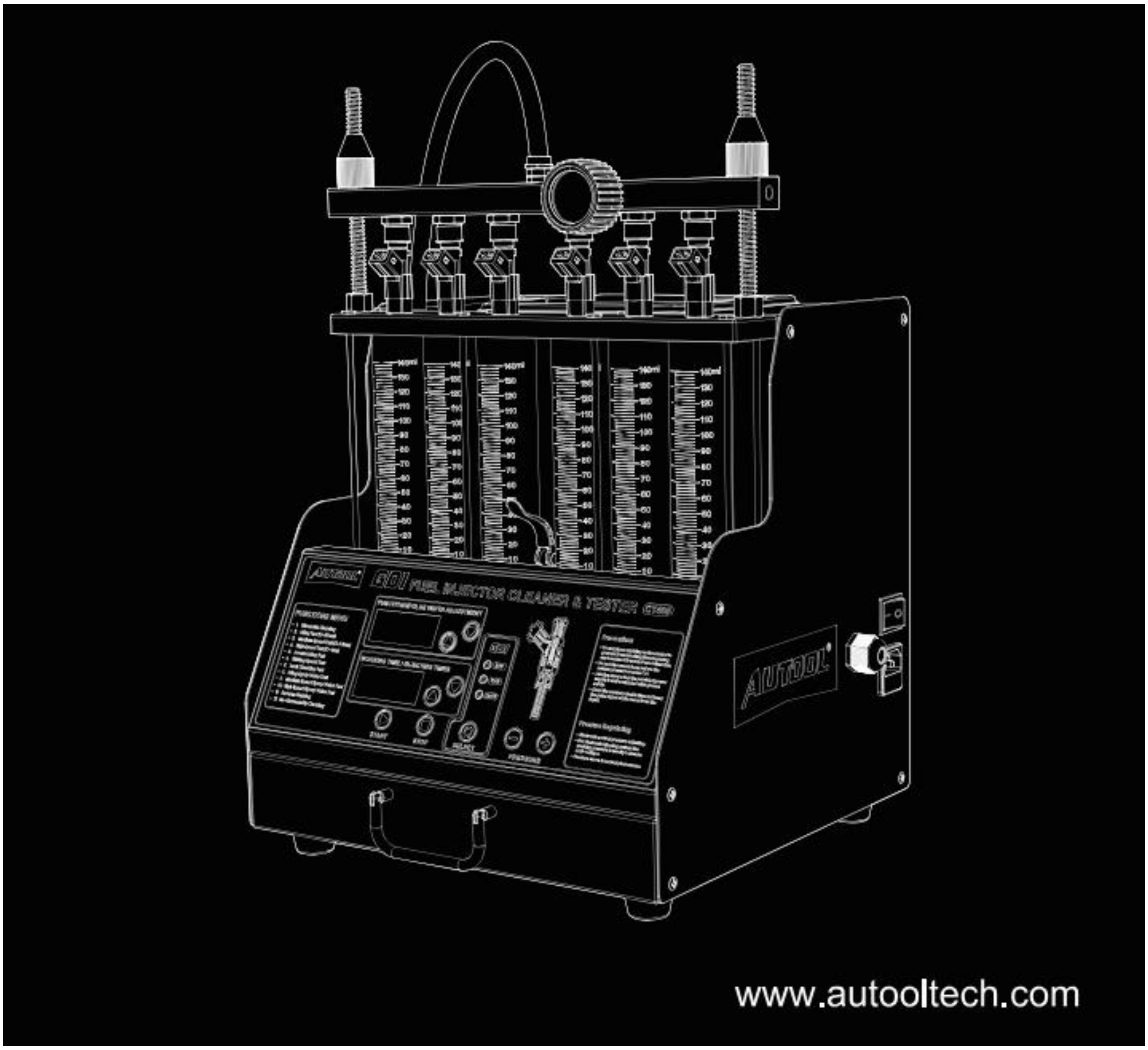
D.4. Manual d'usuari AUTOOL CT400

AUTOOL

AUTOOL CT400

Injector Cleaner & Tester

User Manual



Copyright Information

Table of Contents

Overview

1.1 Functions and features

This GDI Fuel Injector 6-cylinder Cleaner and Tester is a great upgrade, which adapts the latest GDI design. It not only can be used to clean and test the standard injectors, of note that it can carry out GDI injectors cleaning and tesst. It comes with multi voltages available for GDI injectors, which enables to adapt for different types of injector testing. The machine is the necessary and preferred equipment for the automotive serving and maintenance, research, and teaching training departments.

Functions

- Ultrasonic cleaning: To perform simultaneous cleaning on one or several injectors and to remove the carbon deposits on the injector completely.
- Uniformity test: To test the uniformity of injecting amount of each injector.
- Sprayability test: To monitor the spraying status of each injector with the help of a backlight.
- Leakage test: To test the sealing and dribbling conditions of injectors under system pressure.
- Injecting flow test: To check the injecting amount of the injector under specific working parameters (e.g. same time, same number of times).
- Automatic test: Under specific working parameters, test injectors by simulating different working conditions.
- Adopted with the latest unique GDI fuel injector driving software, which can drive 12V, 70V, 120V high-pressure fuel injectors.

Features

- Adopting the powerful ultrasonic cleaning technology, the equipment offers complete cleaning to the injectors.
- Fuel pressure control through microcomputer offers stable pressure control and large adjustable range.
- Adopting high-definition digital control panel display, it makes the operation simple and easy to learn.
- Test liquid level can be displayed visually. It can also be recovered for recycling use.
- With the help of the bright background light of the LED, it is possible to clearly observe the various working conditions of the injectors.
- Replaceable composite coupling with patented and suitable for many models.
- The test time, operating frequency, number of injecting, and minimum switching pulse width of the injector can be adjusted freely within the allowed adjustment range.

1.2 Working environment and technical parameters

Working environment

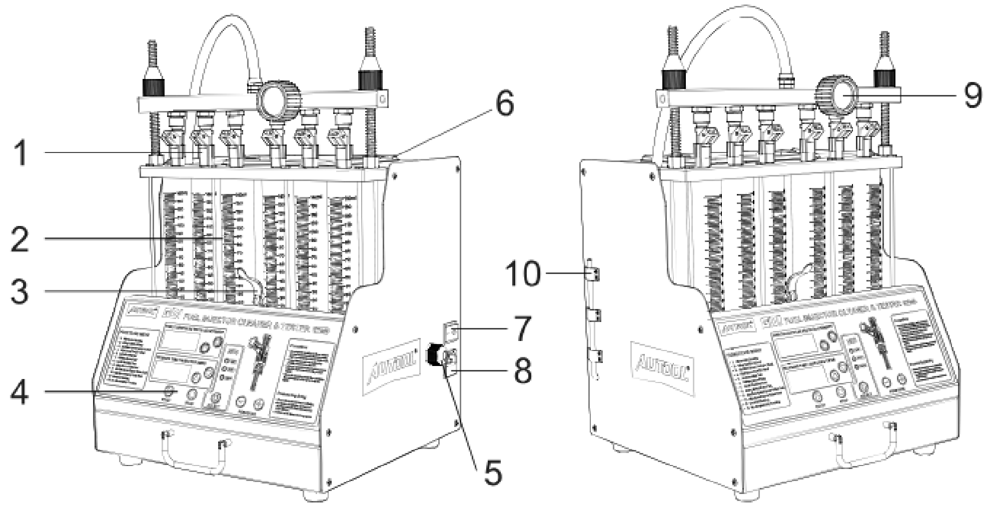
- Power supply: AC 110/220V ±10%
- Frequency: 50-60Hz±0.5
- Relative humidity: <85%
- Ambient temperature: 0 C ~ + 40 C
- External magnetic field strength: <400A/m
- No open flames are allowed around

Technical parameter

- Fuel tank capacity: 1500 ml
- Test tube amount: 140 ml
- RPM range: 0~7500 r/min
- Time range: 0~9900 times
- PWM pulse width: 0~20.0 ms
- System pressure: 0~0.55Mpa (adjustable)
- Timing: 0~20 minutes adjustable
- Ultrasonic cleaning power: 60W (intermittent work)
- Ultrasonic cleaning frequency: 28KHZ±0.5 KHZ
- Dimensions: 390mm (length) x 410 mm (width) x 430 mm (height)
- Weight: 16.6KG

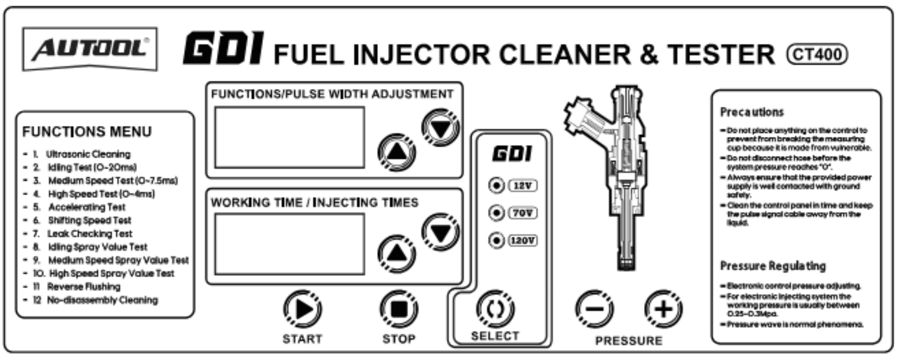
Structure

2.1 Overview structure



1- Filling inlet; 2- Test tube; 3- Drain button; 4- Control panel;
5- Pulse signal cable; 6- Ultrasonic cleaning bath; 7- Power switch;
8- Power socket; 9- Pressure gauge; 10- Test liquid drain valve;

2.2 Control panel



- Pulse width display: function options and pulse width adjustment.
- Display of working hours/injecting times: display the working hours and injecting times of the injectors.
- Start key: press to execute the selected work item.
- Function menu selection buttons.
- Pause key: Press it to temporarily stop the selected work item.
- Time and frequency adjustment button: adjust the working time and spray frequency of the fuel injector.
- Stop key: stop the selected work item and return to the selected work item.
- Pressure decrease adjustment button.

- Pressure increase adjustment button.
- Text description of function menu.

How to use the drain button
When performing work items 8, 9, and 10, press the button to close the drain valve. Then the oil injected by the fuel injectors is closed in the glass tube, so as to compare the amount of oil injected by each fuel injector. After the observation, open the oil drain valve and return the test liquid to the oil tank.

Operation Procedures

3.1 Ultrasonic cleaning

Injector Cleaner takes advantage of the penetrability and cavitation impact wave caused by ultrasonic waves traveling through the middle to provide powerful cleaning on objects with complex shapes, cavities, and pores so that the stubborn carbon deposits can be removed from the injectors.

Preparation:

- Remove the injector from the vehicle engine to check the rubber seals inside for damage. Replace the damaged rubber seals with another same type of rubber seal to avoid leakage during testing. Put the outside of injectors in gasoline or detergent, and wipe them with a soft cloth after cleaning the outside oil sludge carefully.
- Turn on the power (Note: There will be a delay of several seconds when this device is restarted after a long power disconnection).
- Take out the cleaning bracket from the accessory box, then put it into the ultrasonic bath, and put the clean fuel injector in the positioning hole of the cleaning bracket in the ultrasonic bath.

3.1.2 Operation steps

Ultrasonic Cleaning:

- Add appropriate injector cleaning liquid into the ultrasonic bath, which
- slightly immerses over the cleaning bracket will be fine.
- Turn on the ultrasonic switch on the right side of the main unit to start ultrasonic cleaning.
- During the ultrasonic cleaning process, pulse signals can be input to the fuel injector.

Steps:

- Plug the injector pulse signal wires into injectors respectively in turn. (Special injectors need to be connected with adapter wires).
- Press the item selection up and down keys to select the ”01 Ultrasonic Cleaning" item, and then press the working time up and down keys to set the

time. (The system defaults to 10 minutes, if you need to modify the time, you can change it with the up and down keys)

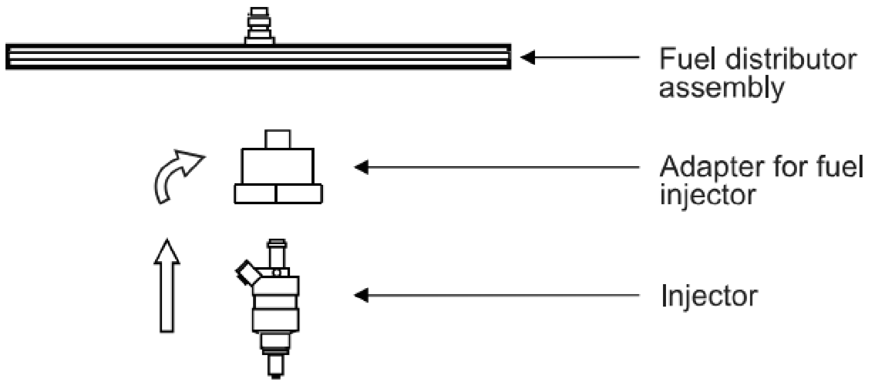
- Press the run key, and the system starts to input pulse signals.
- When finished cleaning, take out the injectors from the ultrasonic tank. Wipe off the cleaning liquid with a soft cloth and prepare for the next operation.
- Notes:
- During the cleaning process, you can hear the intermittent vibration when you take the fuel injector out and put it near your ear, which can determine whether the injector has a pulse signal.
- Before the injector detergent is added into the ultrasonic cleaner, do not turn on the ultrasonic cleaner. Otherwise, damage may be incurred.
- Only the ultrasonic cleaning liquid matched with the machine can be added to the ultrasonic tank, and other cleaning liquid can not be used instead, otherwise, the surface coating of the equipment and the mask will peel off, which will not be covered by the warranty.

3.2 Test functions

This function is to detect the sprayability, dripping, blockage, fuel injecting angle of the fuel injectors and the amount and uniformity of the fuel injection of each fuel injector at different RPM.

3.2.1 Preparation

- Add test liquid. Pour the test liquid from the filling port. (Approximately 1000ML is added, and the liquid level should not be lower than 800ML every time)
- Installation of fuel injectors



Schematic diagram of injector installation

A. Install the injector adapter and the plug into the Fuel distributor assembly
B. Install the fuel injector in the forward direction (apply a little grease on the "O" ring of the fuel injector)

C. Install the fuel distributor assembly and the fuel injectors on the Top assembly plate and tighten and fix it with a fixed screw nut and a fixed screw sleeve. Get ready to test.
D. Select 12v/70v/120v according to injector type.

3.2.2 Steps:

Item 02 idle speed test:

- Connect the quick connector of the black outlet hose on the machine with the male end connector on the fuel distributor assembly, and insert the pulse line of the fuel injector.
- Press the item selection up and down keys to select the "02 Idle Speed Test" item.
- Press the working time up and down keys to set the time. (Normally set to 10 minutes)
- Press the "run" key to start working.
- Rotate the pressure adjustment knob to adjust the pressure to 2-5 kg.(In the electronic spraying system, the oil pressure is generally 2-5 kg).
- Press the up and down keys to select the appropriate pulse width. (The system defaults to 3MS, generally adjusted to 3MS).
- The working time will gradually decrease, and when it reaches 0, the system will stop automatically.

03 middle-speed test:

- Press the item selection up and down keys to select the "03 middle-speed test" item.
- Press the RUN button.
- The rest of the operation steps are consistent with item 02.

04 High-speed tests:

- Press the item selection up and down keys to select the "04 High-speed test" item.
- Press the RUN button.
- The rest of the operation steps are consistent with item 02

05 Accelerated test:

- Press the project selection up and down keys to select the "05 Accelerated test" item.
- Press the RUN button.

Notes:

1) The fuel pressure, working time and pulse width are automatically set by the system. The time system presets 10s as a loop cycle, which can be set by the user.

2) The system will automatically loop three times in a row to simulate the working conditions and fuel spraying amount of the fuel injectors when the engine is accelerating uniformly at 1,500 -15,000 rpm.

06 Various speed test:

- Press the item selection up and down keys to select the "06 Various speed est" item.
- Press the RUN button.

Notes:

1) The fuel pressure, working time and pulse width are automatically set by the system. The time system presets 10s as a loop cycle, which can spare the labor of setting by the user.
2) The system will automatically loop three times in a row to simulate the working conditions and fuel spraying amount of the fuel injectors when the engine is idling (1,500 rpm), middle-speed (9,000 rpm), and high-speed (15,000 rpm).

07 Leakage test:

- Press the item selection up and down keys to select the "07 Leakage test" item.
- Press the working time selection keys to set the time. (Generally set to 1 minute)
- The remaining operation steps are consistent with item 02.

Notes:

1) The pulse width system is preset to 3ms, no need to set it again.
2) Simulate whether the fuel injectors drip and leak when the oil pressure of the vehicle is 0.3Mpa.

Item 08 Idle fuel injecting amount test:

- Press the item selection up and down keys to select the "08 Idle fuel injecting amount test" item.
- Press the up and down keys to set the number of times of injection. (Generally set to 2,000 times)
- The remaining operation steps are consistent with item 02.

Notes:

1) Simulates the working condition and injection amount of the engine at idle speed when the injectors work a certain number of times.

09 Middle-speed fuel injecting amount test:

- Press the item selection up and down keys to select the item "09 Middle-speed fuel injecting amount test".
- The rest of the operation steps are consistent with item 08.

10 High-speed fuel injecting amount test:

- Press the item selection up and down keys to select the "10 High-speed fuel injecting amount test" item.
- The rest of the operation steps are consistent with item 08.

Notes:

1) Uniformity. This is for checking the uniformity carried out at various rpm.
When the test liquid level is at 2/3 of the test tube, please pause or stop the machine to observe the uniformity of the injecting amount. Injecting difference of all injectors on one vehicle should be kept within 2%. Or refer to the relevant technical manual of the fuel injector to determine the uniformity of the injecting amount.
2) Observe the shape of the injectors. Observe whether the injecting shapes and angles of all fuel injectors on the same vehicle are identical at various speeds.
At the same time, you can adjust the injection pulse width of the fuel injectors to compare whether the minimum injection pulse width among the fuel injectors is consistent.
3) Leakage test. Leakage test is to inspect the sealing conditions of the injector needle valve under system pressure. (Observe the tightness of the fuel injectors, generally, there should be no leakage within one minute)

11 Reverse Flush Test:

- Press the item selection up and down keys to select "11 Reverse Flush", and install the injectors in the opposite direction for cleaning.

12 Fully Automatic Cleaning items:

- Cleaning time can be set to a maximum of 20 minutes. Please connect to various special parts that can clean the combustion chamber or throttle.

Maintenance

1. Tidy up

- Turn off the power and unplug the power plug.
- Put all the connectors back into the accessory box for storage.
- Put the ultrasonic cleaner back into the original bottle and seal it, and wipe the equipment clean with a dry soft cloth.
- If it is not used for a long time, open the test liquid valve and drain the test liquid back into the original bottle for sealed preservation.

2. Maintenance
Replacement of test liquid

- Impurities can be built up in the test liquid after being used for a period of time. Do not use contaminated test liquid, otherwise, injector and fuel pumps can be blocked. Drain the test liquid by removing the level indicator on the left of the main unit. It is better to clean the fuel tank with a little test liquid before the tank is filled in with the new liquid. After cleaning, close the test liquid valve again and pour in new test liquid.

Replacement of Fuse

- There is a square box marked with a fuse at the power socket on the left side of the equipment, and the fuse can be seen by opening the square box. If it is blown, replace it with a new one (5A).

Precautions

- Since the test device is quartz glass, which is easy to be broken, please don't place other objects around the device to avoid breaking by bumping.
- If there is no digital display after power on (there may be a delay of several seconds), please check whether the power supply has electricity; if there is a power failure, please check whether the plug is firmly connected, or check whether the fuse is blown. If there is no break, and the switch is still not working after pressing several times, please contact your local dealer, do not disassem- ble it by yourself, otherwise our company shall not warranty.
- Do not switch on the ultrasonic system when there is no ultrasonic detergent in the ultrasonic cleaning chamber. Otherwise, damage to the ultrasonic cleaner can result.
- It must be emptied completely before adding 1000ml of test liquid for every test liquid change.
- The use of unqualified test liquid will cause corrosion of the pump and oil supply line and failure of the pressure gauge.
- Only the ultrasonic cleaning liquid matched with the machine can be added to the ultrasonic bath, and other cleaning liquid can not be used instead, otherwise, the surface coating of the equipment and the mask will peel off, which will not be covered by the warranty.
- Kerosene, gasoline, pure water and other testing and cleaning solutions are strictly forbidden to be used as the testing and cleaning solution for this equip- ment. Otherwise, it will damage the "O" ring and rubber parts of the pipeline inside the equipment and cause leakage.
- Do not mix cleaning liquid with testing liquid.
- Please place the machine on a flat surface and use the four feet to support the weight of the machine, otherwise the ultrasonic cleaning bath will be damaged, which is not covered by the warranty.

Warranty

- Thank you for choosing our products, we will provide you with the following services and promises.
- The warranty period of this product is 1 year.
- After the warranty period expires, repairs will be charged for replacement parts.
- After the failure, please contact the manufacturer, we will give you the most complete service in the shortest time.

The following items are not covered by the warranty:

- Vulnerable parts are not covered by the warranty, including: glass tube, signal sire, stickers, connectors pressure gauge, oil outlet pipe.
- When no cleaning agent is added to the ultrasonic tank, turning on the ultrasonic cleaning switch will damage the ultrasonic system, which is not covered by the warranty.
- If the testing agent is not replaced in time after long-term use, the oil pump filter screen is blocked and the oil pump is burned out of the warranty.
- The use of fuel injector cleaning agent as fuel injector testing agent will cause the fuel pump to burn out, which is not covered by the warranty.
- Man-made faults are not covered by the warranty.

Disclaimer: All information, illustrations, specifications contained in this manual, AUTOOL resumes the right of modify this manual and the machine itself with no prior notice. The physical appearance and color may differ from what is shown in the manual, please refer to the actual product. Every effort has been made to make all descriptions in the book accurate, but inevitably there are still inaccuracies, if in doubt, please contact your dealer or AUTOOL after-service centre, we are not responsible for any consequences arising from misunderstandings.

AUTOOL®

深圳市偶然科技有限公司

广东省深圳市宝安区北八路航城锦驰产业园

Shenhua Innovation Park, Baoan, Shenzhen, China

www.autooltech.com

aftersale@autooltech.com

+86-400 032 0988 / +86-755-27807580

FC CE RoHS Made in China