ELECTRONICS DESIGN REPORT

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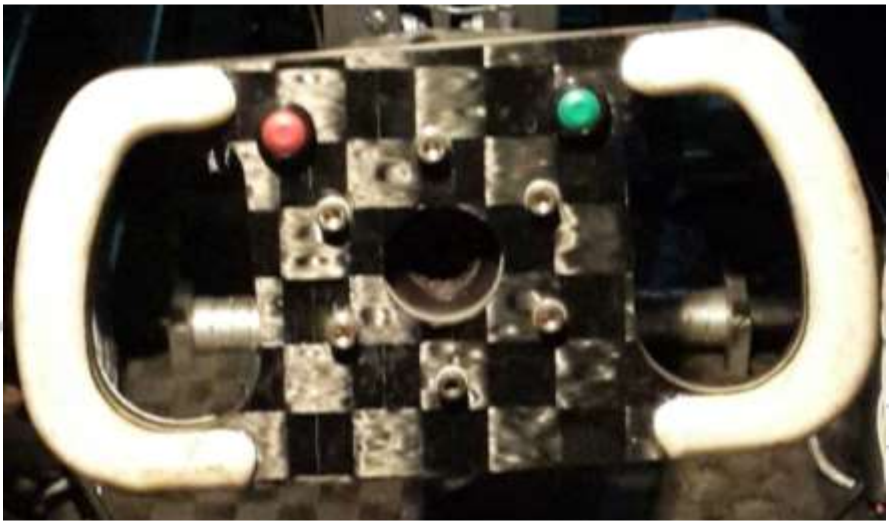
Goal

1. To create an optimized electrical wiring harness.
2. To create a Data Acquisition wiring harness and collect as much as data possible for the sensor during dynamic condition.
3. To create a DASH for better driver performance.

ELECTRONIC BUTTON SHIFTING

INTRODUCTION:

The conventional system for shifting gear i.e. the mechanical lever for gear shifting is widely used. This year we used Electric Button Shifting System to shift gears. At the Formula Student circuit, we require our car to shift gears quite frequently. Getting the slightest edge over our worthy competitors is our utmost priority. With this electronic gear changing system we have been able to achieve that.



Steering wheel with the push buttons

PURPOSE:

Issues faced during manual shifting are following:

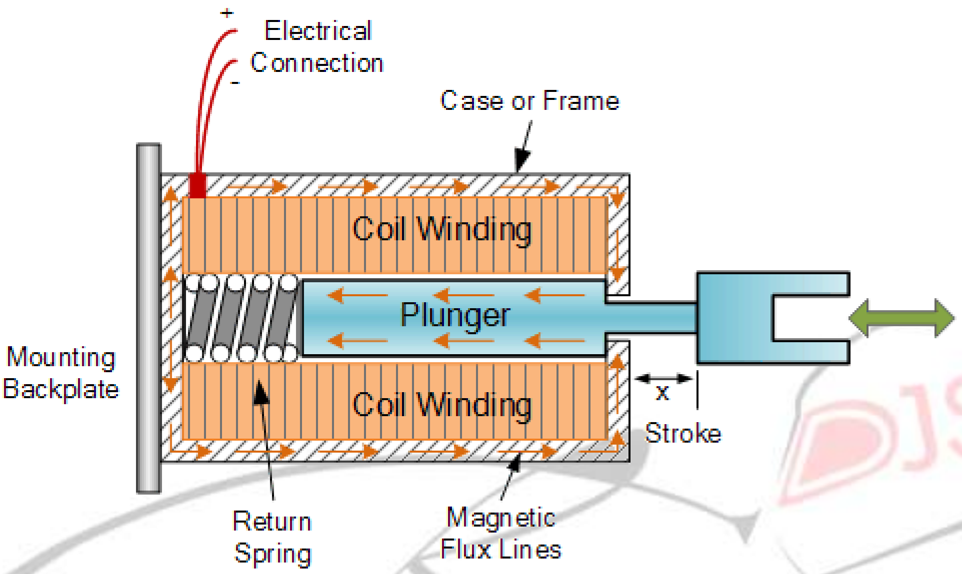
1) The driver having less control on the steering wheel
2) Extra time required to shift the gear
3) Use of clutch

Even though these issues seem to be minor when compared to possible problems in an engine, mastering these is what gives us the edge. Having the system installed on our car we overcome these problems in the following ways:

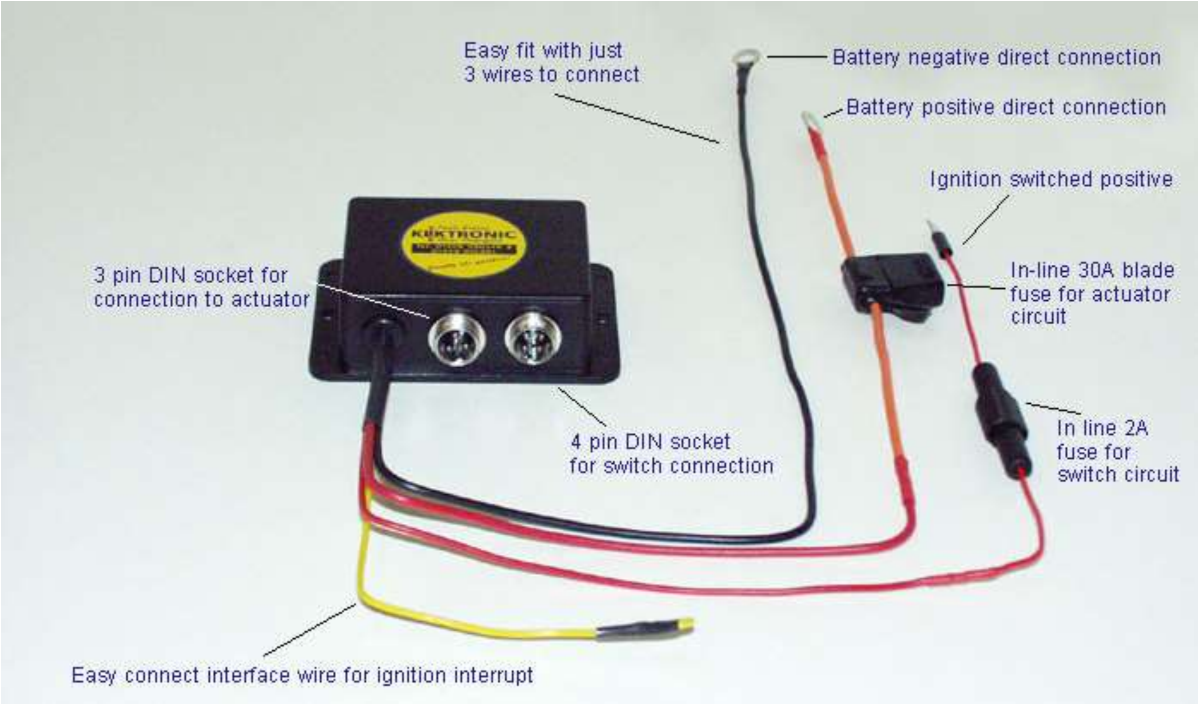
1) The driver can comfortably use the red (for downshifting) and green (for up shifting) buttons without having to release his hand from the steering wheel. Besides, these buttons give a firm tactile feedback when pressed.
2) The primary advantage of using this system is to obtain faster shift times.
3) Up shifting can be made clutch – less by using either the blipping technique or using an ignition interrupt which causes the ECU to kill the engine for a few milliseconds. This causes the engine rpm to drop; thereafter the gear shift takes place.

MECHANISM:

We decided to use the KLICKTRONIC electronic button shifting system to get our job done. Our mechanism is based on the soul principle of a linear solenoid actuator.Linear solenoids basically consist of an electrical coil wound around a cylindrical tube with a Ferro-magnetic actuator or "plunger" that is free to move or slide "IN" and "OUT" of the coils body.



When the up shift button mounted on the steering wheel is pressed, it sends a digital signal to the solenoid's electric control box. This unit decides whether it is an up shift or a downshift signal. Based on that it sends a pulse to the solenoid which is then actuated and a stroke of 52mm is achieved. This stroke length is enough for the maximum up shift gear, i.e. 6^{th} gear and back to neutral position. The arm of the actuator is linked to the rocker arm of the transmission box which moves in a direction corresponding to the direction of motion of the linear solenoid actuator. This would then shift the gear (up or down) to the required position. Up shifting can be made clutch – less by using the blipping technique. However, a downshift will require the use of a clutch



The Control Unit And Wiring

Actuator

Actuator - Length (body): 150mm - Diameter: 50mm - Length of connecting rod (6mm dia): 80mm extended - 30mm retracted.

Power consumption Amps (nominal 12volt supply) : Standard: 25A - High Power: 35A - Super High Power: 48AWeight 1.5Kg.

MOUNTING:

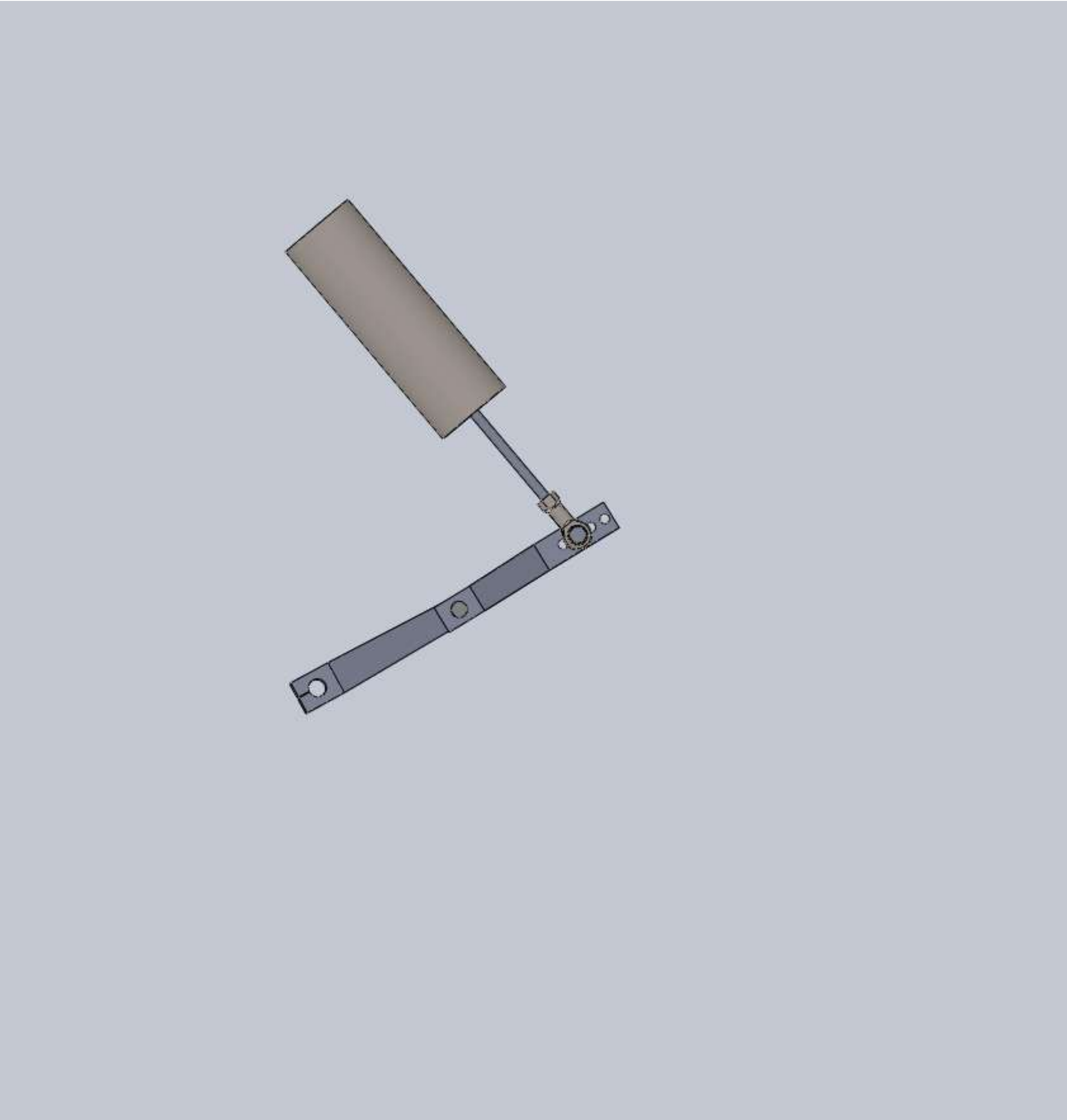
The Solenoid is connected to the rocker arm via connecting rod. Unfortunately, this arrangement was not working in our favour because after mounting the actuator to the chassis, the rod end of the connecting rod was not in the same plane as that of the rocker arm. This meant that one single bolt (which could be used had the plane of the connecting rod been the same as that of the rocker arm) could not be used for assembly of the shifting mechanism.

For this purpose we manufactured an extension in the form of a zigzag shape with holes drilled for adjustment purpose. The extender was then bolted to the rocker arm at one end. The other end had multiple holes drilled, which would allow us to adjust the angle of the solenoid at which we get maximum force exerted at the rocker arm end.

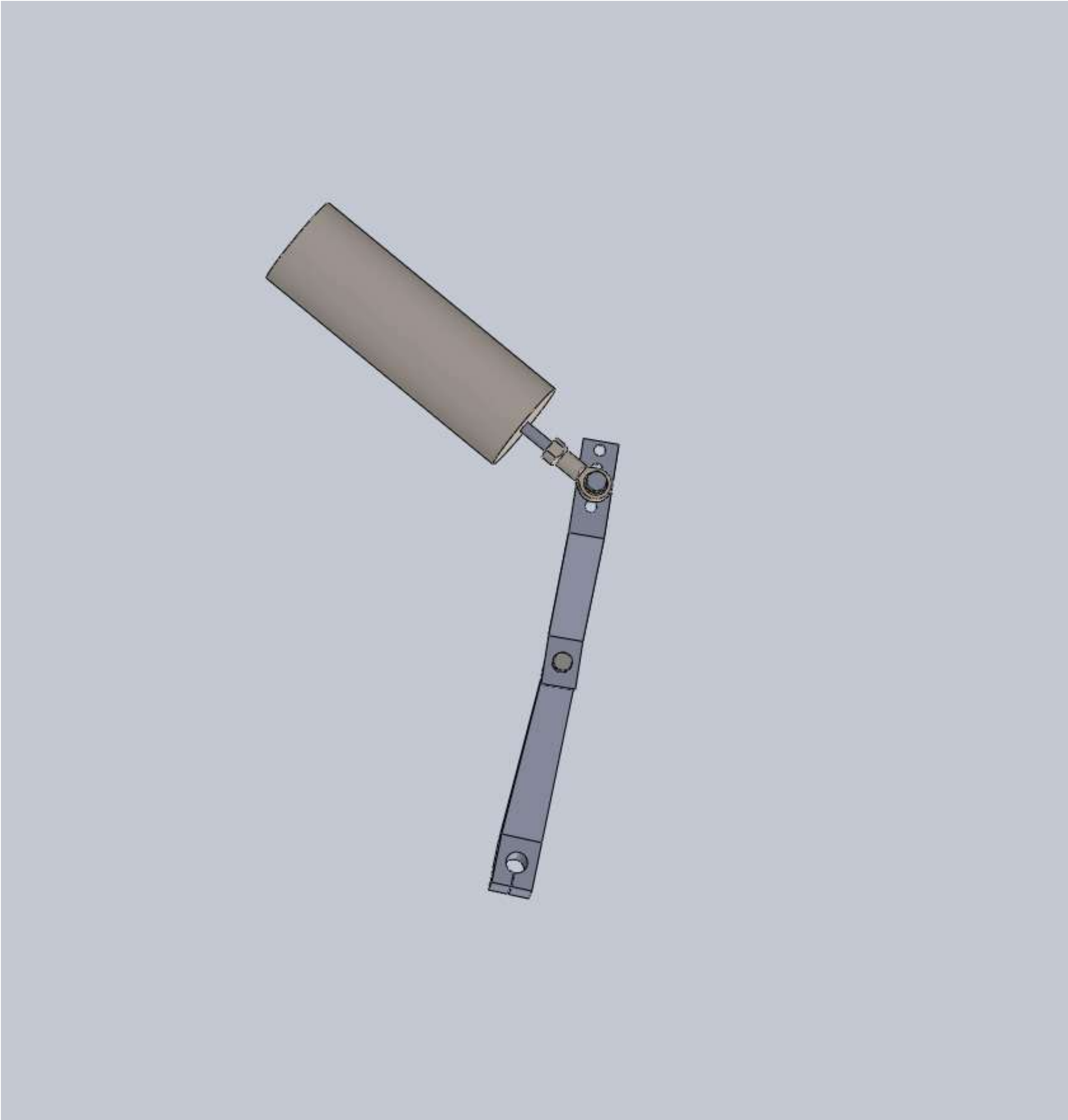
By adjusting the angle of the extender and the angle of the solenoid, we can achieve the desired force from the solenoid. The length of the connecting rod could be adjusted to provide the required push or pull action for up shifts and downshifts. Through multiple iterations of these three adjustments we could achieve the optimum gear shifts.

The following are images of the Actuator – Extender – Rocker Arm assembly.

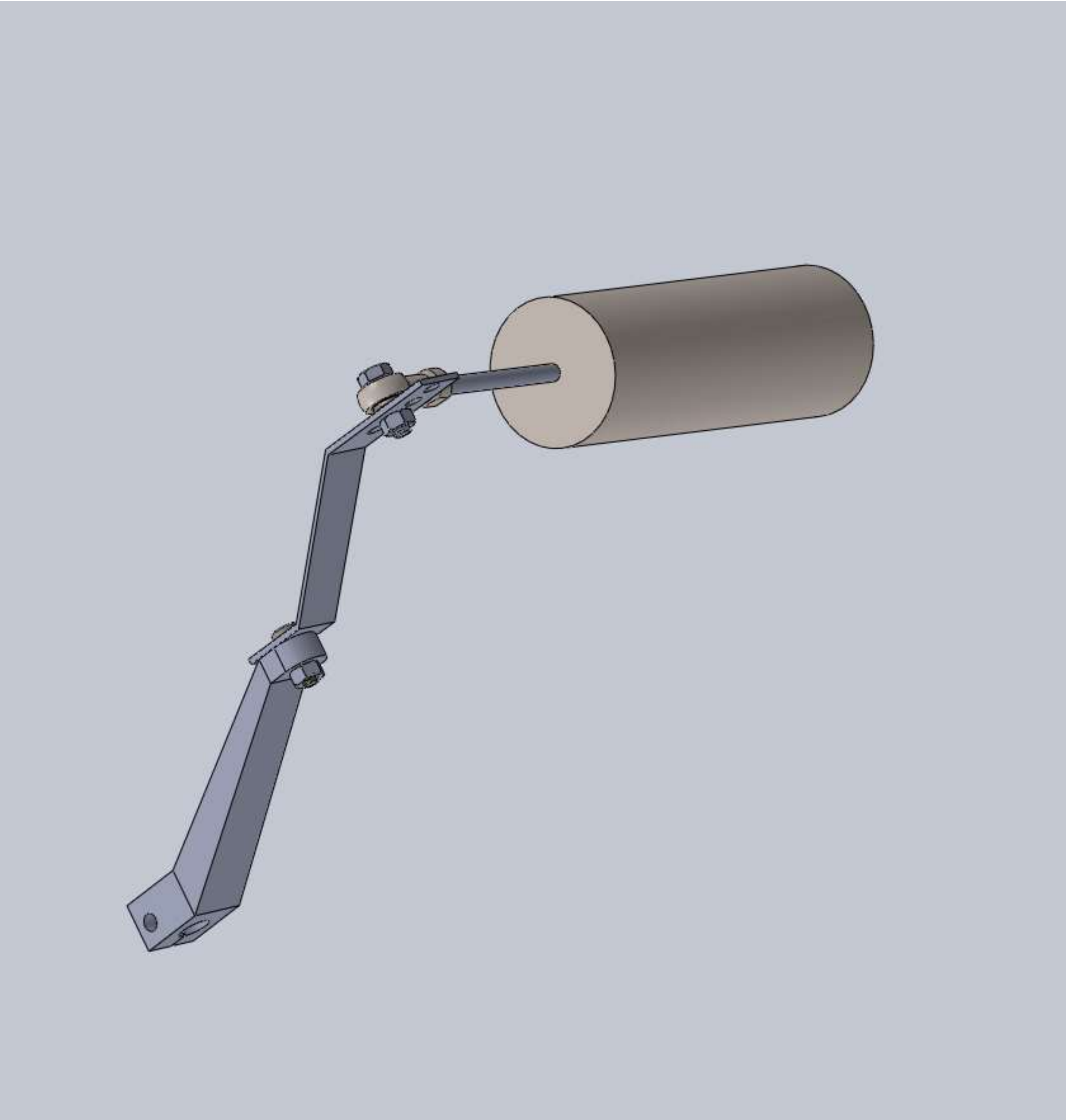
CAD:



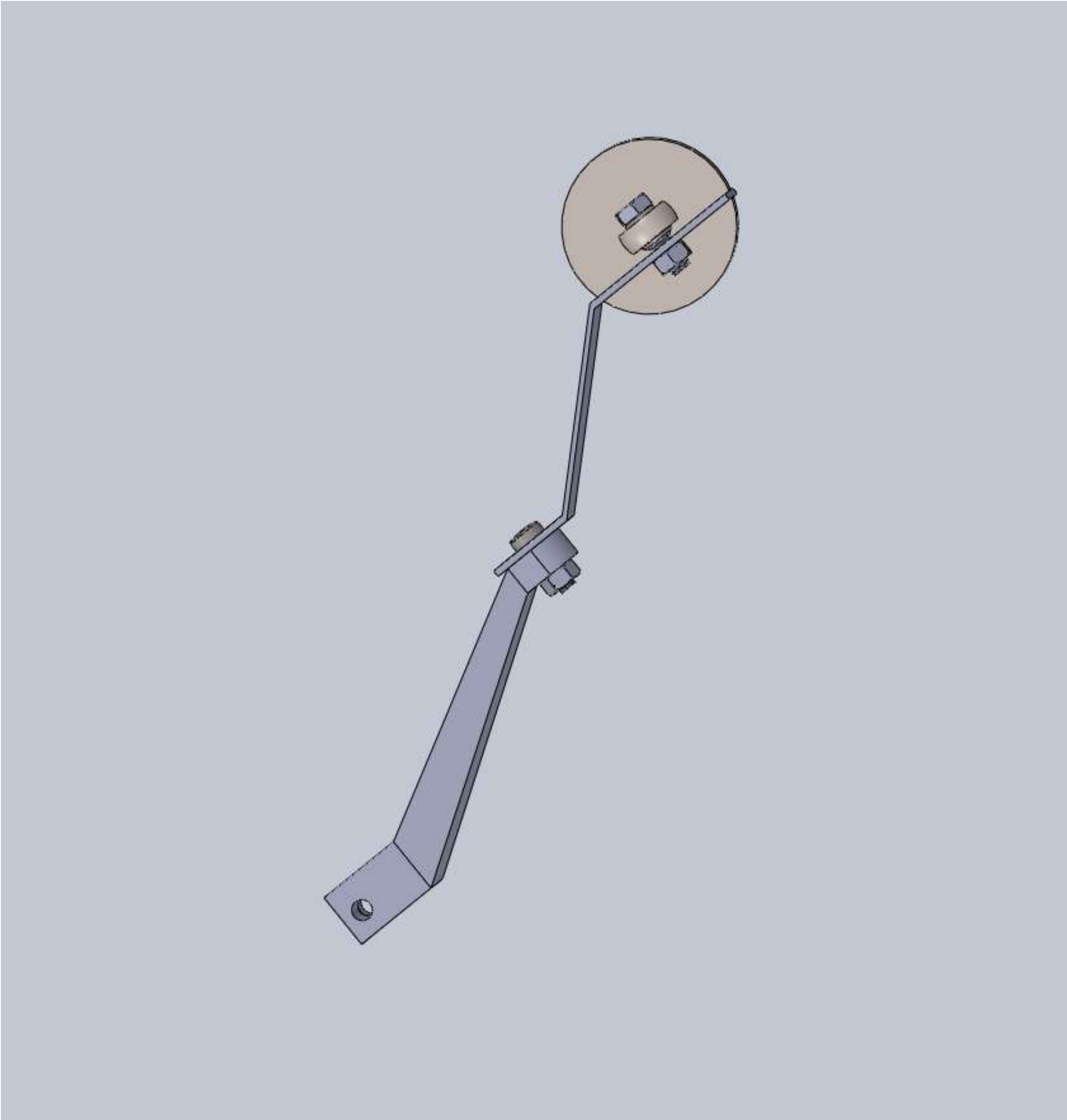
EXTENTION – Total rod length 80mm



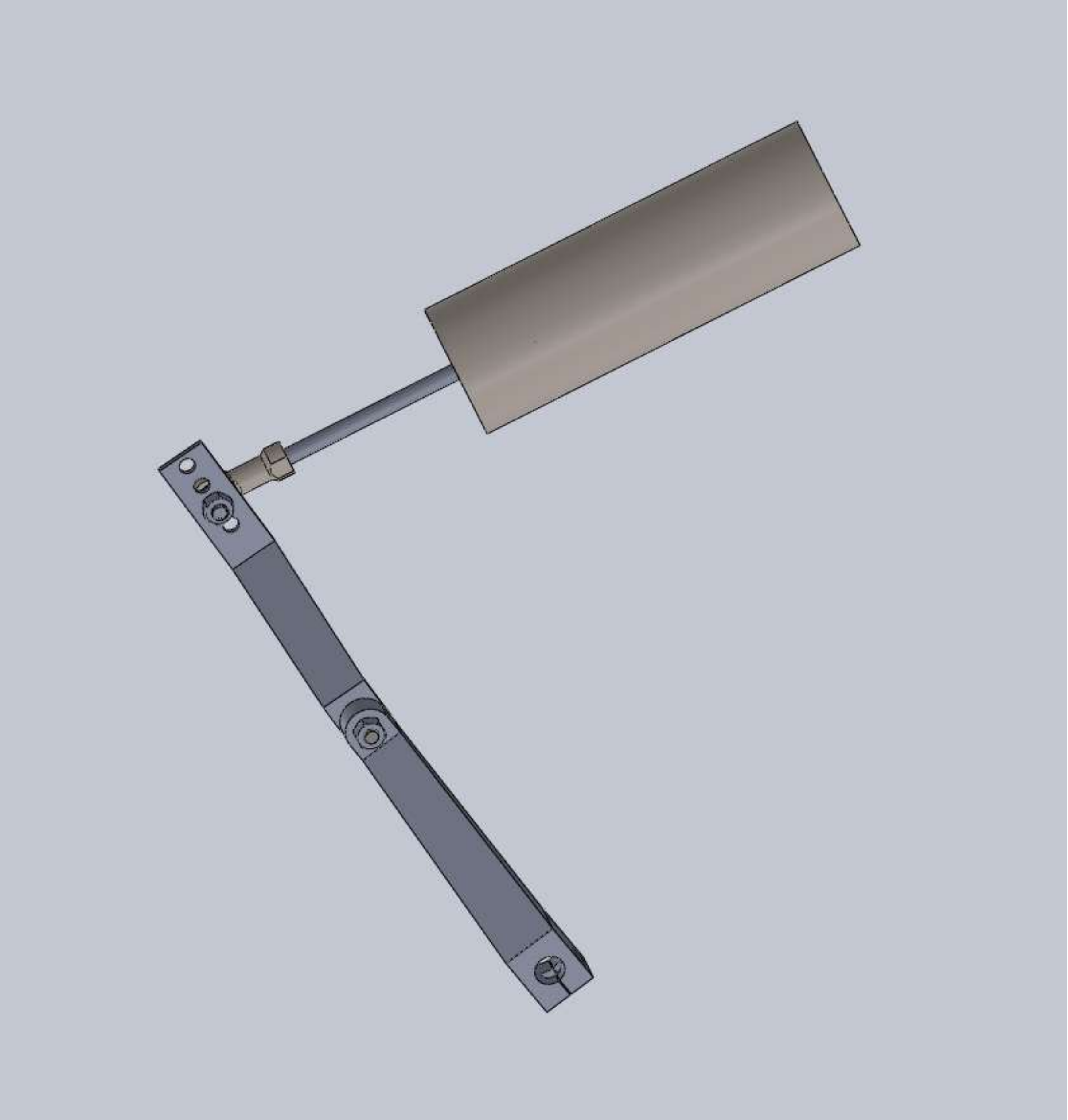
RETRACTION – Total rod length 30mm



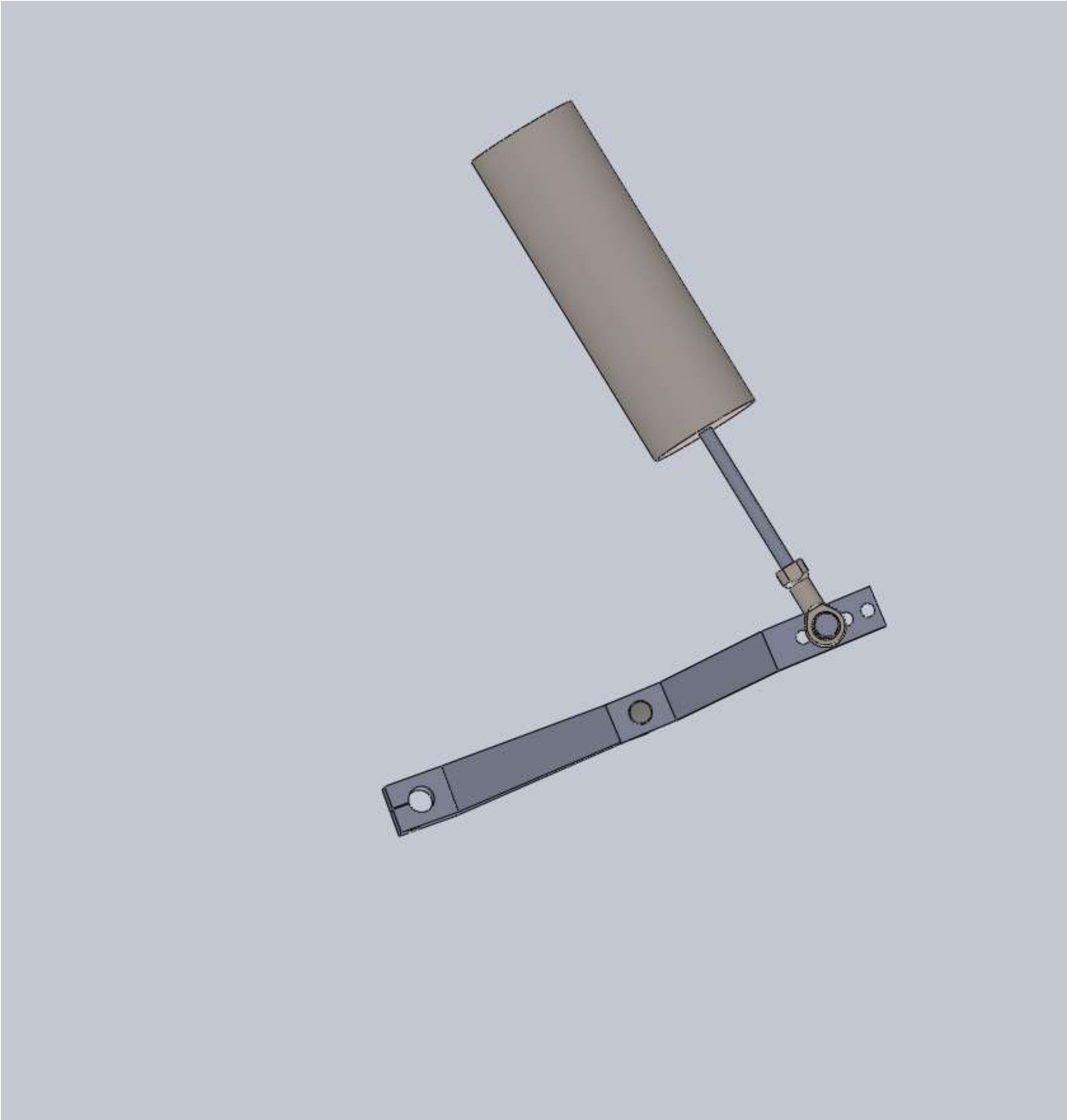
Isometric View



Front View



RHS VIEW



LHS VIEW

WIRING HARNESS:

This year we decided to take a step ahead and manufacture two separate individual harness. It is by far the most important part of a car considering the fact that most cars bow out of the competition due to electrical issues.

MAIN HARNESS: which is the most critical harness as it brings the whole car all together and connected to the ECU.

DAQ HARNESS: which connects various sensors and store the collected data back to ECU.

FIRST ITERATION:

Last year manufactured your own wiring harness. Our plan for this year was to use the optimized version of the wiring harness that we manufactured last year.

The harness which we manufactured last year had a some of issues, major among these were:

1.Over current because the gauge of the wire was not proper which in turn caused rectifier regulator unit burnt off.

2.Frequent Battery Drainage due over current issues, also the Alternator was not able to provide proper value of voltage for recharging mechanism.

3.During testing phase we faced frequent blowing of safety Fuse which shuts down that particular part of the circuit also there were a lot of grounding problems.

Due to all these problems, the team decided to manufacture new optimized wiring harness.

SECOND ITERATION:

In the second iteration, we majorly concentrated on figuring out how to eliminate the over current issues. We decided to separately test the previous year harness part by part and tried to figure out the part of the harness which caused this issue and flaws in the harness. We calculated current in each part and separately calculated the gauge for individual wire. We used the following table for deciding the gauge.

We observed following values of current form testing old harness:

Component	Current (A)
Spark Plug	1.5
Radiator Fan	4.1
Injector	0.5
RF Relay	4.2
Fuel Pump Relay	1.3
Ignition coil Relay	0.8
Power Relay	0.2

AWG	Diameter [inches]	Diameter [mm]	Area [mm^2]	Resistance [Ohms / 1000 ft]	Resistance [Ohms / km]	Max Current [Amperes]	Max Frequency for 100% skin depth
0000 (4/0)	0.46	11.684	107	0.049	0.16072	302	125 Hz
000 (3/0)	0.4096	10.40384	85	0.0618	0.202704	239	160 Hz
00 (2/0)	0.3648	9.26592	67.4	0.0779	0.255512	190	200 Hz
0 (1/0)	0.3249	8.25246	53.5	0.0983	0.322424	150	250 Hz
1	0.2893	7.34822	42.4	0.1239	0.406392	119	325 Hz
2	0.2576	6.54304	33.6	0.1563	0.512664	94	410 Hz
3	0.2294	5.82676	26.7	0.197	0.64616	75	500 Hz
4	0.2043	5.18922	21.2	0.2485	0.81508	60	650 Hz
5	0.1819	4.62026	16.8	0.3133	1.027624	47	810 Hz
6	0.162	4.1148	13.3	0.3951	1.295928	37	1100 Hz
7	0.1443	3.66522	10.5	0.4982	1.634096	30	1300 Hz
8	0.1285	3.2639	8.37	0.6282	2.060496	24	1650 Hz
9	0.1144	2.90576	6.63	0.7921	2.598088	19	2050 Hz
10	0.1019	2.58826	5.26	0.9989	3.276392	15	2600 Hz
11	0.0907	2.30378	4.17	1.26	4.1328	12	3200 Hz
12	0.0808	2.05232	3.31	1.588	5.20864	9.3	4150 Hz
13	0.072	1.8288	2.62	2.003	6.56984	7.4	5300 Hz
14	0.0641	1.62814	2.08	2.525	8.282	5.9	6700 Hz
15	0.0571	1.45034	1.65	3.184	10.44352	4.7	8250 Hz
16	0.0508	1.29032	1.31	4.016	13.17248	3.7	11 k Hz
17	0.0453	1.15062	1.04	5.064	16.60992	2.9	13 k Hz
18	0.0403	1.02362	0.823	6.385	20.9428	2.3	17 kHz
19	0.0359	0.91186	0.653	8.051	26.40728	1.8	21 kHz
20	0.032	0.8128	0.518	10.15	33.292	1.5	27 kHz
21	0.0285	0.7239	0.41	12.8	41.984	1.2	33 kHz
22	0.0254	0.64516	0.326	16.14	52.9392	0.92	42 kHz
23	0.0226	0.57404	0.258	20.36	66.7808	0.729	53 kHz
24	0.0201	0.51054	0.205	25.67	84.1976	0.577	68 kHz
25	0.0179	0.45466	0.162	32.37	106.1736	0.457	85 kHz
26	0.0159	0.40386	0.129	40.81	133.8568	0.361	107 kHz
27	0.0142	0.36068	0.102	51.47	168.8216	0.288	130 kHz

Following table gives the brief idea about various gauge wire that we decided to use while manufacturing the Main Harness.

From	To	Gauge (in mm^2)	Wiring Colour Code
Battery	Master kill switch	16	Red
Master kill switch	Fuse box	5	Red
Fuse box	Fan relay load	2.5	Yellow-Blue
Fuse box	Fuel pump relay load	2.5	
Fuse box	Ignition coil relay load	2.5	
Fuse box	Injector relay load	1	
Fuse box	Power relay load	4	
Relay box	Push start load	1.5	Red Yellow
Master kill switch	AFX	2	Red
Master kill switch	Shifter	2	Red
Master kill switch	Brake light	0.5	Red
Master kill switch	ECU	0.75	Red
Banjo Sensor	Ground	0.5	White
Banjo Sensor	Brake light	0.5	White
Master kill switch	Dashboard	2.5	Red
Power relay load	Aux relay control	1	Green White
Master kill switch	Starter relay	6	
Starter relay control	Push start	1	Orange Yellow
Battery	Ground	16	Black
Injector	Ground	1	Black
Ignition Coil	Ground	0.75	Black
Fuel Pump	Ground	2.5	Black
Radiator fan	Ground	2.5	Black
ECU	Signal	0.5	White
ECU M16	Sensor Supply	0.5	Orange
ECU M26	ECU ground	1	Brown
ECU M09, M18, M20	Ground	1.5	Black

Hence keeping the above table as a reference we decided to manufacture the Main Harness. This helped us to eliminate the over current issues and Battery drainage problems. After this our main aim was to make Main Harness as simple as possible.

THIRD ITERATION:

In this iteration, we deiced to divide main harness into three independent sub-harness this not only provide better understanding but also helps during the troubleshooting the problems in future. Three individual sub-harness were as follows:

1. Sub-Harness 1 which consist of main wiring which connects all the components like Relay and Fuses etc. and sensors on Engine side to the ECU.
2. Sub-Harness 2 which consist of all the connection dealing with Master Kill Switch and the Battery.
3. Sub-Harness 3 which deals with battery recharging part through Master Kill Switch.

Design of Sub Harness 1:

It consists of following components:

1. ECU
2. AFX Unit
3. Stater Relay
4. Relay Box
5. Fuses Box
6. Master Kill Switch
7. BOTS
8. Sensors
9. Break Light

1. ECU

The ECU controls the engine through fuel injection and spark timing. For Spark ignition engines, the quantity of fuel required is in direct proportion to the quantity of air inhaled by the engine. The mass of Air to mass of Fuel ratio (AFR) for ideal operation is stoichiometric. When a three-way catalytic converter is used in production vehicles, the AFR is cycled (through closed loop control) between rich and lean in order for the catalyst to be able to perform both oxidizing and reduction reactions. In racing applications, the AFR is typically maintained rich (that is AFR smaller than AFR stoichiometric) because this produces more power and is safer for the engine

This year also we decided to use the same ECU. The PE3-8400A engine control unit is a compact, adjustable system that handles fuel and ignition responsibilities for almost any engine. It includes 8 injector drivers and 4 internal ignition coil drivers (up to 8 possible with external igniters or smart coils) and comes in an aluminium enclosure. ECU tuning is done with peMonitor software.

General System Features

- Completely adjustable via a laptop
- Waterproof option
- Dedicated CAN bus
- Standard 1MB of on-board data logging
- 25,000+ max RPM
- Password protected access
- Fast and reliable communication via Ethernet
- Extensive error and diagnostic functions
- Primary/Secondary main fuel and ignition tables

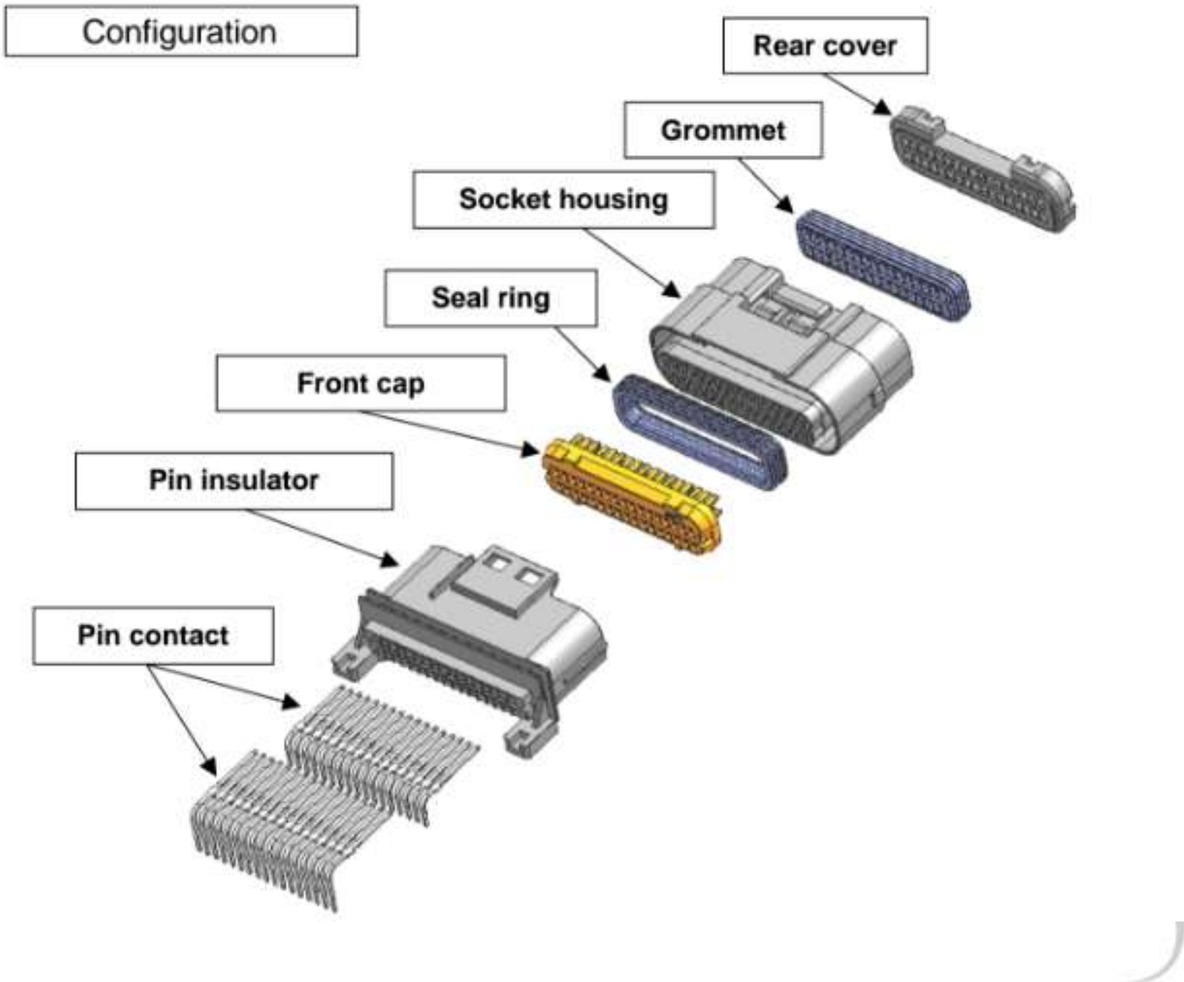
It has two different ports Main port and COM port

Main port has total 34 pins which includes sensor supply and sensor ground, 6 Sensor Signals, 4 analog inputs, 3 Digital inputs, Tachometer output, 10 digital outputs, 2 injector and coil control, 1 main +12V supply input, 3 circuit ground.

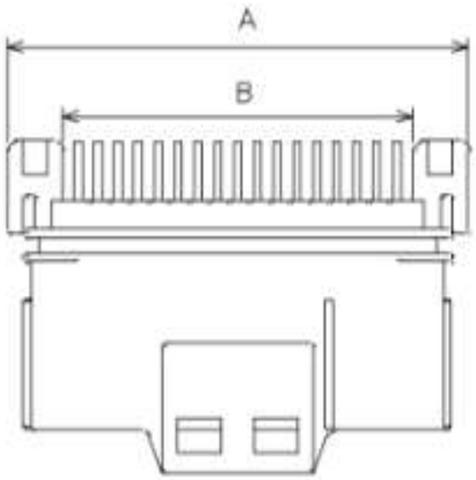
Com port has total 26 pins which includes 4 Ethernet, Can Bus low and high, 4 Analog inputs, 4 Digital inputs, 4 Stepper motor, 6 Injector programable, 2 coil control.

PINS	FUNCTIONS	PINS	FUNCTIONS
M-1	Ignition Coil	M-18	ECU Ground
M-2	Digital o/p 2	M-19	Digital o/p 3
M-3	Injector	M-20	ECU Ground
M-4	N/A	M-21	Digital o/p 4
M-5	Digital o/p 5	M-22	Digital o/p 7
M-6	Fuel Pump Relay Control	M-23	S4/R2
M-7	Fan Relay Control	M-24	Digital o/p 8
M-8	Shock travel (S3)/Ride Height (R1)	M-25	Digital o/p 9
M-9	ECU Ground	M-26	Sensor Ground
M-10	N/A	M-27	Brake light Switch
M-11	Coolant Temperature Led	M-28	Air Temperature
M-12	TMAP	M-29	Coolant Temperature
M-13	Wheel Speed	M-30	TPS
M-14	Wheel Speed	M-31	N/A
M-15	N/A	M-32	CPS
M-16	5V Sensor Supply	M-33	Sync Sensor Signal
M-17	Tachometer Output	M-34	ECU Power i/p (+12V)

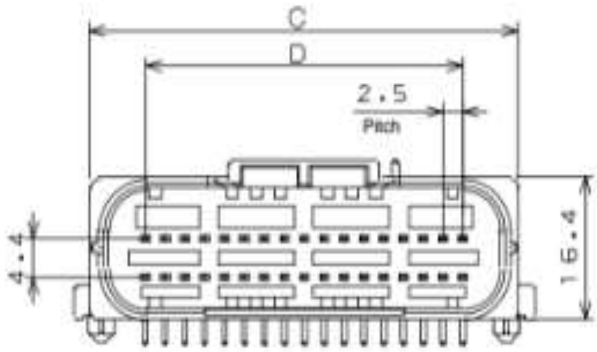
The following table gives the detailed explanation of the connection of the Main Harness with the Main port of ECU.

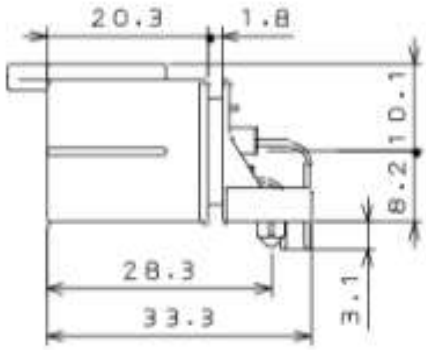


ECU connector



	A	B	C	D	E
12pos.	30.5	16.5	26.5	12.5	23.5
18 pos.	38	24	34	20	31
26 pos.	48	34	44	30	41
34 pos.	58	44	54	40	51



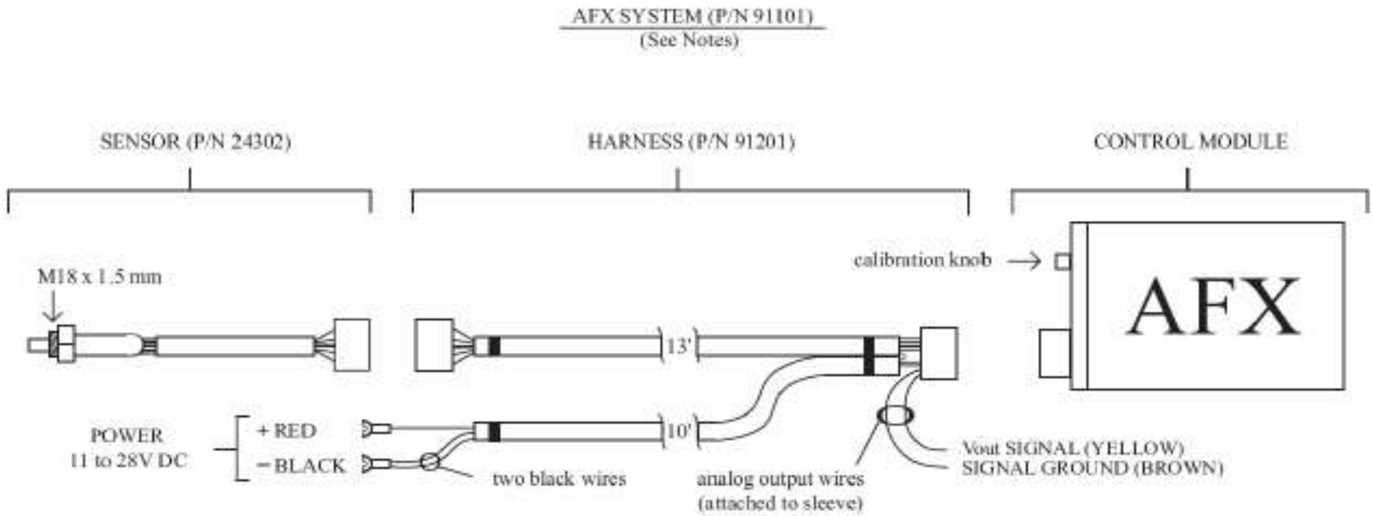


ECU connector dimension

2. AFX Unit

The AFX is a tool to measure the air-fuel ratio (AFR) delivered to carbureted and fuel injected performance engines. Its measurement range is 9.00 to 16.00 AFR for gasoline. This range equates to 0.62 to 1.10 λ (Lambda). For maximum AFR sensor life, the sensor must be powered when in the exhaust of a running engine.

The quality of the AFR measurement depends on the quality of the power you supply the AFX with. The ground terminal (two BLACK wires) should be connected directly to the battery's negative terminal or the body of the vehicle (if metal). Supplying power and ground through a vehicle's cigarette lighter is not recommended. The power terminal (RED wire) should have 11 to 28V DC attached (via a switch or relay) whenever the engine is running. If the sensor is not powered when the engine is running, sensor life will be shortened. The AFX (including sensor) draws less than 2 amps.



AFX Wiring:

1. The AFX considers the point where the two BLACK wires connect to their ground as the 0 (zero) volt reference point.

2. When utilizing the analog output feature of the AFX, always be sure to connect the system ground (two BLACK wires) to the same location as the analog SIGNAL GROUND (BROWN wire). The analog output wires (YELLOW, BROWN) may be lengthened as long as the appropriate gauge wire is used and the connection is solid.

3. It is advised to connect the BLACK wires directly to battery ground or as close to this point as possible. Do not extend the two BLACK wires using a single wire or else this can cause a shift in the ground level of the analog output SIGNAL GROUND (BROWN wire) and any device linked to the analog output (data acquisition or engine controller) will receive an incorrect signal.

4. The RED wire is for system power positive (+). It is acceptable to route this wire through a fuse and/or relay where needed. The wire may be lengthened as long as the appropriate gauge wire is used and the connection is solid.

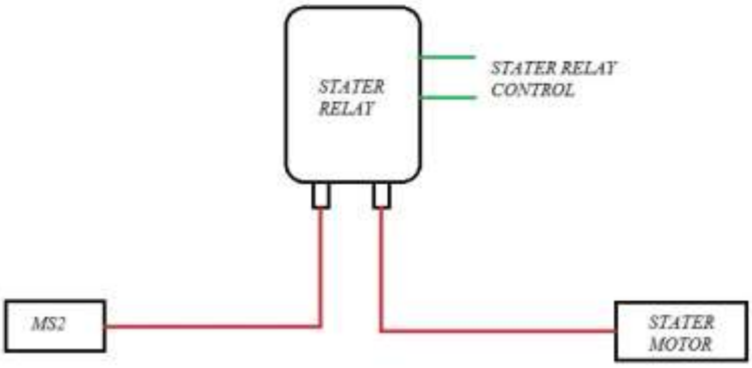
5. The AFX requires approximately 3A for one minute at start-up and after that, requires less than 1.5A for continuous operation.

6. The AFX can operate on any DC supply voltage between 11V ~ 28V. If the power supply to the AFX drops below 11V for even a short time (i.e. during cranking), the AFX will reset itself. Maintain the supply voltage above 11V; above 13V is ideal.

7. If the AFX system constantly resets itself, the cause is most likely low supply voltage or excessive electrical noise from the ignition system. Use a strong battery and route the wiring harness and controller away from ignition components.

3. Starter Relay

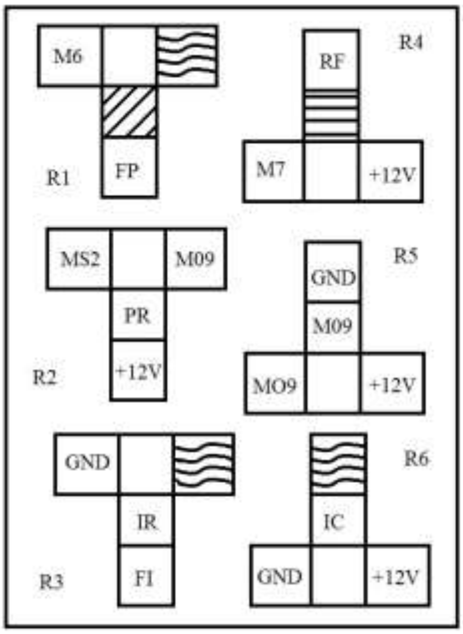
Starter Relay is used to give the positive +12V from battery to the Starter Motor when the Starter Relay control signals are applied. Control signal are produced when the driver press the push start button on the dash. Block diagram of the system is shown below.



Starter Relay wiring

4. Relay Box

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a separate low-power signal, or where several circuits must be controlled by one signal. We implemented our whole Rule compliant harness using six Relays. The following diagram shows the internal structure of Relay Box.



R1 - Fuel Pump Relay

R2 - Power Relay

R3 - Injector Relay

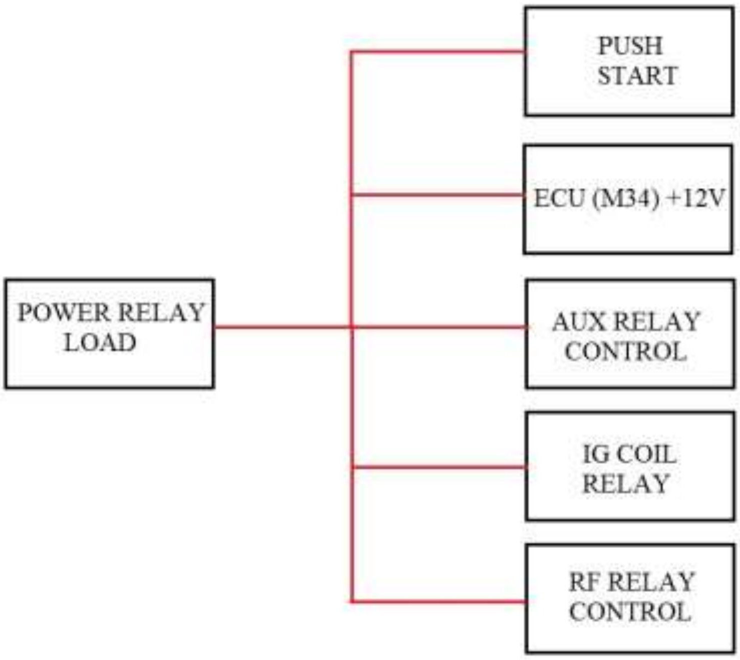
R4 - Radiator Fan Relay

R5 - AUX Relay

R6 – Ignition Coil Relay

1. **Power Relay (R2)**

As the name suggest it gives power i.e. +12V to components like push start, ECU, Ignition coil, Radiator Fan etc. As from the internal structure we can see that MS2 and M09(ECU ground) are the control terminals whereas PR (Power Relay which comes from MS2 to Fuses) and +12v act as the load terminals.



2. **AUX Relay (R5)**

Auxiliary relay gives us extra security function. The main function of this relay is to make sure that there is no short in the system at any point of time due to other relays. Basically, this relay provides a virtual ground which controls the other relays.

3. **Fuel Pump Relay (R1)**

This relay provides power to Fuel Pump motor. This motor helps to pump fuel from fuel tank to the fuel injector against gravity. As long as control signals i.e. cockpit kill switch (which is represented by) is turned closed and the ECU send the signal (M6) fuel pump will work in the desired way. M6 signal help us to control the fuel injection timings.

4. **Injector Relay(R3)**

It gives Power to the Injector which is basically a solenoid. Here also cockpit kill switch () act as control terminal. On receiving the control signal the injector just inject the fuel in the Engine combustion chamber.

5. **Radiator Fan Relay(R4)**

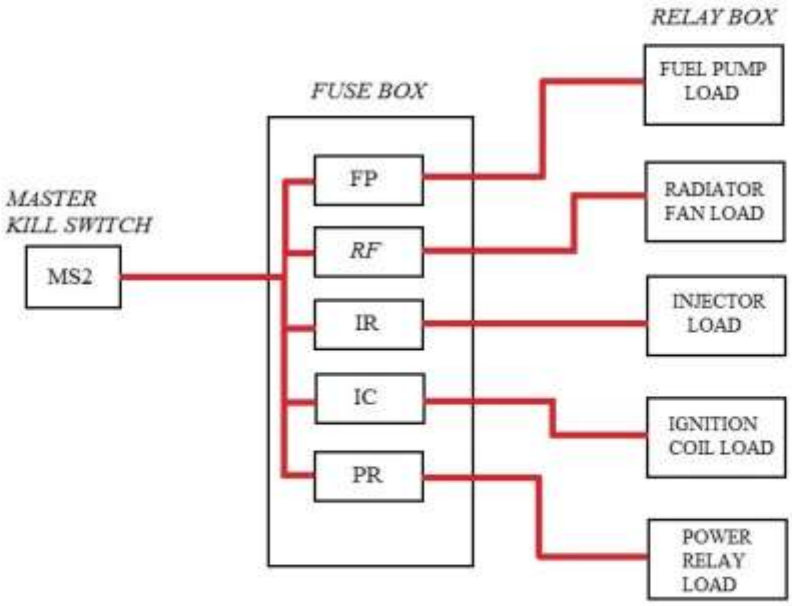
This relay give us flexibility of turning On and Off the radiator fan as per your need. M7 signal from ECU act as control signal. We can set the temperature range such that as soon as that temperature is reached ECU will send the control signal which turn the fan On. We have implemented a switch () between +12V and radiator fan. This help us to make sure that the radiator fan does not drain out the battery during testing when the engine isn't on.

6. **Ignition Coil Relay (R6)**

This relay controls the Ignition. As ignition coil is connected to spark plug, if ignition coil does not get power then there is no spark hence there is no combustion. Here cockpit kill switch () is connected in series with ignition coil.

5. Fuse Box

For the safety of all the components from high current we decided to use Fuses. It helps us to maintain a current limiting factor for a component. If this value exceeds (due to short circuit or some other reason) then the Fuses blows Off breaking the continuity of the circuit and thus protecting the component from overcurrent problems.



FUSE BOX INTERNAL CONNECTION

FP- Fuel Pump in line Fuse (A)

RF- Radiator Fan in line Fuse ()

IR- Injector Relay in line Fuse ()

IC- Ignition Coil in line Fuse ()

PR- Power Relay in line Fuse ()

Following block diagram shows that all Fuses are connected in series with Fuel pump, Ignition Coil, Power Relay, Radiator Fan, Fuel Injector Relay which in turn gives up the overcurrent protection.

6. Master Kill Switch

The master kill switch is used to pass all the battery current through one switch, to different electrical feed circuits. It eliminates the possible damage caused by the alternator circuit. It is used to cut the supply to the ECU, Ignition and fuel pump. Also, the Master kill switch kills the battery and alternator as well

7. Break over travel Switch

It is a normally closed switch. It is connected in series with the cockpit kill switch and the other end goes to the ignition coil relay. It is used to cut Fuel Pump and Ignition only.

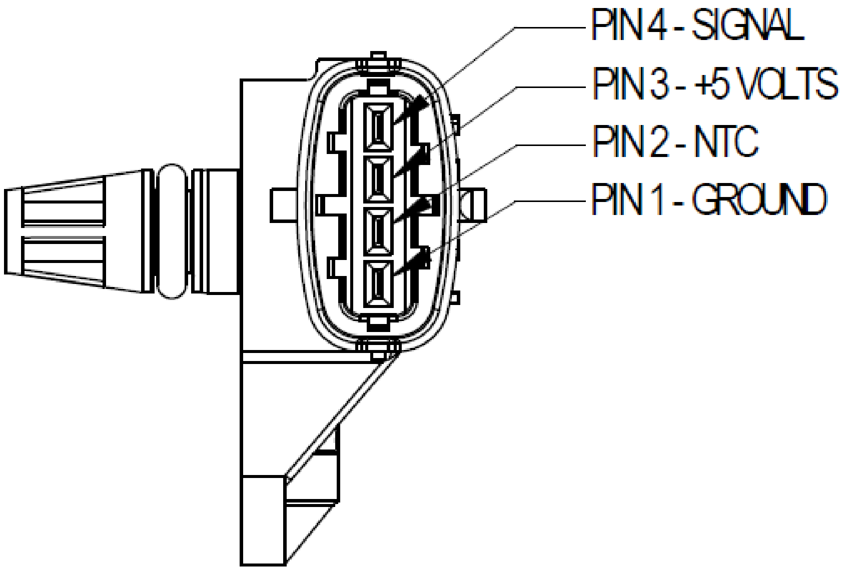
8. Sensors

The ECU requires knowledge on the engine status in regards to its crank angle, engine rpm, engine load (determined through Manifold Absolute Pressure or Throttle Position Sensor), coolant temperature, air temperature, Exhaust Oxygen (Lambda) sensor etc. So in order to get the data we use various sensors in our harness.

1. TMPS (Manifold Absolute Pressure)
2. TPS (Throttle Position Sensor)
3. CPS (Crank Position Sensor)
4. CTS (Coolant Temperature Sensor)
5. Lambda sensor

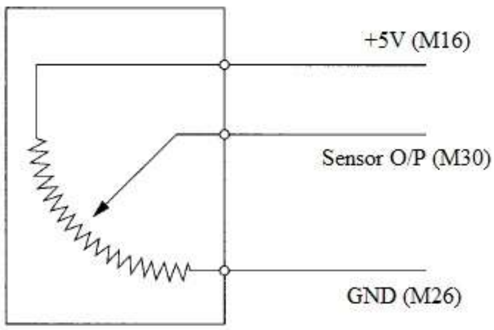
1. TMPS (Manifold Absolute Pressure)

The MAP sensor is used to provide intake manifold pressure measurement which can be used as an engine load indicator. Sometimes this is also referred to as Manifold Air Pressure, however the use of the word Absolute is more descriptive as it has to be appreciated that the pressure being measured is not gauge but absolute. The gauge pressure refers to pressure quantity above atmospheric pressure. Ambient pressure is 100kPa (14.7 psi) in an absolute scale and not zero. MAP sensors are typically four wire (ground, signal, NTC and supply).



2. TPS (Throttle Position Sensor)

A throttle position sensor (TPS) is a sensor used to monitor the throttle position of a vehicle. The sensor is usually located on the butterfly spindle/shaft so that it can directly monitor the position of the throttle. It has three wires (black, brown, white). There is a potentiometer arrangement which changes the voltage according to position and this measured voltage is used by ECU to inject the fuel accordingly to maintain air to fuel ratio. The voltage value varied according to the moment of the butterfly valve. Voltage varies from 0.4V to 4.5V.



3. CPS (Crank Position Sensor)

The function of the crank and cam sensors is to provide knowledge of angular position and speed of the engine to the ECU. The ECU requires knowledge of angular position of the engine crank so that spark and fuel are generated at the desired crank angle. This sensor are inductive type, two wire (or three wire) and operate on the principle that a voltage is generated in a coil when iron (a tooth) goes past the sensor at some speed.

4. **CTS (Coolant Temperature Sensor**)

The coolant and air temperature sensors are usually thermistors. Thermistors are resistors whose resistance changes with temperature. Used in conjunction with a pull-up resistor, the thermistors and pull-up resistor make a potential divider whose voltage output depends on temperature. The voltage is read by the ECU to provide temperature measurement.

5. **Lambda sensor**

The Universal Exhaust Gas Oxygen) sensor is a 5-wire wideband Lambda sensor. It is used to control fuel and ignition systems to optimize a car's performance in the areas of emissions and fuel economy. The internal heater in the sensor is powerful enough to allow accurate measurement when the exhaust gas temperature is at room temperature. The sensor will take approximately 20 seconds to heat up.

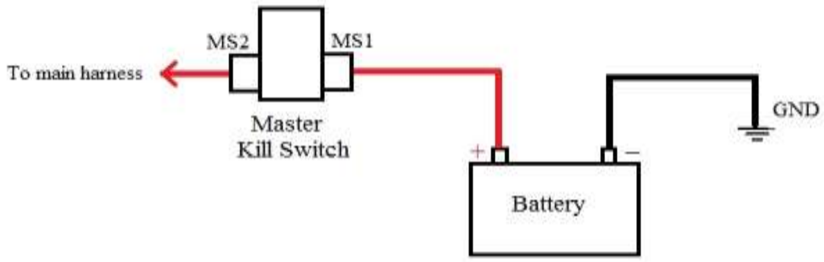
9. **Break Light**

Break light is powered by +12V which comes from MS2 of the kill switch. The trigger which helps us to identify that the break light is pressed is given by ECU (M27).

Design Sub Harness 2:

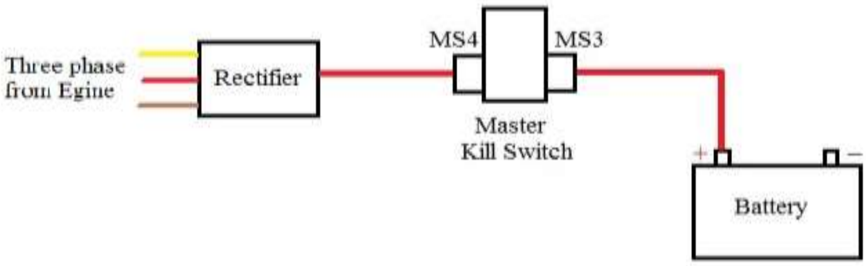
Last year we kept the battery behind the seat due to which we had to put a secondary firewall according to rule. Accessibility was also poor so this year we decided to change the battery position to get better accessibility. But because of this we have to make a battery box which is non-conductive.

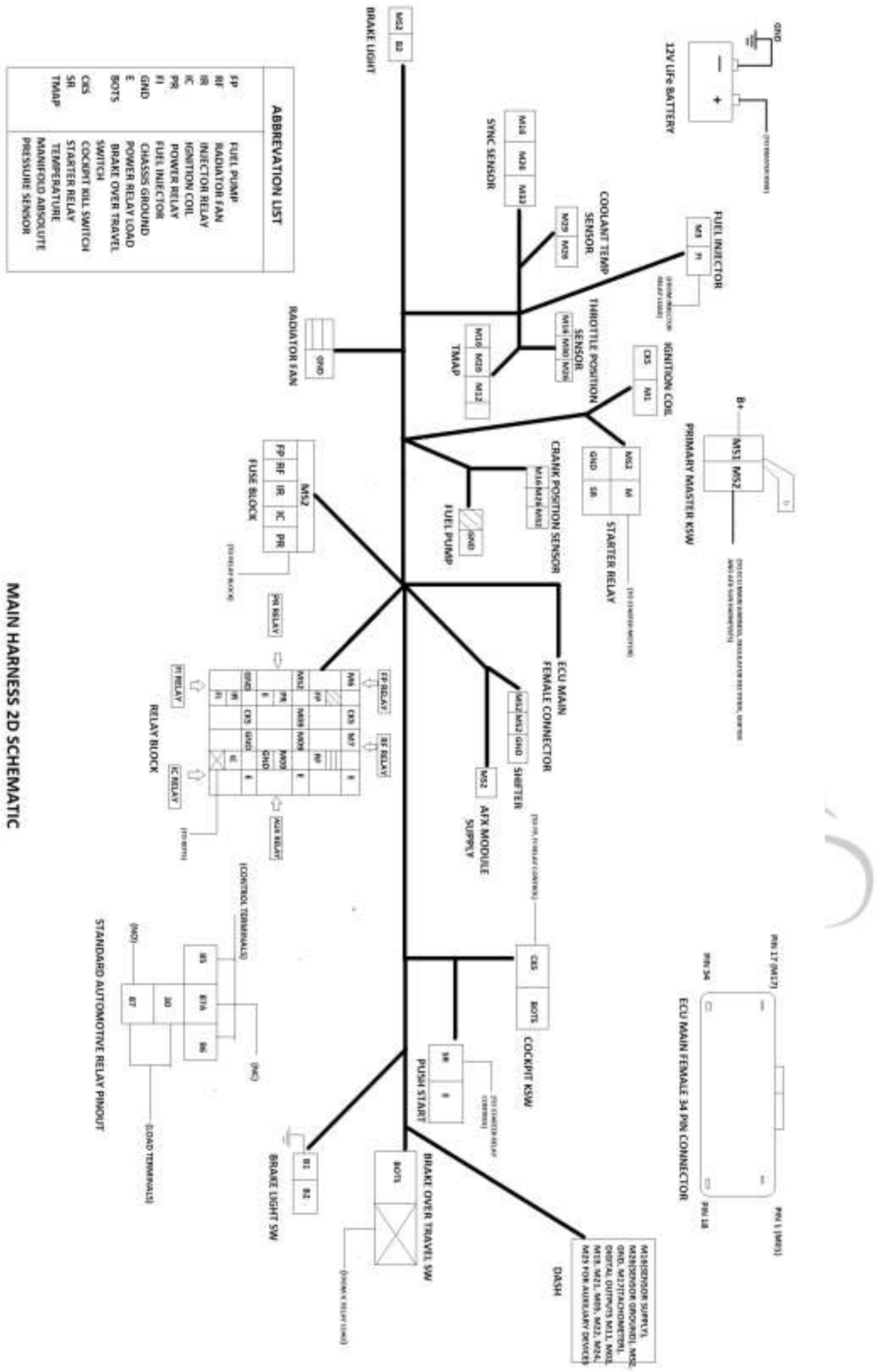
This sub-harness deals with the battery connections to master kill switch. Main battery positive goes to MS1 of master kill switch and negative terminal goes to chassis ground.



Design Sub Harness 3:

As we use battery for powering various components, due to this the charge in the battery reduces so in order to maintain the charge in the battery we use an 3 phase rectifier which convert three phase supply which comes from engine to a constant DC supply. This dc supply is used to charge the battery. This DC supply is also passed through master kill switch and finally applied to battery.

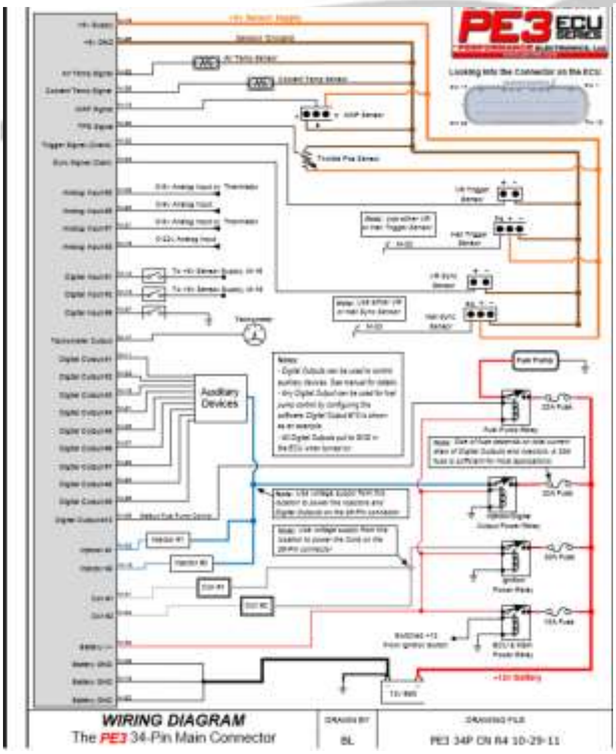


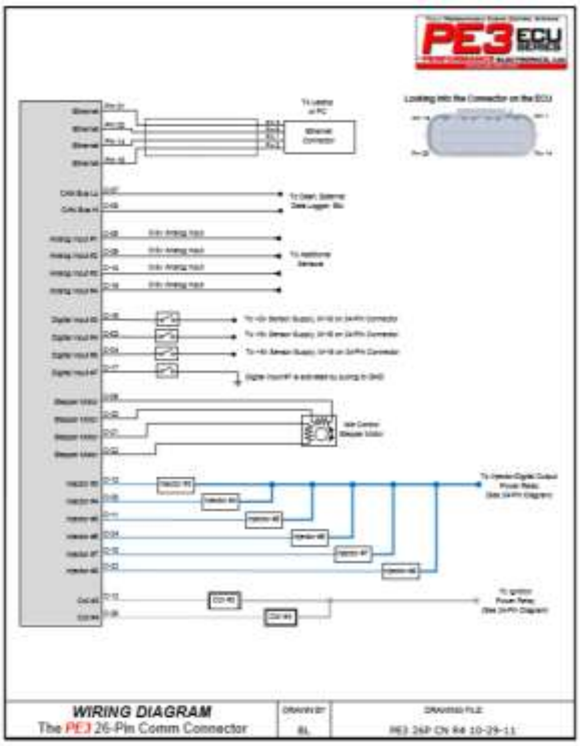

MAIN HARNESS 2D SCHEMATIC
ABBREVATION LIST
FP FUEL PUMP
RF RADIATOR FAN
IR INJECTOR RELAY
IC IGNITION COIL
PR POWER RELAY
FI FUEL INJECTOR
GND CHASSIS GROUND
E POWER RELAY LOAD
BOTS BRAKE OVER TRAVEL SWITCH
CKS COCKPIT KILL SWITCH
SR STARTER RELAY
TMAP TEMPERATURE MANIFOLD ABSOLUTE PRESSURE SENSOR
12V LiFe BATTERY
BRAKE LIGHT
SYNC SENSOR
COOLANT TEMP SENSOR
FUEL INJECTOR
THROTTLE POSITION SENSOR
TMAP
IGNITION COIL
PRIMARY MASTER KSW
RADIATOR FAN
STARTER RELAY
CRANK POSITION SENSOR
FUEL PUMP
FUSE BLOCK
PR RELAY
FP RELAY
RF RELAY
FI RELAY
IC RELAY
AUX RELAY
RELAY BLOCK
ECU MAIN FEMALE CONNECTOR
SHIFTER
AFX MODULE SUPPLY
COCKPIT KSW
PUSH START
BRAKE OVER TRAVEL SW
BRAKE LIGHT SW
DASH
ECU MAIN FEMALE 34 PIN CONNECTOR
STANDARD AUTOMOTIVE RELAY PINOUT
(CONTROL TERMINALS)
(LOAD TERMINALS)

DATA ACQUISITION HARNESS DESIGN

Simulation of vehicle dynamics on software can give helpful data up to some extent, but real track data during testing is the only thing that gives us a clear idea about how good is the agreement between our calculations and the real case scenario. That is why this year we decided to design and manufacture a data acquisition system. Initially we had begun with the idea of developing a full fledge on board DAQ system equipped with a telemetery. As this was the first time we were attempting to implement such kind of system on our race car, we decided not to go ahead with it. Nevertheless, this remained a subject that we researched on extensively as hopefully it is something that we will be able to implement in the coming seasons. We decided to use our ECU for data acquisition purpose. The ECU has some available inputs that can be used to store data through external sensors.

The following is the wiring diagram of a PE3 ECU





As it can be seen in the above diagram, there are 4 analog inputs and 4 digital inputs available in both the main and communication ports of the device. The ECU has 1 MB of space dedicated for the purpose of data acquisition that permits storage of 20 minutes of sensor data when stored at a frequency of 100Hz. Therefore, we designed a harness using the following inputs from the two ports.

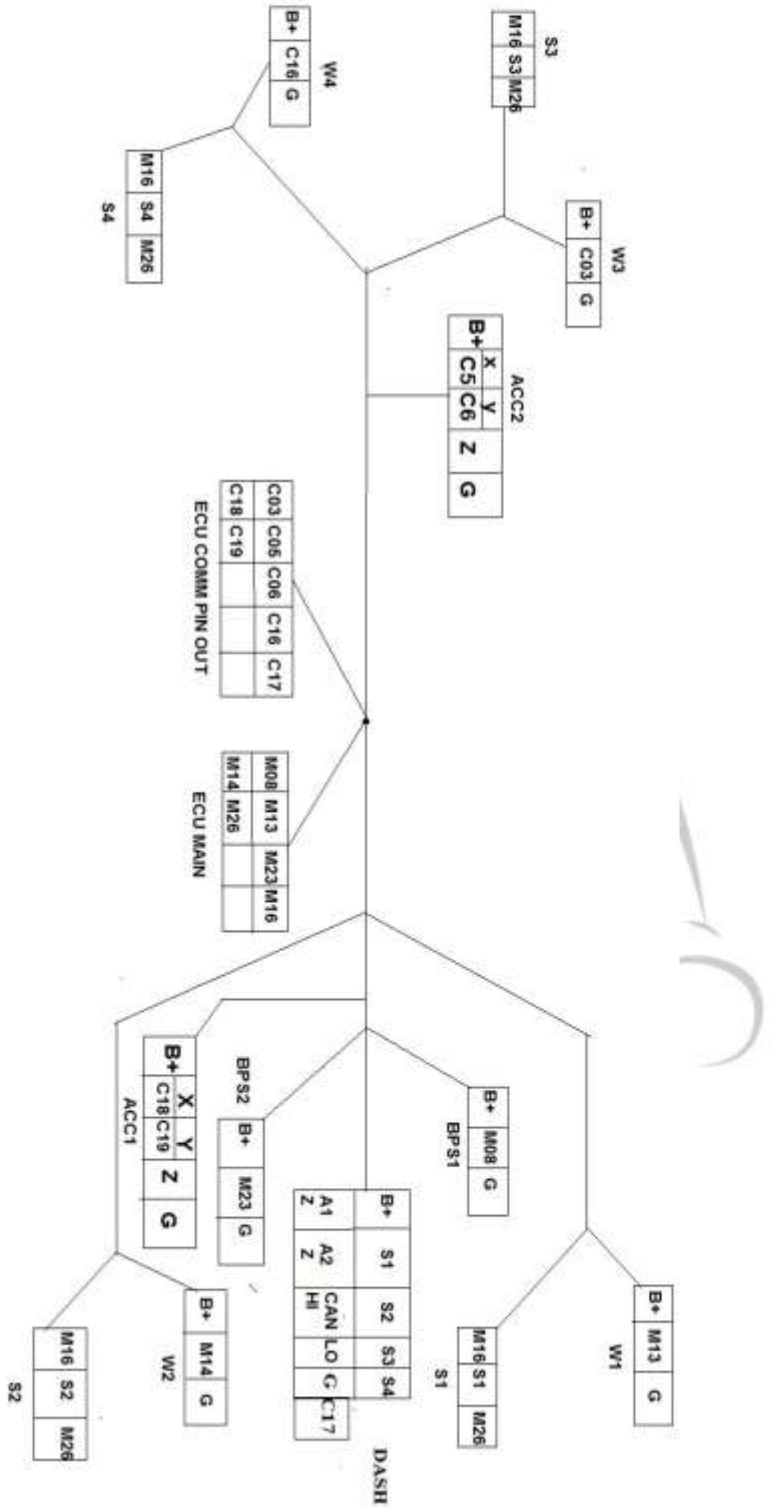
Inputs from main port:

M08, M13, M23, M16, M14, M26

Inputs from the comm port:

C03, C05, C06, C16, C17, C18, C19

In order to use the main port inputs for the DAQ harness, we split the required wires from the main port female connector and connected a standard 6 pin connector at the terminals. The male part of the same connector and the communication port female connector were provided at the sensor output terminals of the DAQ harness.



CODE	SENSOR
S1, S2, S3, S4	SHOCK TRAVEL
ACC1, ACC2	ACCELEROMETER
BPS1, BPS2	BRAKE PRESSURE
W1, W2, W3, W4	WHEEL SPEED

DAQ harness 2D schematic

As it is seen in the above diagram, we made provisions for shock travel, wheel speed, accelerometers and brake pressure sensors. The sensors were given a constant 12V input at the supply terminals through a voltage regulator PCB as supply from the car's alternator unit output consists of ripples which could induce noise in the data obtained or could even possibly damage the sensors.

WHEEL SPEED SENSORS

There are 4-wheel speed sensors (one at each wheel) shown in the schematic. The wheel speed sensors that we used are standard hall effect sensors. Digital inputs M13, M14, C03 and C16 are given to W1, W2, W3 and W4 sensors respectively.

Sensor calibration: The sensing element is in contact with the rotor. The rotor has 35 slots. Therefore, according to hall effect sensor principle, the sensor will give 35 pulses in one wheel rotation. Therefore, to get the RPM the wheel the frequency must be multiplied by a factor of $\frac{60}{35}$. Therefore, user data of the wheel speed sensor digital inputs was setup accordingly in order to log the RPM directly as it is easier to interpret.

Plot No. U-15, JVPDScheme, Bhaktivedanta Swami Marg,VileParle(W),Mumbai- 400 056.
Contact No: 9664029448/9930028539. E-mail: info@djsracing.in Website: www.djs-racing.com

BRAKE PRESSURE SENSOR

We have used two brake pressure sensors (BPS1 and BPS2) at Tee joints of supply and return of the brake fluid lines. The digital inputs M08 and M23 are used for BPS1 and BPS2 respectively. We have used Sens4speed's EPT3100 series pressure sensors with the input range of 10 to 32V dc and output range between 0 to 5Vdc capable of measuring pressure between 10 to 100 bar.

Sensor calibration: As the output varies linearly between 0 to 5Vdc for a pressure range between 10 to 100 bar, the user data was setup such that the value displays 10 for 0V (corresponding to 10 bar) and 100 for 5V output (corresponding to 100 bar).

Problems faced while testing BPS sensor:

1. The datasheet didn`t mention the wiring connection of the BPS sensor we assumed that red is +12v and black is ground.

2.The remaining wire that is green and white when checked for output gave the following result

White wire

- It gave constant 12v output

Green wire

- The sensor gave constant 0.3v output irrespective of the pedal position.
- Sometimes it gave a reading of 5v and then start dropping to 0v.

So, we decided to mail the manufacture and wait for their response.

ACCELEROMETER:

We made provisions for two accelerometers (look for ACC1 and ACC2) in the harness schematic. However, we used only one of them during testing close to the car's centre of gravity. The sensor gives acceleration value in the X, Y and Z directions (along all the spatial Cartesian axes). Digital inputs C18, C19 for X and Y of ACC1 and C05, C06 for X and Y of ACC2 respectively are used. Sensor outputs in the Z direction have been extended to the dash to be logged by an external Arduino circuit board since we were running out of ECU inputs for data logging. We used Texense's accelerometer whose supply voltage ranges from 5 to 16Vdc and output ranges from 0 to 5Vdc for an acceleration range of negative 5Gs to 10Gs.

Sensor calibration: The digital input user data was calibrated according to the following table provided by the manufacturer:

Problems faced while testing Accelerometer sensor:

We tuned Accelerometer sensor and it was working properly. But when we used data logging (DAQ) function of ECU it gave us the data for one min later the data stored get corrupted. Hence, we were not able to use it properly

Calibration table		
	5G 400mV/G	10G 200mV/G
-10		0.5
-5	0.5	1.5
0	2.5	2.5
+5	4.5	3.5
+10		4.5

Out of Range

SHOCK TRAVEL SENSORS

In order to measure the damper displacement, we decided to use four shock travel sensors along the 2 front and 2 rear dampers of our car. For this we attempted to use linear potentiometers from a local manufacturer instead of automotive grade shock travel sensors as they were not easily available and very expensive. Shock travel data was something that was relatively less important at this stage for our vehicle dynamics team. Also as the data was logged through the ECU inputs, we ran out of inputs to be used for these sensors. The variable terminal of the potentiometers was extended to the dash as shown in the schematic so that data could be logged on an external Arduino circuit board along with the Z direction outputs of the accelerometers.

Unfortunately, we were unable to use the potentiometers due to space constraints while mounting them.

.

DASHBOARD

As this year's topmost priority was to make the previous electrical system more reliable since last year was the first time the team had switched onto a custom ECU, there hasn't been a significant change in the car's dashboard with respect to the number components placed on it. Nevertheless, we have attempted to make an improvement relative to the previous car's dash design which will be justified in the coming sections.

DESIGN

The previous dash just consisted of two carbon fibre plates cut in an approximate rectangular shape with filets at the edges with radius equal to the inner radius of the front roll hoop and were placed at the either sides of the steering mount. The plates were zip tied to the FRH. Holes of different sizes were drilled on the plates to place the cockpit kill switch, radiator fan switch, push start switch and coolant temperature indicator LED. Tachometer and gear indicator were mounted on the steering mount.

This year's dash design:

Keeping in mind the space constraints, weight, aesthetics and ease of evacuation of the driver during egress, the dash has been carefully and accurately designed on CAD. The material that we selected is carbon fibre as it possesses great strength accompanying low weight making it the most viable option for this purpose. For rigid and reliable dash mounting, bolts with nylon lock nuts have been used at multiple points on the structure in order to positively lock it with the chassis.

COMPONENTS PLACEMENT

As it is visible in the design, the cockpit kill switch has been placed on the right side of the dash with the radiator fan switch mounted at some distance towards the left of the kill switch, the starter has been placed on the left side of the dash. The central area, which the part covering the steering mount consists of a 3d printed case of dimensions 7cm x 11cm containing gear indicator and tachometer PCB. Holes of appropriate diameters were precisely drilled using a hand drill.

COMPONENTS

1. COCKPIT KSW

The cockpit kill switch that we use is a NC push/pull type kill switch. As it is obligatory, from ON position, pushing the kill switch disables electrical supply to ignition coil, fuel pump and the injector. Twisting the kill switch from OFF position again enables the supply. As it is shown in the main harness schematic (refer the ECU harness section of the report), one of the terminals of the kill switch is connected to the ignition coil relay load, which in turn acts as a supply to ignition coil, and supply to one of the control terminals to fuel pump and fuel injector relay through the brake over travel switch. Hence the cockpit kill switch in open condition will disengage supply from the ignition coil, fuel pump and the fuel injector thereby killing the engine.

2. RADIATOR FAN SWITCH

The radiator fan switch that we use is push button type switch featuring a 12V LED in a circular fashion.

As shown in the main harness schematic, the control terminals of the radiator fan relay are the load of the power relay and one of the digital outputs of our ECU (we use digital output M07 for this purpose). We have setup the M07 user data such that the output provides ground as soon as the coolant temperature exceeds 85 degrees centigrade thus enabling supply from the radiator fan relay load. A wire is connected from this load to one of the NO terminals of the switch whereas the other terminal goes to the radiator fan. Thus, switch in ON position with the coolant temperature exceeding 85 degrees will turn the radiator fan on.

3. **PUSH START**

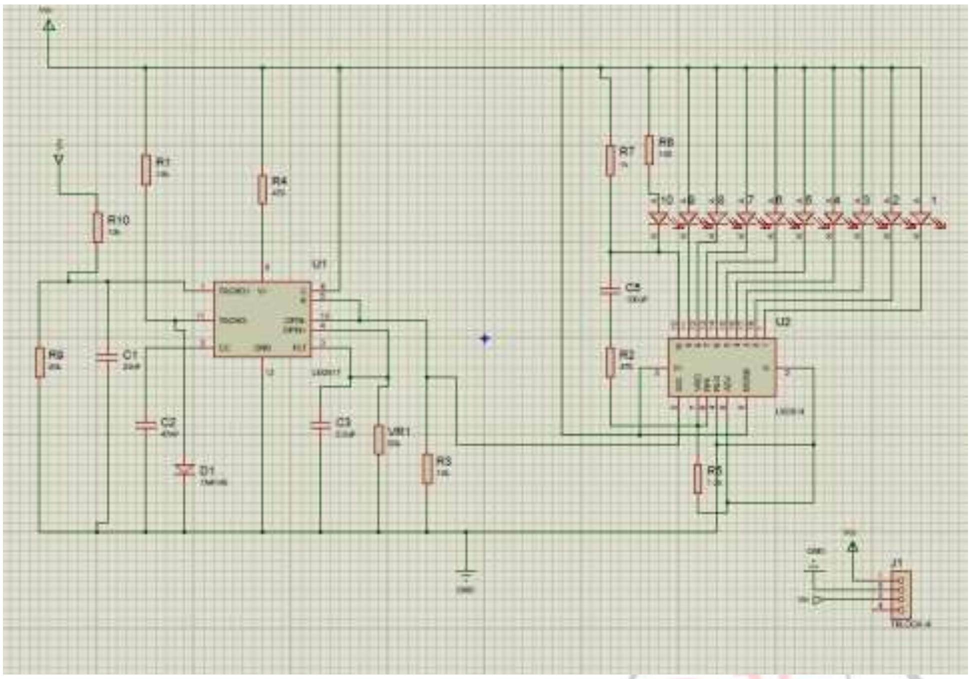
   We use an NO type switch as a starter where one of the terminals goes to the power relay load and the other to the starter relay control. Thus, switch in ON condition energises starter relay cranking the starter motor.

4. **TACHOMETER AND GEAR INDICATOR**

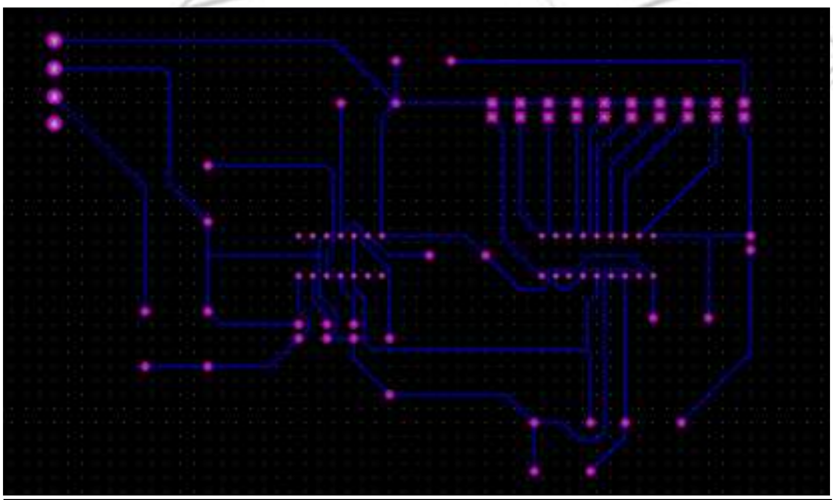
   Last year the tachometer was made up of LEDs connected in parallel with a common anode 5V supply and 7 unused digital outputs that we had provided at the dash. The LEDs were placed in holes drilled in acrylic sheet of the mount size. The digital outputs were provided at the LED cathodes and the ECU user data was setup appropriately for sequential glowing of LEDs at predetermined engine RPM range. The gear indicator consisted of a 7 segment display that was driven by a programed Arduino UNO circuit board that indicated a number corresponding to the gear that was engaged.

   TACHOMETER PCBs

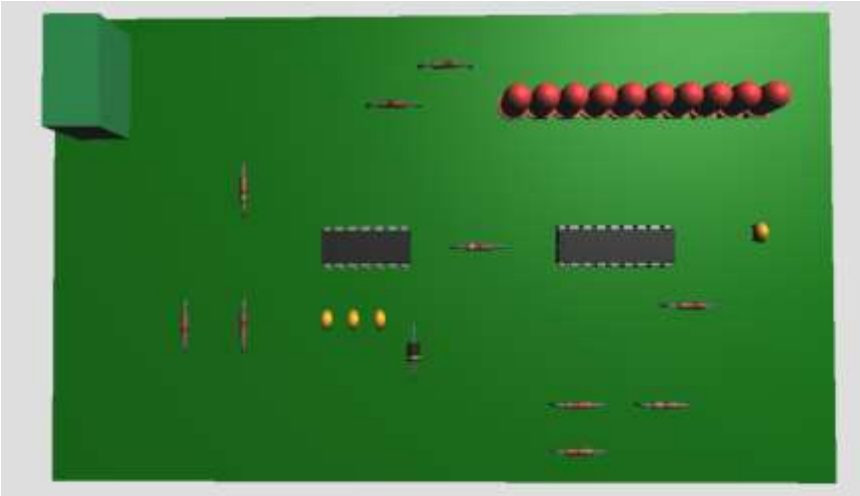
   As a step, ahead to last year's tachometer design, we decided to make the tachometer driven by our ECU's M17 pin that is a dedicated output for tachometer instead of individually switching ON the LEDs using digital outputs. It gives out a square wave of 30% duty cycle with amplitude equal to 12V (battery supply voltage). Hence we designed a PCB using LM2917 and LM3914 microcontrollers.



Tachometer PCB wiring diagram using M17



PCB schematic

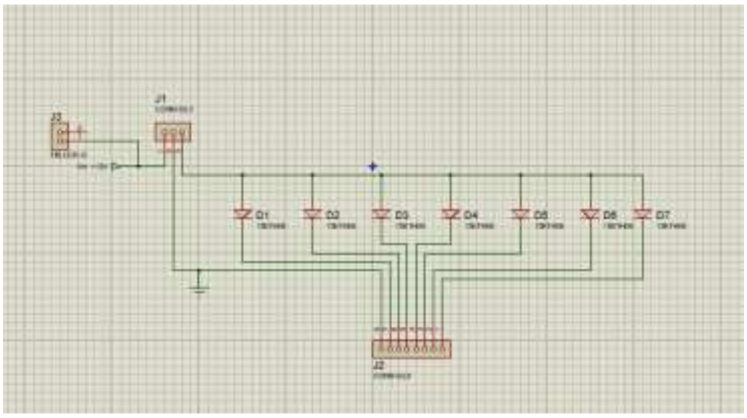


PCB layout

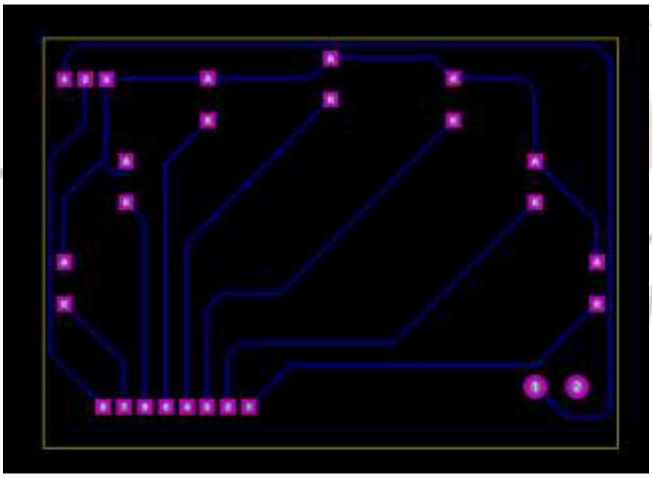
LM2917 is monolithic frequency to voltage converter IC with a high gain op amp designed to operate different loads when the frequency exceeds a given rate. In the above PCB layout, this IC is used to provide different voltage levels at different input frequencies from the digital output. These voltage levels are used to drive LM3914 which is a monolithic integrated circuit that senses analog voltage levels and drives 10 LEDs, providing a linear analog display. This is achieved by driving 10 individual comparators referenced by a precision voltage divider within the IC.

Unfortunately, although the circuit worked fine when tested in the lab using a frequency generator on a CRO, the circuit failed to work on the car under dynamic condition as it picked up noise due to vibrations. Thus, data obtained from the tachometer was highly random and unreliable that confused the driver during testing the car on track.

Using digital outputs was the only option available that assured feasibility and reliability. Hence, we designed a PCB using digital outputs as shown below.



Tachometer wiring diagram using digital outputs



PCB schematic

A 3 pin 12V to 5V voltage regulator is used as a common anode supply to the circuit LEDs. The LED cathodes are given digital outputs through an 8 pin PCB connector. User data has been setup to glow the first, second, third till the seventh LED in sequence at different RPM range starting from 1500RPM for the first LED to 8500RPM for the seventh.

GEAR INDICATOR PCB

As previous car's gear indicator was driven using an Arduino circuit board, this year we decided to shift on Atmel ATMEGA32 microcontroller. The IC was programed on Atmel Studio 6 which is an IDE for Atmel integrated circuits. The KTM engine has a 6 pin connector that is dedicated for the purpose of gear indication. When a particular gear is engaged, the terminal of the 6-pin connector corresponding to that gear gets shorted to engine ground. Otherwise the terminal remains in a state of high impedance. Hence this connector was used as a signal input to the PCB and the microcontroller was programed based on the lines of this logic. The gear engaged was indicated using a 7-segment common anode LED display.

Features of Atmel ATMEGA32 microcontroller are as follows:

• High-performance, Low-power Atmel AVR® 8-bit Microcontroller

• Advanced RISC Architecture

• High Endurance Non-volatile Memory segments

– 32Kbytes of In System Self-Programmable Flash program memory

– 1024Bytes EEPROM

– 2Kbytes Internal SRAM

• Peripheral Features

– Two 8-bit Timer/Counters with Separate Prescalers and Compare Modes

– One 16-bit Timer/Counter with Separate Prescaler, Compare Mode, and Capture Mode

• Special Microcontroller Features

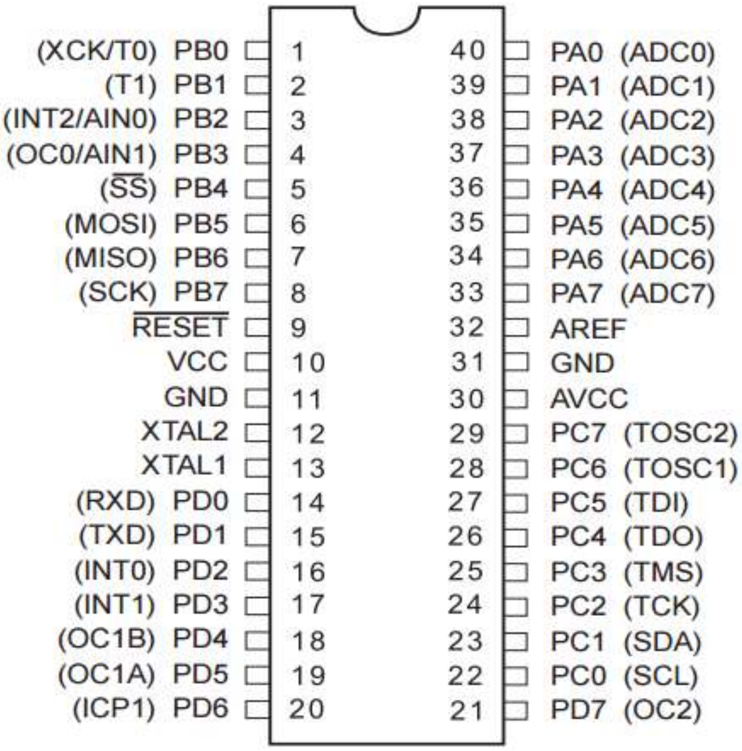
• I/O and Packages

– 32 Programmable I/O Lines

• Operating Voltages

– 2.7V - 5.5V for ATmega32L

– 4.5V - 5.5V for ATmega32



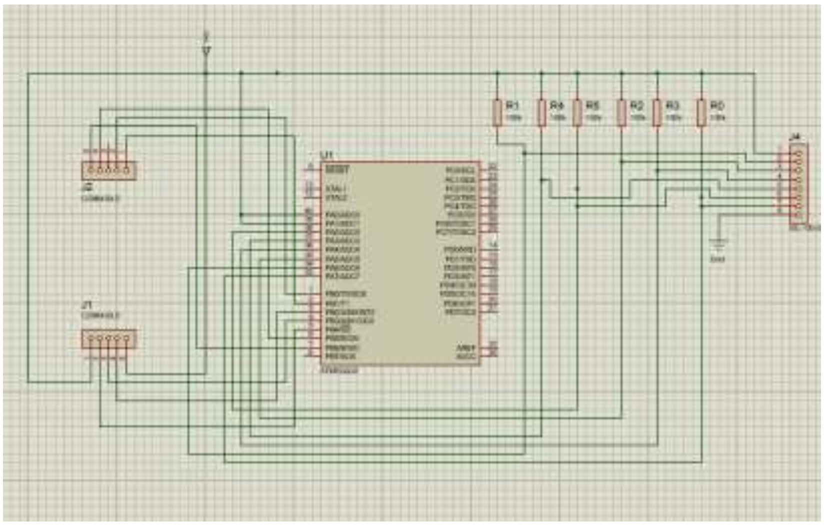
Pin out diagram

Here is the code:

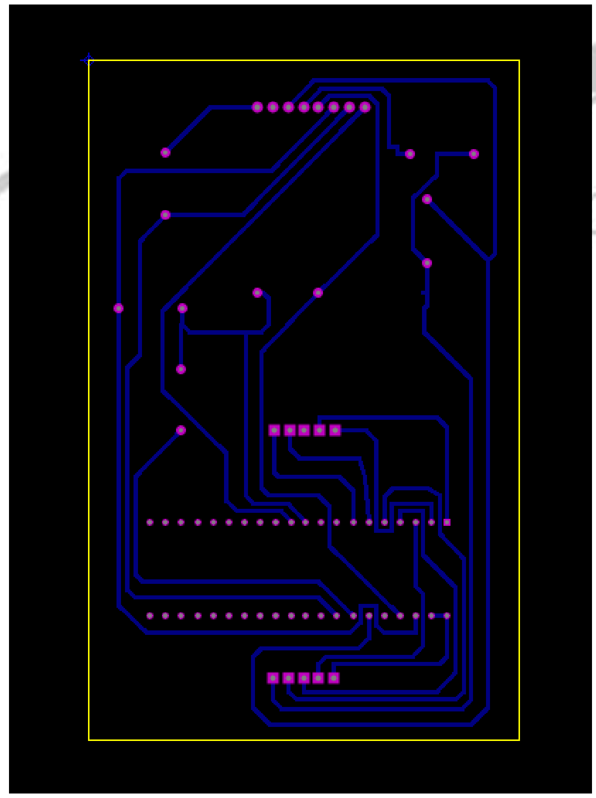
```
/*
 * Gear_Indicator_03.cpp
 *
 * Created: 23-08-2016 22:50:06
 *  Author: DJS Racing
 */


#include <avr/io.h>
/*Includes io.h header file where all the Input/Output Registers and its Bits are defined for all
AVR microcontrollers*/
```

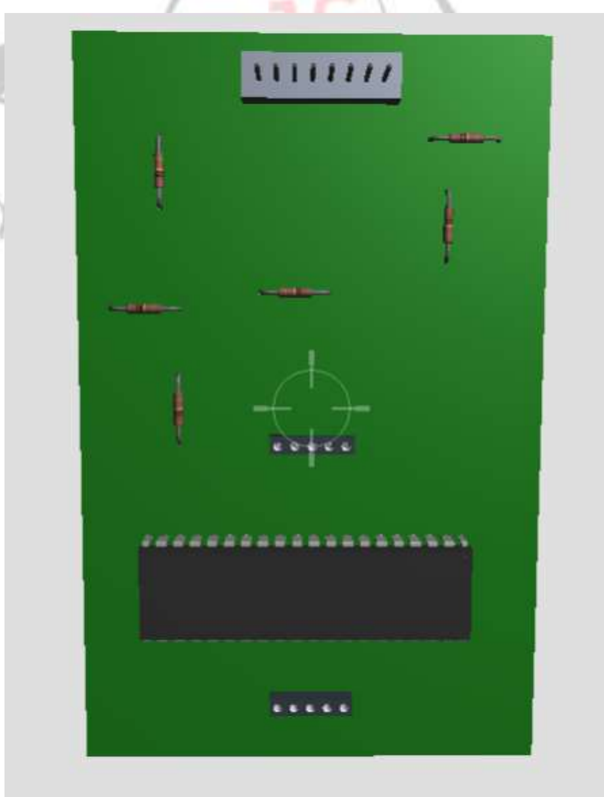
```
#define F_CPU 1000000
/*Defines a macro for the delay.h header file. F_CPU is the microcontroller frequency value
for the delay.h header file. Default value of F_CPU in delay.h header file is
1000000(1MHz)*/


#include <util/delay.h>
/*Includes delay.h header file which defines two functions, _delay_ms (millisecond delay)
and _delay_us (microsecond delay)*/


#define _7SEGMENT_PORT  PORTB
/*Defines a macro for the 7segment.h header File. _7SEGMENT_PORT is the
microcontroller PORT Register to which the data pins of the 7-segment Display are
connected. Default PORT Resister in 7segment.h is PORTB*/


#define _7SEGMENT_TYPE  COMMON_ANODE
/*Defines a macro for the 7segment.h header File. _7SEGMENT_TYPE is the type of 7-
segment Display (Common Cathode or Common Anode) we are interfacing. Default type of
7-segment display in 7segment.h is Common Anode*/


#include <avr/7segment.h>
/*Includes 7segment.h header file which defines different functions for 7-segment display.
7segment header file version is 1.1*/


int main(void)
{
 DDRB=0xff;
 /*All the 8 pins of PortB are declared output (all pins of 7 segment display are connected)*/


 /*Start of infinite loop*/
 while(1)
 {
  switch(PINA)
  {
   case 0b01111111:
```

```
{
 display_7segment(0);
 break;
}

case 0b10111111:
{
 display_7segment(1);
 break;
}

case 0b11011111:
{
 display_7segment(2);
 break;
}

case 0b11101111:
{
 display_7segment(3);
 break;
}

case 0b11110111:
{
 display_7segment(4);
 break;
   }
   case 0b11111011:
   {
display_7segment(5);
break;

   }
case 0b11111101:
{
 display_7segment(6);
 break;
}

 }
}
}
```



Gear indicator wiring diagram

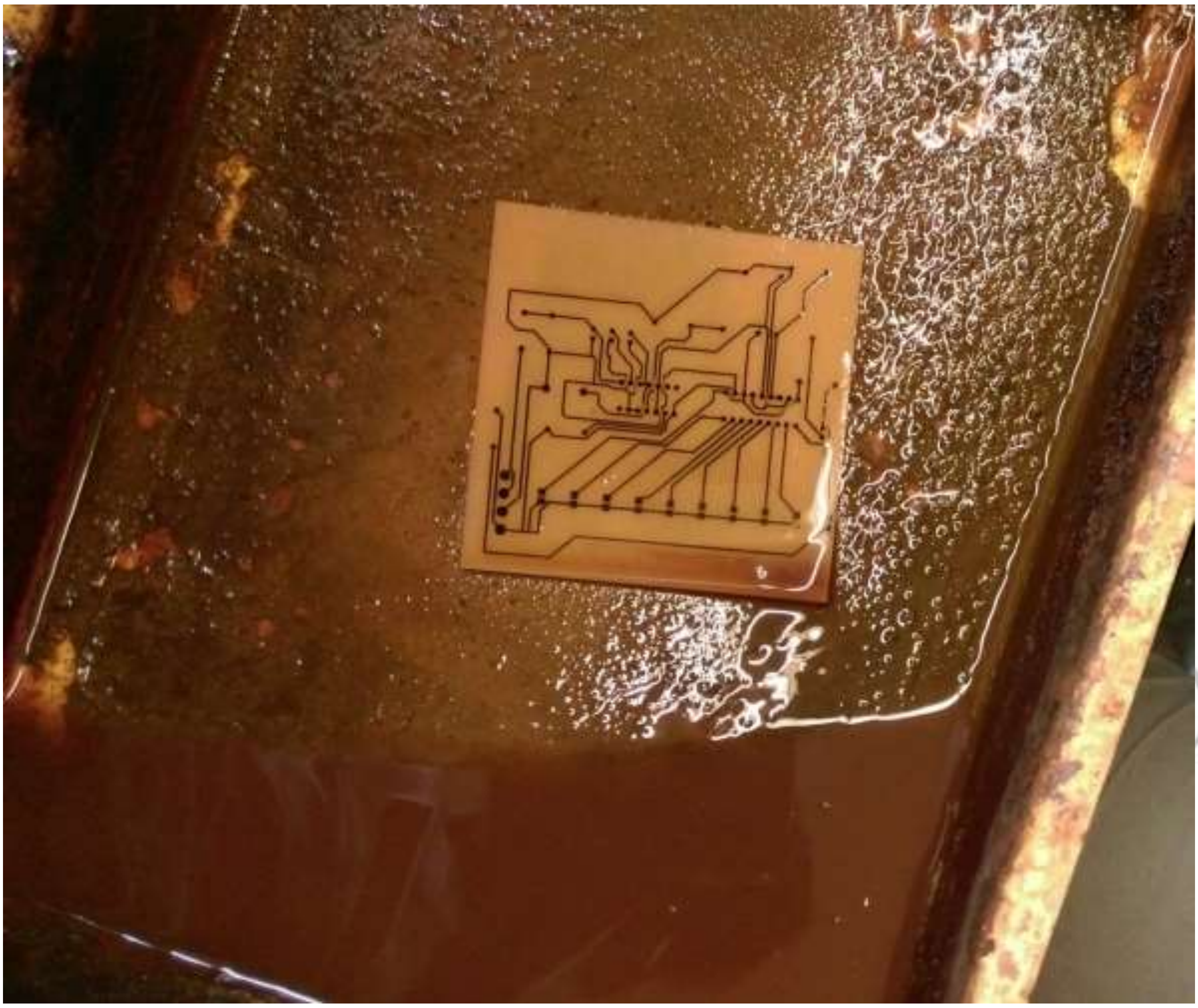




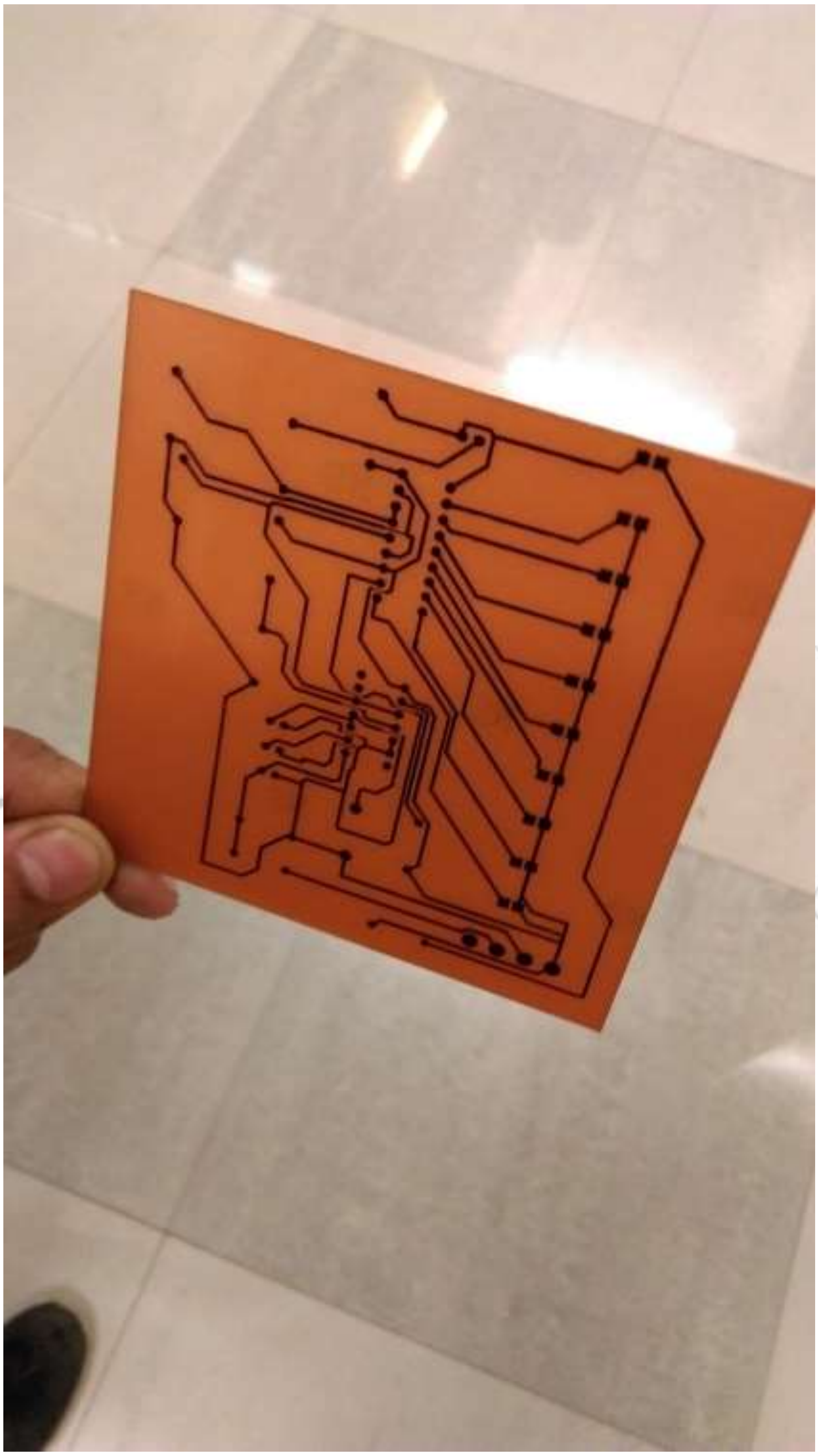
PCB schematic

PCB Layout

A 7 segment LED display was used to ensure better daylight visibility. LCDs delivering same amount of brightness were either not available or were too expensive, thus ruling them out as the feasible option.



Etching Process



PCB after Etching Process

MANUFACTURING:

The main aim with regard to manufacturing the wiring harness was that the end product should be reliable and that good wiring practice seeded to be followed.

1. Wire type and size were chosen based upon load requirements, temperature and operating environment. We made sure that the wire size we were using was not too small for the load size. A variety of insulation types were used for varying temperature and environmental conditions.

2. Terminals (i.e. ring, spade etc.) are not only sized by hole or opening size, but also by wire size. A correctly sized terminal/wire combination, when crimped properly, will result in a very reliable connection. Terminals were elected based upon the wire sizes selected and the connectors procured with the KTM 390 engine.

3. Connectors were wiring harness of the KTM 390 itself to ensure the comparability with the engine side connectors.

4. Fuses and relays were used as per the design of the wiring diagram. A Fuse box and a Relay box were used to ensure environmental protection and easy access for swapping fuses and relays.

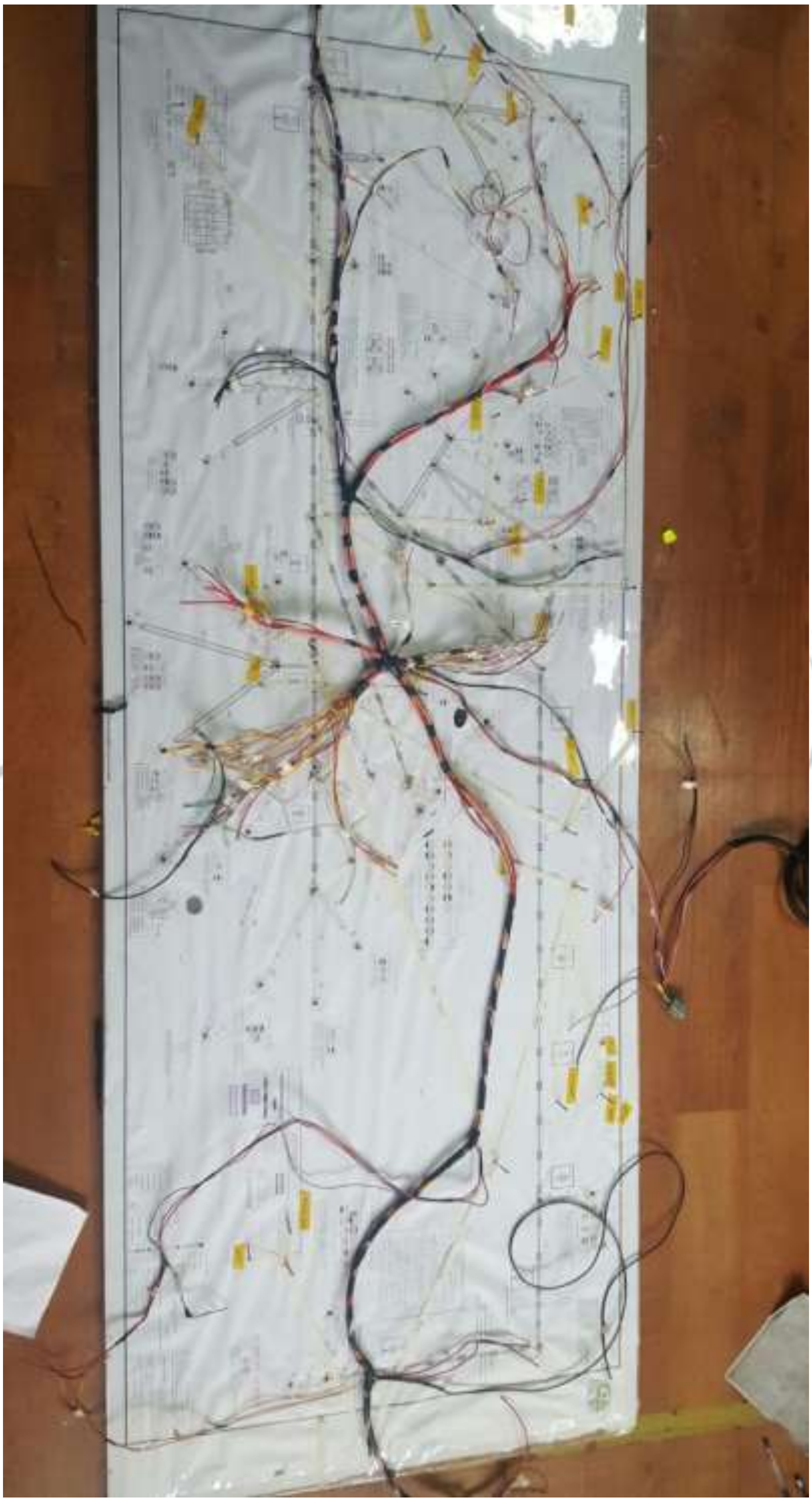
5. The wires were spliced wherever the wire needed to be split or when the length of the wire was in adequate.

6. Special attention was paid to the ground connection as the whole electrical system can fail due to an improper ground connection .Bolts were welded on the chassis to provide reliable chassis ground points .

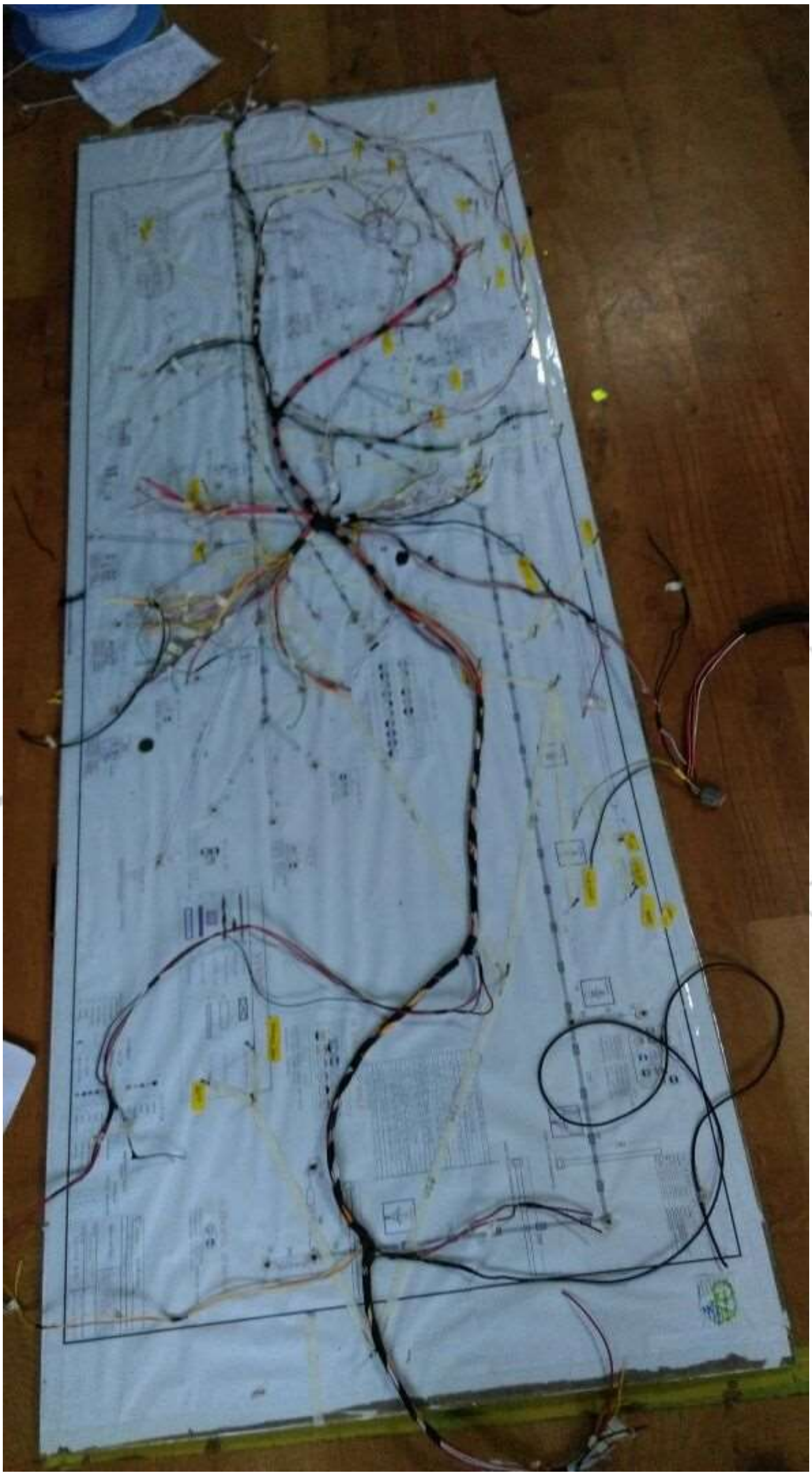
7. All the wires were wrapped in nylon shrouds and cotton taped to ensure protection from the heat and the elements.

8. The wires were routed along the body and the roll cage along one side of the car away from the exhaust to ensure that the wires or the connectors do not burn off.

Final Harness After Manufacturing



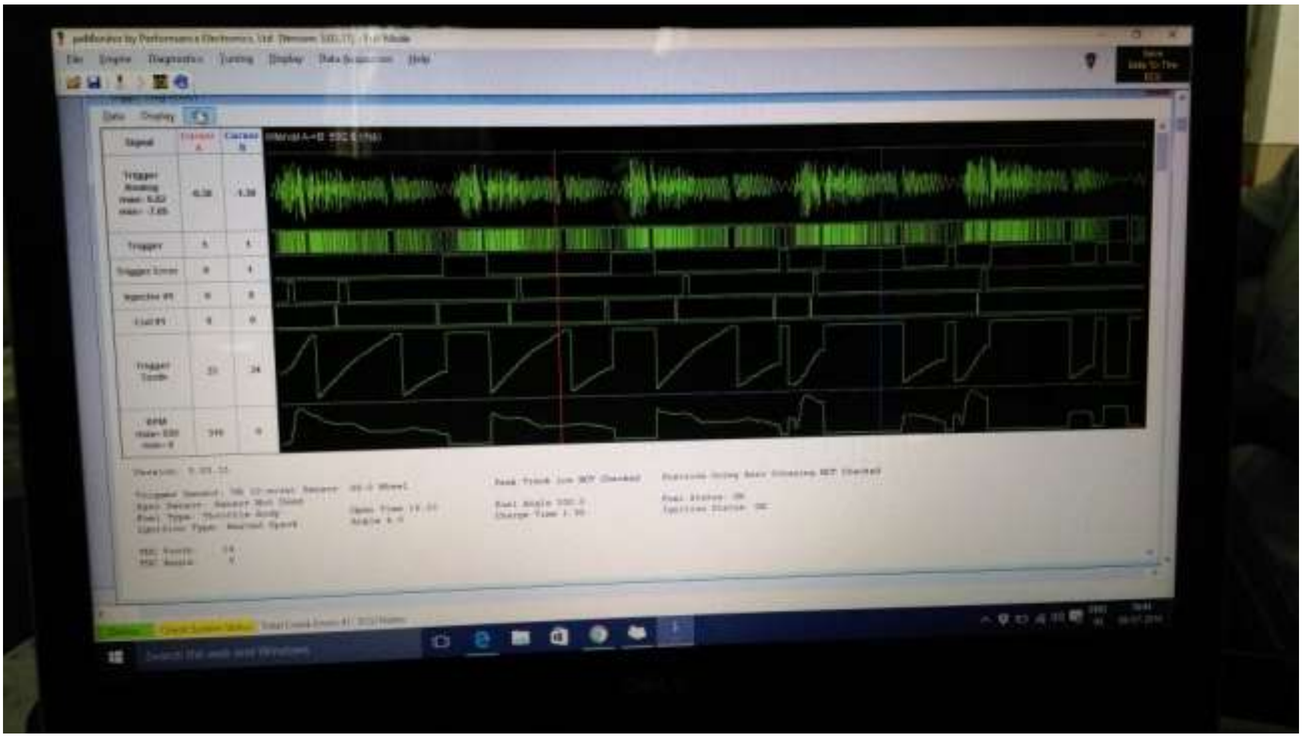
Main Harness Layout.



Testing

After manufacturing the Harness, we started to test it and we faced problems, some of the major problems are:

1. CPS wiring, we connected three wire positive +5V (sensor supply), negative (sensor ground) and sensor signal. When we connected the harness side connector to the CPS connector all the other sensor where not getting proper +5V supply there was a huge drop in sensor voltage. After removing the connector of CPS all sensor was getting proper +5V. Later after some research and troubleshooting we realized that CPS has only two wire negative and sensor output other wire was indicating neutral gear. As we connected positive to neutral gear wire which was at ground potential, there was a sudden drop in sensor supply voltage. Hence, we removed that positive wire and hence it was working fine then after.



This was the graph that we obtained while cracking the engine with all three wires connected. There was many Error trigger that was we obtained which was not at all desired.

2. We faced some shifting problems while testing it was shifting randomly.

Problem Faced:

- Shifting was not reliable.
- It was not shifting to the 1st gear.
- In line 2Amp Fuse was blown twice.
- There was a short between wire connecting actuator and the shifter module.
- Actuator was at angle which was not desired.

Blown Fuse

Shorted wire

Troubleshooting

- Checked the continuity between shifter buttons and shifter module was fine
- Checked the value current flowing through each switch in order to check that switching is working fine
- In order to take care of shorting of wire we have filled the gap with Loctite 3090.
- First applied red tape on it then cotton tape.
- After that made the cotton tape in that region wet with feviquick so now its very hard and no bending in that region
- Welded new bracket in order to get 90° angle.

Actuator Angle

Final after all process

3. Another problem AFX module was not working as configured. It was showing some garbage value on the display. Ideally it should show 16.00 on the display. So, we tried to reconfigure AFX module and connected again but still the problem was not solved. So, we started to check the continuity between all the wires. One wire was not showing continuity but it was difficult to figure it out. So, we removed all the shroud and then we figured out that AFX was not getting the ground properly because the crimping between the wire and ring terminal was damaged due to stress. So finally, we removed that ring terminal and we shouldered a new ring terminal and again recalibrated the AFX module, now finally it was working fine. It showed 16.00 on the display as tuned.

4. Fan ground wire (Black wire) which goes to fan motor assembly was loose due to this there was problem of grounding of the fan. Due to this Motor speed was fluctuating at various speed and the cfm was not constant. So, we made a proper connection so that this issues is not faced in the future. Also, the shifter wire was coming of the connector. So, we shouldered that wire properly on the terminal to get rigidity.

Conclusion

We successfully manufactured the rule compliant harness into three different parts this year. Also, according to rule all the current pass through master kill switch and Ignition system cuts when cockpit kill switch is pressed. It was reliable, also fire proof, water proof and used cotton tape to avoid any break in wire due to stress or Sharpe edges. This season DAQ was not a success as we had planned because ECU had some issues regarding storing the data. Dash was also made of carbon fibre and designs were better than last season.