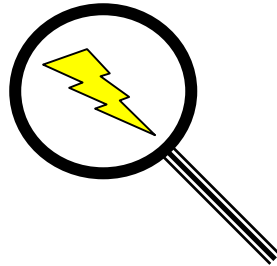


# SparkViz



## *Variable RPM Spark Plug Ignition Tester*

### *Construction Guide* v1.0

**Doc Version:** 1.0  
**Updated:** 23rd January 2006

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# 1 Introduction

SparkViz is a standalone spark plug ignition tester with variable RPM control. SparkViz enables the user to visually examine and compare the quality of the spark plug ignition arc at both low and high RPMs. Unlike a conventional engine, SparkViz fires all four plugs simultaneously, enabling the user to compare the spark plug arc quality (colour and strength) for all four plugs simultaneously.



SparkViz is suitable for:

- Testing old or newly adjusted spark plugs over a variable rev range (up to 12,000 rpm).
- Identifying weak spark plugs
- Identifying poor arcing at low or high revs
- Seeing and compare for yourself the arc quality of various spark plug makes and brands.

## 1.1 Purpose of Document

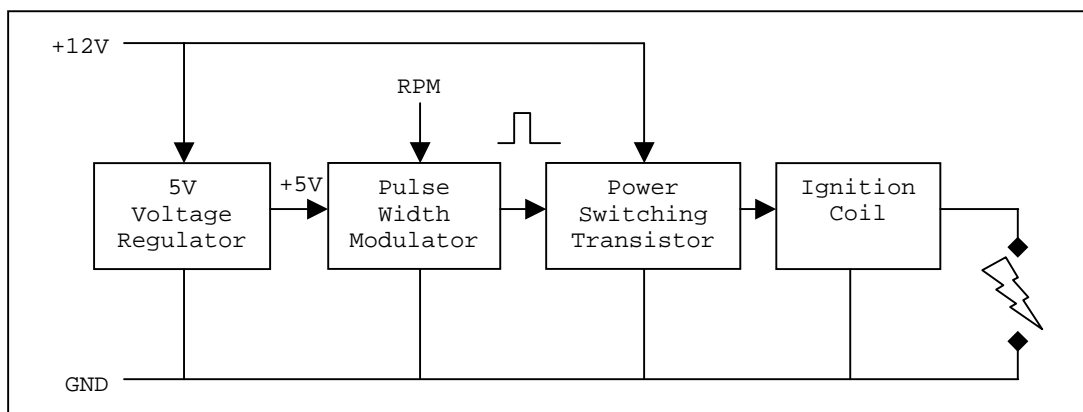
This document serves as a guide to the design overview, construction and testing of the SparkViz tool.

## 2 Design Overview

The SparkViz design comprises of the following functional units:

- Voltage Regulator
- Pulse Width Modulator
- Power Switching Transistor
- Ignition Coil (also referred to as coil pack)

The diagram below shows a high level functional view of SparkViz.



A detailed component level circuit schematic of the above can be found in Appendix A.

The voltage regulator converts the 12V input, to a regulated 5V output supply for the Pulse Width Modulator.

The Pulse Width Modulator (PWM) is a custom micro controller (ArcGen) which generates the firing signal pulse according to the RPM setting. In addition to manual RPM control, it also provides an automatic ramp mode setting, whereby the RPM is automatically ramped up and down periodically. A full datasheet for the ArcGen micro controller can be found in Appendix B.

The power switching transistor is driven by the PWM signal to periodically switch on and off the current flowing through the primary low-tension coil. The power transistor is an n-channel enhancement mode MOSFET capable of handling the maximum current required by the primary coils. A typical current requirement for the ignition coil is 5A (at 12000 rpm). A suitable alternative n-channel MOSFET capable of handling the maximum current and voltage could be used as an equivalent. The author has used an STP55NE06, capable of handling up to 55 Amps at 60V DC. In parallel with the MOSFET is an RC circuit to suppress an AC spike transients produced by the coil.

Ignition coils used in cars come in various forms:

- Conventional single ignition coil with distributor cap
- Double ended coil (DEC)
- Coil per cylinder (CPC)

A conventional ignition system is based on a single ignition coil whereby the spark is distributed to the spark plugs via a rotary distributor. This coil could be used for a single spark output, but is unsuitable for multi-plug output due to the redundant distributor cap, and possible weak spark when shared by four concurrent firing plugs

A double ended coil pack is ideal for use with SparkViz. In this system two cylinders share one ignition coil. Both ends of the secondary coil side are directly connected to the relevant spark plug. This means two sparks are always ignited, one ignites during the compression stroke, and the other (waste spark) is fired during the exhaust stroke. Ensure that the coil pack

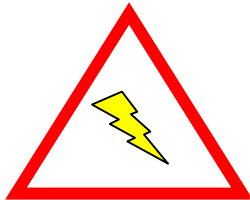
is passive (simple transformer type), and does NOT contain any active components for an internal amplifier.

In the coil per cylinder ignition system, each spark plug has its own coil, and can be controlled individually. These coils can also be used with SparkViz.

The DEC coil pack is the most common form of distributorless coil pack. As all four plugs are fired simultaneously (for ignition arc comparison reasons), there is not much benefit in using a coil per cylinder setup. Note that the ArcGen micro controller assumes no “wasted spark” for the RPM setting (ie only one spark per revolution).

An ignition coil has a primary coil and secondary coil. The primary coil connections are referred to Low Tension (LT), and usually operate at 12 Volts. The secondary coil connections are referred to as High Tension (HT), and produce the spark output at very high voltages (in the order of tens of kilovolts).

#### **HIGH VOLTAGE WARNING:**



Ignition Coil packs can produce very high voltages (exceeding 10,000 volts!). Although these high voltages may be at low currents, they are still very dangerous, and at best very unpleasant experiences.

**DO NOT ATTEMPT TO CONSTRUCT OR USE THIS DEVICE unless you are fully aware of all SAFETY PRECAUTIONS AND RISKS WITH HIGH VOLTAGE WORK.**

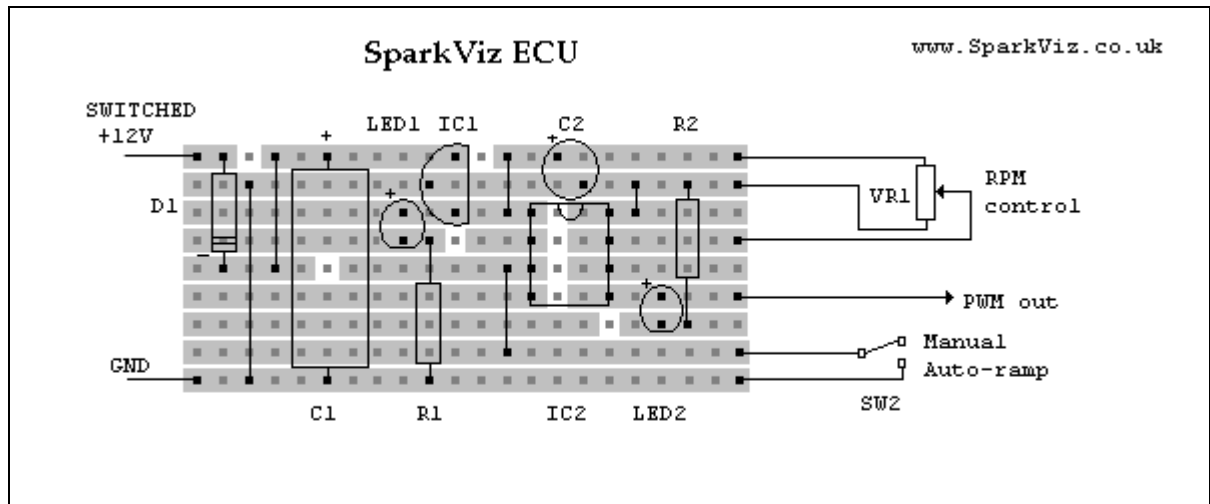
Always use insulated high voltage leads. Never touch live high voltage connections.

**READ THE DISCLAIMER BEFORE PROCEEDING.**

## 3 Construction

### 3.1 Electronic Control Unit

The SparkViz electronic control unit (ECU) comprises of the voltage regulator and pulse width modulator. This can be constructed on a small piece of stripboard (9 tracks x 22 holes) as shown below.



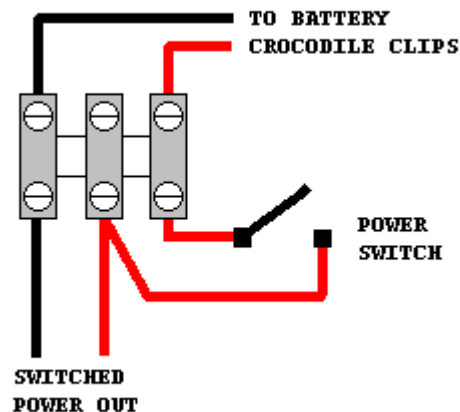
Please refer to Appendix A for the component key. For clarity, the above diagram shows the component side view with transparent underside tracks. Note there are 9 breaks in the tracks.

### 3.2 Hardware Mounting

The remaining components used in SparkViz require heavy current cable, capable of handling a minimum current of 5 amps.

The incoming power cable should be terminated with heavy duty crocodile clips (25 amp variety), suitable for direct battery connection. This should then be fed into the SparkViz enclosure via a suitable strain relief cable grommet.

The incoming power cable, power switch and switched supply should be wired as shown below. If you wish, you may also add a suitable fuse in series with the power switch.



If the SparkViz enclosure box is metal, you must also ground the case.

The power MOSFET must be mounted with a suitable heatsink. If the enclosure box is metal, you may wish to mount it to the metal casing. As the metal enclosure is earthed, and the TO220 heatsink lug is live with voltage, you MUST USE A MICA/RUBBER INSULATOR AND PLASTIC BUSH with heatsink compound when mounting the MOSFET to the heatsink.



Mount the user controls in a convenient and safe place on the enclosure.



### 3.3 Coil Pack Connection

On choosing a double ended coil (DEC) pack, you will need to identify the low tension primary ignition coil connections. If possible, you should obtain a matching plug-in connector for the coil pack. If this is not available, it should be possible to crimp on suitable connectors to make the individual connection.

How do you identify which terminal connections to use? Ideally, you will have an electrical schematic for the coil pack being used in a particular vehicle. A selection of pinouts for popular DEC coil packs is listed in Appendix C. If this information is not readily available for the coil pack of your choice, you should be able to determine the connections using a multimeter in resistance check mode.

Switch the multimeter to a medium resistance reading (eg 200Kohm). Begin by testing the resistance of the High Tension (HT) coils for a pair of spark lead output connections. This should be in the order of tens of kilo ohms for each pair.

Now switch the multimeter to the lowest resistance reading (eg 200 ohm). The coil pack should have at least 3 low tension terminal connections (some have four or more). The Low Tension primary coils are typically around 1 ohm in resistance. Note the resistance of all terminal combinations. From this list identify the two pairs with the same resistance readings (around 1 ohm, eliminating any zero ohm readings) Both pair of readings may share a common ground terminal.

The pair of parallel wired ignition coils should be wired to the MOSFET and R-C transient spike suppressor components as shown in Appendix A.

Ensure the coil pack is securely mounted inside the enclosure case, as they are often heavy.

### 3.4 Spark Plug Connection

Each spark plug has two connections:

- High Tension (HT) voltage from the coil pack (via the HT ignition leads).
- Ground via the spark plug body to the negative battery terminal.

The HT connection from the coil pack connect to the spark plugs via the HT leads. The HT leads must provide electrical insulation at all connections from the coil pack to the spark plugs (in the form of rubber insulating connector grips). Never touch HT connections during live operation.

The ground connection can be made using suitable diameter sized spring tool clips. These should hold the spark plug firmly in position on the enclosure case and provide a good earth connection. Each spring clip should be firmly connected to the ground connection cable (heavy current wire) using a nut, bolt and lock washer.



Ensure all HT leads are well insulated, with no cracks or bare connections. Always use rubber grommets when passing HT leads through a metal enclosure.

## 4 Testing

### 4.1 Testing ECU

On completion of ECU construction, the ECU unit should be tested as a standalone unit (PWM OUTPUT DISCONNECTED).

1. REMOVE the ArcGen micro controller from the 8 pin DIL socket.
2. CONNECT a 12v power supply or battery to the ECU unit power terminals.
3. The RED power LED should LIGHT UP, indicating a 5V regulated output.
4. MEASURE the regulated output voltage to ensure it is sitting at 5V.
5. DISCONNECT the power to the ECU unit.
6. INSERT the ArcGen micro controller into the socket with the CORRECT ORIENTATION.
7. Switch the RPM control setting to minimum (towards GND terminal on potentiometer).
8. Switch the RPM MODE setting to MANUAL
9. (OPTIONAL): Connect an audible piezo transducer to the PWM output and ground. This will help you to audibly listen to the PWM output.
10. CONNECT a 12v power supply or battery to the ECU unit power terminals.
11. The RED LED should light up, and the GREEN LED should PULSE once every second.
12. Turn up the RPM potentiometer, and the GREEN LED should FLICKER at a faster rate. For those with the optional audible output, the tone should increase in frequency up to 200Hz at 12,000 RPM.
13. Switch the MODE to AUTO-RAMP.
14. The output PULSE RATE and TONE should drop to minimum immediately. and gradually rise to the preset RPM setting, after which it will ramp back down and up repeatedly.
15. Try altering the maximum preset RPM via the potentiometer knob, and observe the behaviour. It should oscillate between minimum and the new maximum RPM setting.
16. Switch the MODE to MANUAL.
17. Now vary the RPM control to directly alter the pulse/tone.
18. DISCONNECT the power to the ECU unit.

### 4.2 Testing Assembled SparkViz Unit

This test should be performed once all components have been assembled and mounted safely into position.

TO TEST THE SPARKVIZ UNIT:

1. Ensure the unit is DISCONNECTED from the battery and SWITCHED OFF
2. ALL spark plug gaps are adjusted
3. ALL spark plugs are connected firmly to the HT ignition leads
4. ALL spark plugs are connected to ground firmly via the spring clips
5. All HT connections are dry
6. All HT leads are in good and safe condition, with no cracks or bare connections.
7. Switch to MANUAL mode with minimum RPM setting via control knob.
8. CONNECT to battery
9. SWITCH ON SparkViz unit
10. The Spark plugs should SPARK once every second
11. Increase the RPM setting and observe the spark RATE
12. Switch to AUTO RAMP mode and observe the ramp up/down behaviour.
13. SWITCH OFF SparkViz unit.
14. DISCONNECT from the battery

## 5 Troubleshooting

This section describes possible symptoms, and causes of problems. Basic electronic multimeter skills are assumed.

### 5.1 ECU Troubleshooting

These tests should be performed with the ignition coil disconnected.

#### Red Power LED does not light up

1. Check Power connections, measuring voltages in and out, from the terminal block.
2. Check for defective power switch or poor terminal block connections.
3. Check protection diode is functioning. Reverse bias diode test with multimeter should read approx 0.6v.
4. Check the 7805 voltage regulator. Input voltage should be around 12V, Output regulated voltage should be 5V. If the output voltage drops below 4.8V or above 5.2V, replace the voltage regulator.

If the Voltage regulator has died, find out why, as it may happen again. Possible reasons are:

- Poor insulation between MOSFET TO220 package and heatsink connected to ground. This could cause spike voltages to leak to ground, damaging the voltage regulator.
- Check R-C connections for spike suppressor circuit.

#### Green PWM LED stays OFF permanently

1. Ensure ArcGen micro controller is inserted in the correct orientation.
2. Measure voltage supply between pins 1 and 8 of the micro controller. Positive terminal of multimeter at pin1, negative terminal at pin 8. Ensure reading of +5 volts (not -5V)
3. If ECU tests fail, replace the ArcGen micro controller.

#### RPM control knob does not function in MANUAL mode

1. Ensure voltage between end pins of potentiometer is 5 volts.
2. Ensure voltage at middle pin of potentiometer varies between 0v and 5v, between minimum and maximum setting. If voltage does not change, replace potentiometer.
3. Repeat step 2 checking voltage at pin 7 of the ArcGen micro controller.
4. Replace ArcGen micro controller.

### 5.2 Battery Troubleshooting

#### Green LED flickers, but no SPARKING (or weak intermittent sparking)

1. Check battery is supplying adequate current to energise the coil packs. Switch multimeter into DC current test mode, and measure current flow by placing in series between positive battery terminal and positive crocodile clip. Switch on SparkViz, and current demand should increase from 0.1A to 5A with increasing RPM. If current flow fails to increase, weak supply battery is a possible cause. Re-test with a fully charged battery.
2. Proceed to MOSFET troubleshooting

### 5.3 MOSFET Troubleshooting

#### MOSFET Testing: Green LED flickers, Good battery, but no SPARKING

1. Remove MOSFET from circuit.
2. Discharge MOSFET by temporarily connecting a piece of wire between all 3 pins.

3. Test resistance between SOURCE (-) and DRAIN (+) pins. Resistance should be infinite or at least in the mega ohms. If reading is zero, this indicates a faulty short circuited MOSFET. Replace the MOSFET.
4. Switch multimeter to diode test and connect (-) to SOURCE and (+) to GATE.
5. Without touching any of the pins with your hand, now measure resistance between SOURCE(-) and DRAIN (+). Resistance should be < 100Kohm for a good MOSFET.
6. Now discharge the GATE to DRAIN with a piece of wire.
7. Test resistance between SOURCE (-) and DRAIN (+) pins. Resistance should again be infinite or in the mega ohms for a good MOSFET.

If the MOSFET has failed, try and find out why, otherwise it may happen again. Possible causes are:

- Poor mica and bush electrical insulation between nut and bolt use to mount heatsink to TO220 package. Measure resistance for any short circuit between the heatsink and TO220 package.
- Check heatsink is thermally adequate for your MOSFET current rating. Ensure you use a good thermal heat transfer compound between TO220 package and mica and heatsink.

If MOSFET is good, proceed to Coil pack/HT troubleshooting.

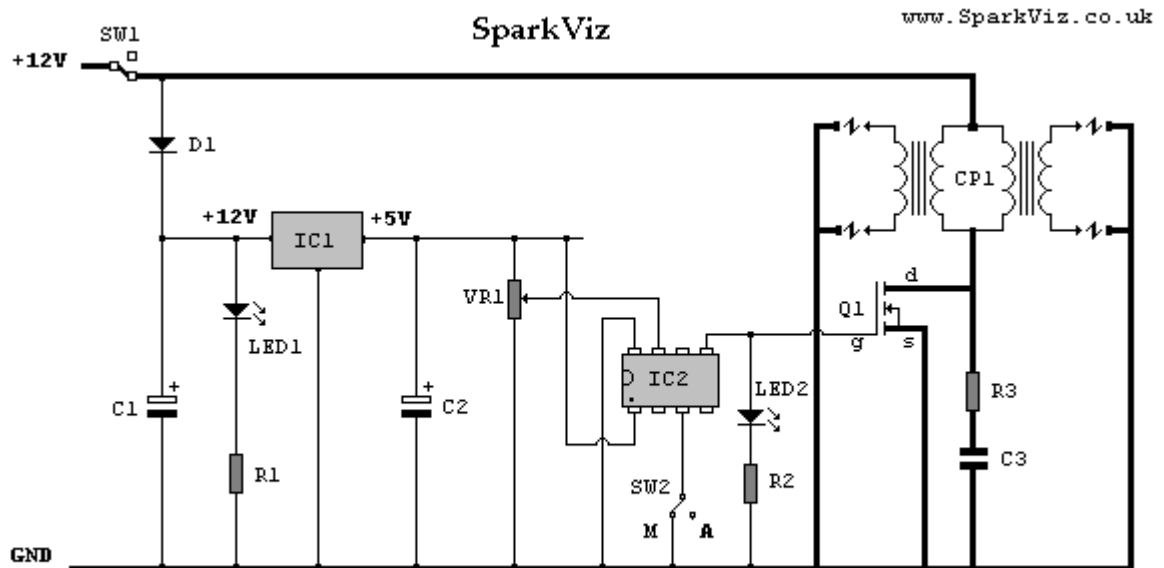
## 5.4 Coil Pack/HT Troubleshooting

**All test should be performed with coil pack disconnected.**

### **Green LED flickers, but no SPARKING, Good Battery, Good MOSFET**

1. Check Primary coil resistance of each coil individually. Should be low resistance, less than a few ohms. Any High resistance readings indicate a suspect coil pack.
2. Check secondary coil resistance between pairs of HT ignition lead outputs for each paired coil. Resistance should be in the Kilo ohms (approx < 10Kohm). Higher resistance readings (in the mega ohms) indicate a suspect coil pack.
3. Check resistance of HT leads. Should be in the kilo ohms range or lower. A single faulty HT lead may show up as a weak or "no spark" for both spark plugs connected to the same coil. Try swapping HT leads with other pair to eliminate a faulty lead. Replace faulty HT lead.
4. Check spark plug ground clips are grounded, by measuring resistance between negative crocodile clip and each spark plug clip (should be less than a few ohms).

## 6 APPENDIX A: Detailed Schematic



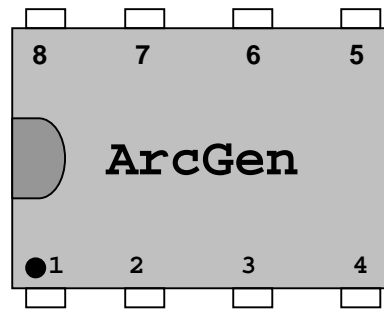
Component	Description	Comments
C1	220uf 16V electrolytic	axial
C2	10uf 35V electrolytic	radial
C3	250V 100nF X rated	Spike suppressor capacitor
CP1	Double ended coil pack	Constructors choice (eg Sagem SL96)
D1	1N4001	Reverse Protection diode
IC1	LM7805 300mA	5V voltage regulator
IC2	ArcGen micro controller + 8 pin DIL socket	Pulse Width Modulator available from <a href="http://www.sirpic.com">www.sirpic.com</a>
LED1	3mm Red LED	Power on LED
LED2	3mm Green LED	Firing Signal LED
Q1	STP55NE06 n-channel MOSFET	55 amp, lower rating MOSFET will do.
R1	1k ohm 0.6W	
R2	1k ohm 0.6W	
R3	100 ohm 0.6W	spike transient load
SW1	Power Switch	heavy current
SW2	Mode switch	Mode: Manual / Auto-Ramp
VR1	10k ohm Potentiometer	RPM control

Note: Darker wiring lines, represent heavy current wire (minimum 5A current capacity).

## 7 APPENDIX B: ArcGen Micro Controller

The ArcGen micro controller is a custom programmed PIC microchip 12F675 device for use with SparkViz. ArcGen can be purchased from the SirPic website (<http://www.sirpic.com>) in hex file format (for programming a PIC 12F675 device).

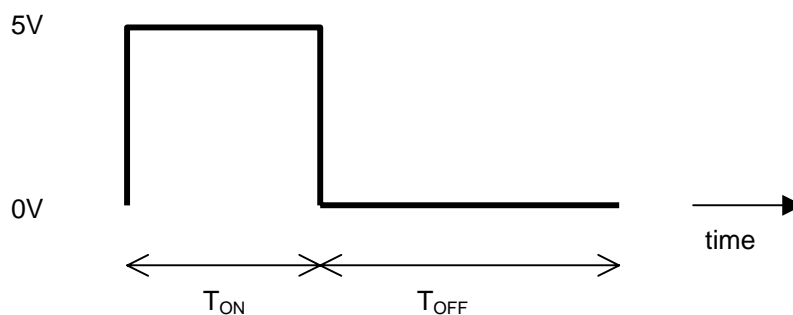
### 7.1 Pinout



Pin	Description	Comments
1	<b>Vdd</b>	Drain (+5V)
2	<i>Reserved for future use</i>	
3	<b>RPM MODE</b> Select Input	Manual = Grounded (0V) Auto-Ramp = Floating (+5V)
4	<i>Reserved for future use</i>	
5	<b>PWM OUT</b>	Pulse width modulated output for RPM setting and mode.
6	<b>IRTX OUT</b>	Infra Red Output at 9600 baud, for use with Palm PDA + SirPic + IrTx interface. Transmits Version info + Debug trace. (see <a href="http://www.sirpic.com">http://www.sirpic.com</a> for more details)
7	<b>RPM CONTROL</b> (Analogue Input Voltage)	Analogue voltage between 0 and +5V. 0v = Minimum RPM +5V = Maximum RPM (12,000)
8	<b>Vss</b>	Source (GND)

### 7.2 PWM Output Signal

The PWM Output signal comprises of a "PULSE ON" duration ( $T_{ON}$ ) followed by a "PULSE OFF" tail duration ( $T_{OFF}$ ). Where, "PULSE OFF" is represented by 0V and "PULSE ON" is represented by +5V, as shown below.



$T_{ON}$  has a fixed “PULSE ON” duration of 4 milliseconds. This is sufficient time to energise the coil-pack, before switching back to “PULSE OFF”, and generating the spark.  
 $T_{OFF}$  has a variable delay ranging between 1 msec and 0.996 second. This variable tail delay is used to control the RPM.

Where:

$$T_{PERIOD} = T_{ON} + T_{OFF}$$

$$Freq = 1 / T_{PERIOD}$$

$$RPM = (60 \times Freq) = 60 / T_{PERIOD}$$

For example when  $T_{OFF}=1\text{msec}$ :  $F=200\text{ Hz}$ ,  $RPM=12000$   
 Similarly, when  $T_{OFF}=0.996\text{ sec}$ :  $F=1\text{ Hz}$   $RPM=60$

Hence by varying the  $T_{OFF}$  interval, the RPM is controlled.

The RPM Control voltage is used to directly vary  $T_{OFF}$ .

### 7.3 Manual and Auto-Ramp Mode

In “MANUAL” mode, the RPM increments in the following sequence (from a minimum of 60 rpm = 1Hz = 1 spark every second):

60, 200, 400, 600, 800, 1000, 1200,.....11800, 12000 rpm.

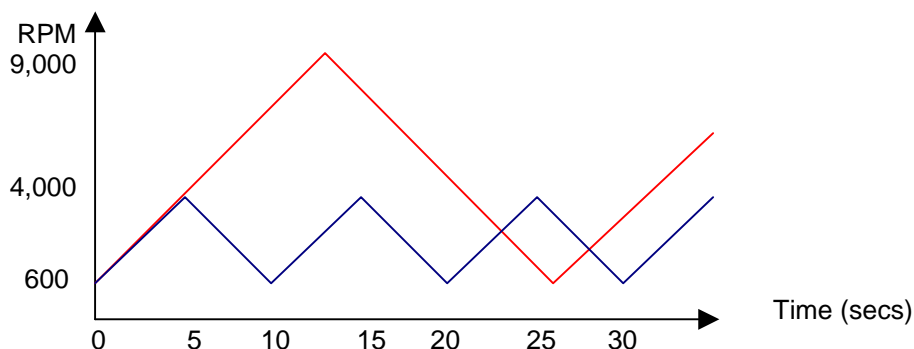
In “AUTO RAMP” mode the RPM is continuously ramped up and down to the maximum preset RPM setting (RPM control voltage), to provide a “hands free” demonstration.

In “AUTO-RAMP” mode, the RPM is ramped up and down in increments of 200 rpm, from a minimum of 600 rpm to the maximum preset RPM control (12000 rpm shown in sequence below).

600, 800, 1000, 1200,.....11800, 12000 rpm.

In “AUTO RAMP” mode, the RPM is stepped up linearly in approximately 0.3 second intervals for each 200 rpm increment (ramp step). If the maximum RPM is set to 12,000 rpm it will take approximately 17 seconds to ramp up to the maximum RPM, and then ramping back down to 600 rpm (taking an additional 17 seconds).

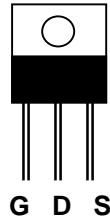
As the maximum RPM setting is decreased, the total ramp up and ramp down period decreases accordingly. This is illustrated below where the red line represents a maximum setting of 9,000rpm, and the blue line represents a maximum of setting 4,000 rpm.



## 8 APPENDIX C: Miscellaneous

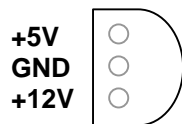
### 8.1 T0220 Package Pinout

Front view:



### 8.2 LM7805 Voltage Regulator Pinout

Top View:



### 8.3 Popular DEC Coil Pack Pinouts

Coil Pack Manufacturer	Used in vehicle	Pinout & Comments
SAGEM SL96	Peugeot 306 1.6 Year:1994 Engine type: TU5JP	Looking into male connector on coil pack.  Pin 1 (Left): Primary coil 1 (+) Pin 2: Primary coil 2 (+) Pin 3: unused Pin 4 (Right): Common ground for both coils (-)  Approx dimensions: 13cm (L) x 10cm (W) x 9cm (H). Height is with ignition lead connectors.
MOTORCRAFT	Ford 1.6 ZETEC engine	Looking into male connector on coil pack.  Pin 1 (Left): Primary coil 1 (+) Pin 2: Common ground for both coils (-) Pin 3 (Right): Primary coil 2 (+)  Approx dimensions: 11cm (L) x 11cm (W) x 13cm (H) Height is with ignition lead connectors.

## 8.4 Miscellaneous Hardware Items

Description	Quantity	Comments
Stripboard / Veroboard	Minimum 9 tracks x 22 holes	For ECU panel
8 pin DIL	1	For seating ArcGen micro controller.
Single core bell wire	0.5m	For ECU jumper connections and in/out wiring
Heavy current wire (Min 5A @ 12VDC)	0.5m	Terminal block/coil pack/MOSFET connections
Twin power cable	1m	39 strand loudspeaker wire is ideal.
Strain Relief Grommet	1	For incoming power cable
Tool clips	4 x 10mm diameter	For securing and grounding spark plugs.
Mica Insulator	1	For TO220 MOSFET
Insulator Bush	1	For TO220 MOSFET
Nuts and bolts	7	For TO220 MOSFET, tool clips terminal block, and grounding metal case.
Enclosure Case	1	Suitable to house coil pack + ECU
Crocodile clips	2	Heavy duty 25 amp
Terminal block	3 pairs	For internal power distribution
High Voltage Warning Label	1	Place in a clearly visible location on the enclosure box.