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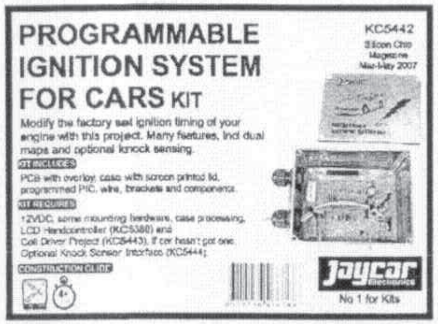
KC5442: KIT – PROGRAMMABLE IGNITION SYSTEM MK2

Silicon Chip Magazine March 2007 (p16 – p27), April 2007 (p66 – p78), May 2007 (p74 – p83)

Rev 1A

Batch No: 7W9060



Customers please note:

- The supplied PCB has an overlay showing the various configurations for the different trigger inputs.
- Some case machining is required.
- Additional parts are required for the Points to Hall Effect Sensor conversion.

PLEASE READ BEFORE COMMENCING CONSTRUCTION

The guarantee on this kit is limited to the replacement of faulty parts only, as we cannot guarantee the labour content you provide. Our Service Department does not do general service on simple kits and it is recommended that if a kit builder does not have enough knowledge to diagnose faults, that the project should not be started unless assistance can be obtained. Unfortunately, one small faulty solder joint or wiring mistake can take many hours to locate and at normal service rates the service charge could well be more than the total cost of the kit.
If you believe that you may have difficulty in building this kit (which is simply a complete set of separate parts made up to a list provided by the major electronics magazines) and you cannot get assistance from a friend, we suggest you return the kit to us IN ITS ORIGINAL CONDITION for a refund under our satisfaction guarantee.
Unfortunately, kits cannot be replaced under our satisfaction guarantee once construction has been commenced.

CONTACTS:

For queries with regards to the design aspects of this kit please contact the Project Designer. It is recommended to check the designers/publishers website for further notes and errata since this document was issued.
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www.siliconchip.com.au, silchip@siliconchip.com.au

For **quality issues** please contact the **Production Manager** at Jaycar Electronics and provide the following information:

- Product Number
- Batch No
- Details of Quality Issue

Notes and Errata (at time of print):
It is recommended to check the designers/publishers website for further notes and errata since this document was issued, before starting construction.
The project article has been updated with relevant notes and errata. It will therefore differ from the original article published in the magazine.

Possible Substitutions			
Original Part	Original Part Desc	Subst Part	Subst. Part Desc.
N/A			

PARTS LIST

Please note that catalogue numbers refer to suitable products from the Jaycar product range. Quantities listed refer to the actual number of items required. When purchasing items separately, take pack quantities into account.
[1] *See section about Substitution* [2] **See section about Notes & Errata** [3] Processed Panel not part of Case listed
Catalogue numbers starting with "E" or listed as "Special Order" (incl. processed panels) are Kit specific and may not be readily available.

For queries with regards to the design aspects of this project please contact the Project Designer.

COMPONENTS COMMEN TO THE VARIOUS PROGRAMMABLE IGNITION CONFIGURATIONS

RESISTOR(S)

Cat.#	Qty*	Description	Component Ident And/Or Location
HP1250	10	PIN PCB 0.9MM GLD	
RR0524	9	RES 0.5W MTL 10R 1%	Brown Black Black Gold Brown
RR0564	1	RES 0.5W MTL 470R 1%	Yellow Purple Black Black Brown
RR0572	1	RES 0.5W MTL 1K0 1%	Brown Black Black Brown Brown
RR0578	1	RES 0.5W MTL 1K8 1%	Brown Grey Black Brown Brown
RR0580	2	RES 0.5W MTL 2K2 1%	Red Red Black Brown Brown
RR0596	3	RES 0.5W MTL 10K 1%	Brown Black Black Red Brown
RR0612	2	RES 0.5W MTL 47K 1%	Yellow Purple Black Red Brown
RR0620	2	RES 0.5W MTL 100K 1%	Brown Black Black Orange Brown

CAPACITOR(S)

Cat.#	Qty*	Description	Component Ident And/Or Location
RC5316	2	CAP CER NPO 22P 50V 10% P=5MM	22pF
RC5336	2	CAP CER NPO 1N 50V 10% P=5MM	1n / 1000p / 102
RC5348	1	CAP CER NPO 10N 50V 10% P=5MM	0.01uF / 10n / 103
RE6066	1	CAP ELECT RB 10U 16V 105C P=2MM 5X11MM	10uF / 16V
RE6130	3	CAP ELECT RB 100U 16V 105C P=2.5MM 5X11	100uF / 16V
RE6220	1	CAP ELECT RB 1000U 16V 105C P=5MM 10X21	1000uF / 16V
RM7010	1	CAP MKT 1N 100V P=5MM 7.5X2.5X6.5MM	1.0n / 1n0 / 102
RM7065	1	CAP MKT 10N 100V P=5MM 7.5X2.5X6.5MM	0.01uF / 10n / 103
RM7125	3	CAP MKT 100N 100V P=5MM 7.5X2.5X6.5MM	0.1uF / u1 / 100n / 104
RM7145	1	CAP MKT 220N 100V P=5MM 7.5X3.2X8MM	0.22uF / u22 / 220n / 224

SEMICONDUCTOR(S)

Cat.#	Qty*	Description	Component Ident And/Or Location
EZ9017	1	IC PROG (KC5442) 16F88-E/P* DIP18	
PI6458	1	SKT IC MACHINED 18PIN	
RQ5299	1	CRYSTAL 20MHZ HC49US	20MHZ
ZR1004	1	DIODE 1N4004 400V 1A DO41	1N4004
ZR1162	1	DIODE P4KE 13.6V 16A STANDOFF 400W AC	P16CA
ZT2115	1	TRAN BC337/BC877 NPN 50V 800MA TO92	BC337
ZV1560	1	VREG LM2940CT-5 +5V 1A L/DROP TO220	LM2940

JAYCAR ELECTRONICS PTY LTD (ABN 65 000 087 936), 100 SILVERWATER RD, SILVERWATER, NSW 2128, AUSTRALIA
Tel: (02) 9741 8555 Fax (02) 9741 8500 www.jaycar.com.au kits@jaycar.com.au

HARDWARE / WIRE(S) / MISCELLANEOUS (small)

Cat.#	Qty*	Description	Component Ident And/Or Location
EF1154	1	SCREW M3X6MM SLOT R/HD ZP	
EF1167	4	SCREW M3X20MM POZI CSK SP	
HM3212	1x2 & 1x3 way	HEADER SGL VRT 40WAY P=2.54MM	
HM3240	2	JUMPER SHUNTS P=2.54MM	
HP0149	1	WASHER NYLON M3 FLAT WHT	
HP0403	1	SCREW M3X10MM PHIL R/HD SP	
HP0414	1	SCREW M3X25MM PHIL R/HD SP	
HP0425	5	NUT M3 SP	
HP0433	8	WASHER MTL M3 S/PRF INT/T SLV	
HP0905	2	SPACER MTL TAPPED HEX M3X15MM	
HP0921	4	SPACER NYLON TAPPED HEX M3X6.3MM	
HP1350	2	LUG SOLDER TIN ID4.3XID2X17.6MM0	
LF1250	3	FERRITE BEADS FX1115	
LO1242	1	RING CORE IRON HY2 15X8X6.5MM	
NS3015	1	SOLDER 60/40 1MM	
PM0852	2sets	NUT SET LOCKING (D CONNECT) L6MM	1set = 1nut, 1 washer, 1screw
PM0854	2	SCREW (D CONNECT) 13MM	
ST0335	1	SWITCH TGL MINI SPDT SLD TAG	
WW4016	70cm	WIRE EN CU 0.5MM 24BS	
WW4032	20cm	WIRE TIN CU 0.71MM 22AWG	
WH5533	10cm	HEATSHRINK 5MM X 1.2M BLK	

HARDWARE / WIRE(S) / MISCELLANEOUS (large)

Cat.#	Qty*	Description	Component Ident And/Or Location
EB2211	2	PNL ALU 80X35X2MM	
EC8250	1	PCB (KC5442) NTN 05104071 102X81MM 03/07	with overlay
HB5064	1	ENCL BOX DIECAST 119X93.5X56.5MM	with screen printed lid
HP0725	2	CABLE GLAND IP68 4-8MM	
HP1203	4	CABLE TIE 100X3MM BLK	
PS0768	1	SKT PCB D25 HI-SPEC SOLDER	
WH3012	2m	CABLE HU RND 13X0.12MM L/D BRN	
WH3014	2m	CABLE HU RND 13X0.12MM L/D YEL	
WH3040	2m	CABLE HU RND 24X0.2MM H/D RED	
WH3041	2m	CABLE HU RND 24X0.2MM H/D BLK	
WH3042	2m	CABLE HU RND 24X0.2MM H/D GRN	

For queries with regards to the design aspects of this project please contact the Project Designer.

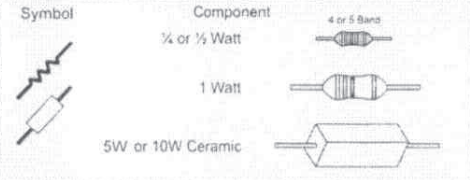
COMPONENTS SPECIFIC TO THE VARYING PROGRAMABLE IGNITION CONFIGURATIONS

Cat.#	Total	((Points Qty))	(Reluctor Qty)	{Hall Effect Qty}	[[Crane Qty]]	[Piranha Qty]	Description	Component Ident And/Or Location
HP1250	2		1	2	2	2	PIN PCB 0.9MM GLD	
RC5332	1		1				CAP CER NPO 470P 50V 10% P=5MM	470p / 471 / n47
RR0548	1			1			RES 0.5W MTL 100R 1%	Brown Black Black Black Brown
RR0550	1				1	1	RES 0.5W MTL 120R 1%	Brown Red Black Black Brown
RR0604	1				1	1	RES 0.5W MTL 22K 1%	Red Red Black Red Brown
RR3274	2	1					RES 5W W/W 100R	5W 100R
RT4656	1		1				TRIMPOT 25TURN 100K TOP ADJ SPECTROL	100K / 104
RR0572	1		1	1			RES 0.5W MTL 1K0 1%	Brown Black Black Brown Brown
RR0596	2		2				RES 0.5W MTL 10K 1%	Brown Black Black Red Brown
RR0612	1		1				RES 0.5W MTL 47K 1%	Yellow Purple Black Red Brown
ZT2115	1		1				TRAN BC337/BC877 NPN 50V 800MA TO92	BC337
RM7022	1		1				CAP MKT 2N2 100V P=5MM 7.5X2.5X6.5MM	2.2n / 2n2 / 222

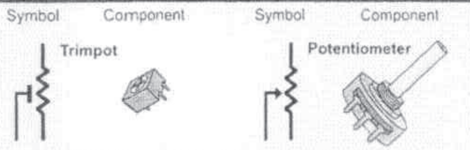
COMPONENT IDENTIFICATION

This section will help you to match some of the symbols used in schematics (electronic circuit diagrams) to the physical component used in the actual product. You will see the symbol on the left and the component on the right.

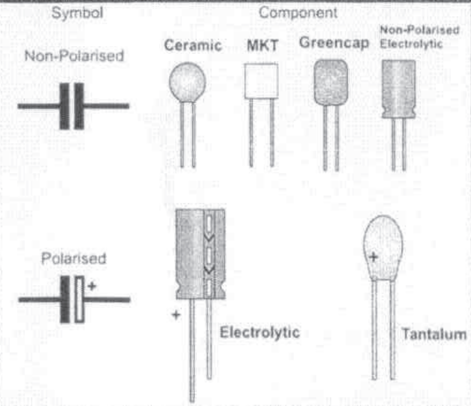
RESISTORS



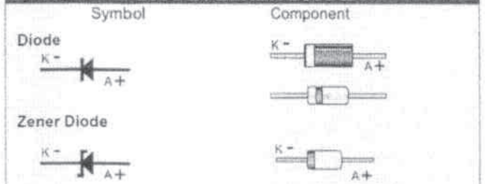
VARIABLE RESISTORS



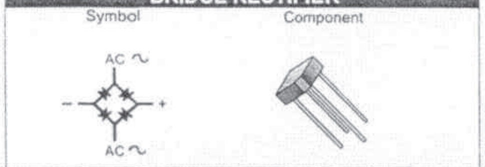
CAPACITORS



DIODE / ZENER DIODE

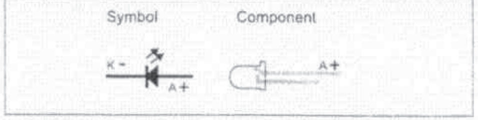


BRIDGE RECTIFIER

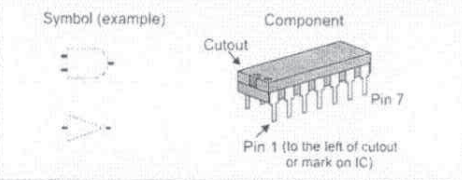


COMPONENT IDENTIFICATION

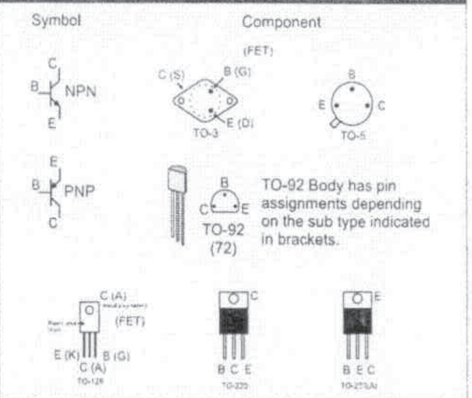
LED's



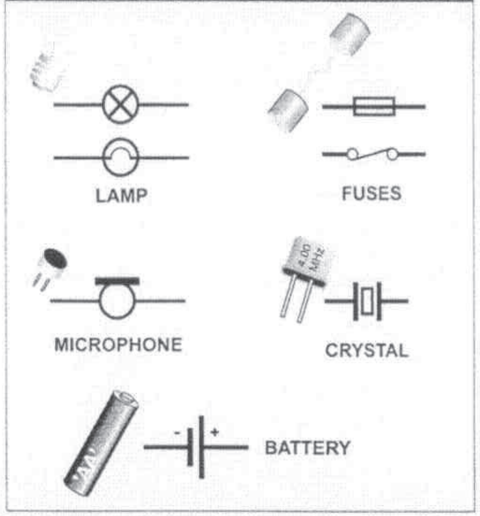
INTEGRATED CIRCUIT (IC)



TRANSISTORS

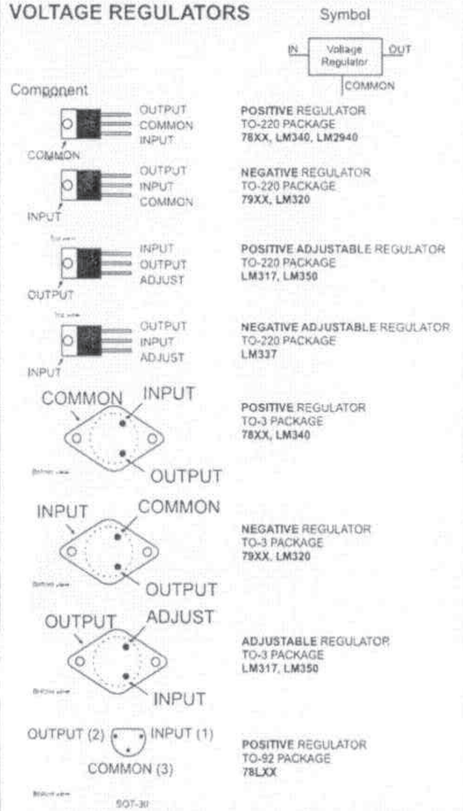


COMPONENT IDENTIFICATION



COMPONENT IDENTIFICATION

VOLTAGE REGULATORS



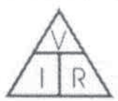
OHM'S LAW

The most basic law in electronics. The relationship between resistance, voltage and current is determined by Ohm's Law (*). If you know two out of the three values you can work out the third.

$V = I \times R$

$I = V/R$

$R = V/I$



The formulas are:

V is Voltage
I is Current in Amps and
R is resistance in Ohms

Jaycar Electronics

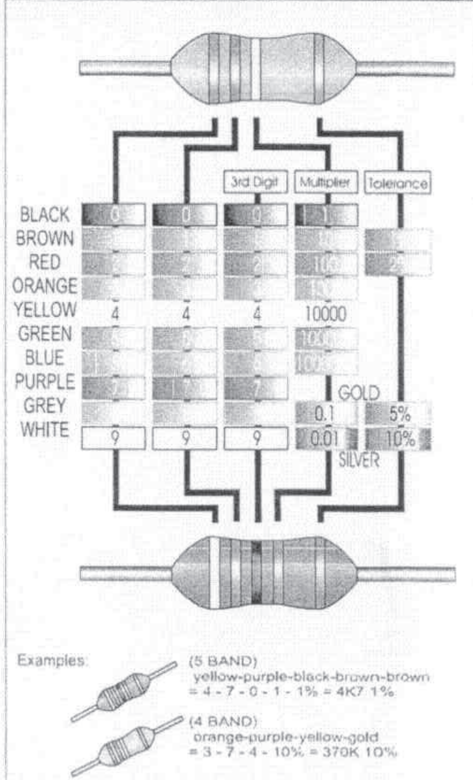
No 1 for Kits

kits@jaycar.com.au

COMPONENT REFERENCE CHART

Ver 1.2 - 01.12.2004

RESISTOR COLOUR CODES

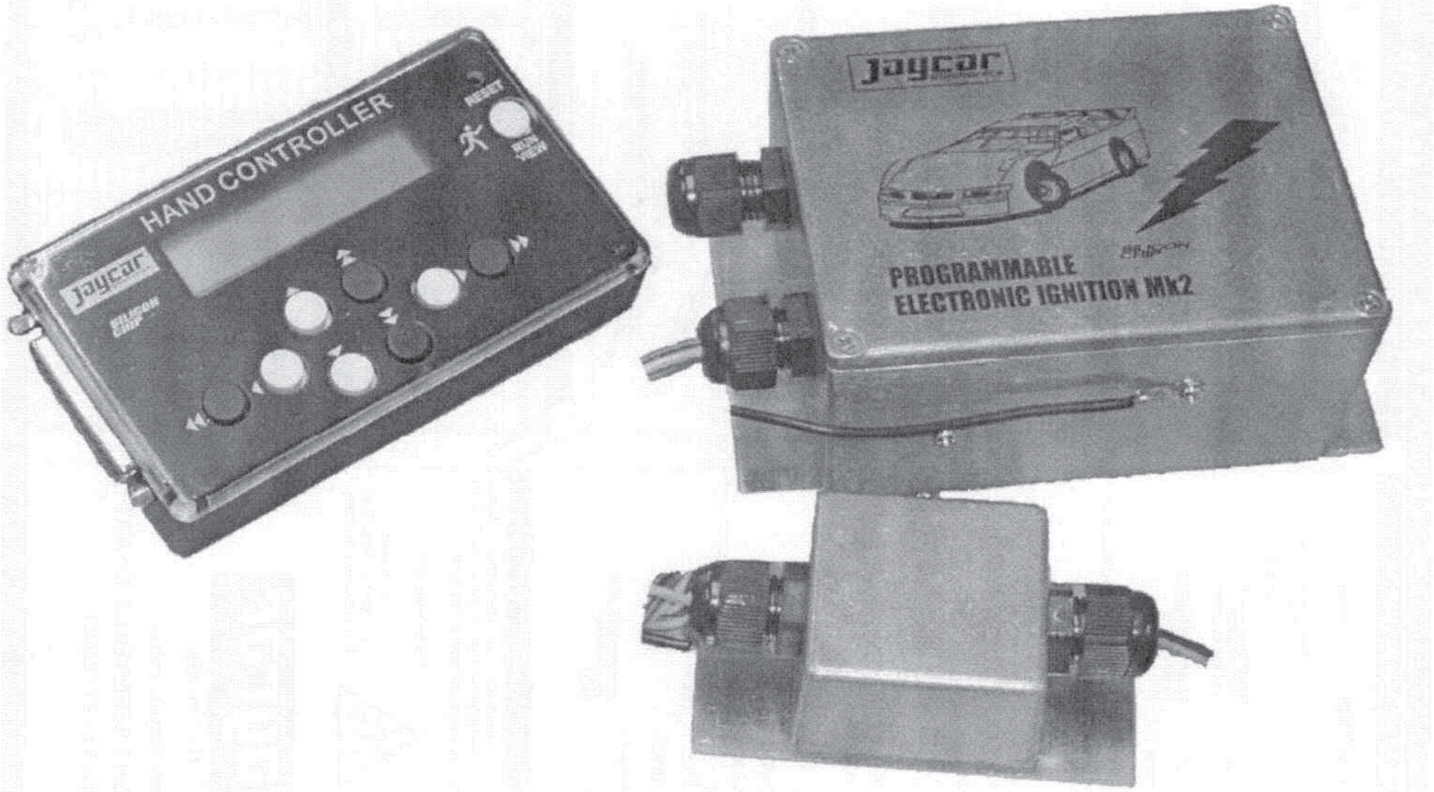


CAPACITOR CODES

Microfarads (u)	Nanofarads (n)	Picofarads (p)	EIA code
-	-	100pF	101
-	0.22nF	220pF	221
0.001uF	1nF	1000pF	102
0.0047uF	4.7nF	4700pF	472
0.01uF	10nF	-	103
0.047uF	47nF	-	473
0.1uF	100nF	-	104
0.47uF	470nF	-	474
1uF	1000nF	-	105

ZENER DIODES (1 WATT UNLESS SPECIFIED)

Part no.	Voltage	Part no.	Voltage
1N4728	3V3	1N4744	15V
1N4729	3V6	1N4745	16V
1N4730	3V9	1N4746	18V
1N4731	4V3	1N4747	20V
1N4732	4V7	1N4748	22V
1N4733	5V1	1N4749	24V
1N4734	5V6	1N4750	27V
1N4735	6V2	1N4751	30V
1N4736	6V8	1N4752	33V
1N4737	7V5	1N4753	36V
1N4738	8V2	1N4754	39V
1N4739	9V1	1N4761	75V
1N4740	10V	1N5349B	12V 5W
1N4741	11V	1N5352N	15V 5W
1N4742	12V	1N5374	75V 5W
1N4743	13V		



Programmable Ignition System for Cars. Pt1

by John Clarke

Want to program the ignition timing on your car? Now you can, with this completely new design. It can be used in older cars which presently do not have electronic ignition or used as an "interceptor" for cars with engine management systems.

OUR PREVIOUS Programmable Ignition was originally published in March 1996 and proved to be a very popular project with readers. This was subsequently updated as the Programmable Ignition Timing (PIT) Module in the June and July 1999 issues of SILICON CHIP.

The updated PIT module included a basic 2-step advance curve and a 1-step vacuum advance that changed the timing according to engine load. In operation, it was used to control the High Energy Ignition design from the June 1998 issue.

This latest Programmable Ignition from SILICON CHIP is far more advanced in features and its ability to produce an accurate advance curve. It is also a complete stand-alone ignition system that is triggered by an engine position sensor and then drives the ignition coil. It can be triggered from one of many sensors in a distributor, including points, reluctor, Hall effect, optical trigger and the 5V signal from the car's Engine Control Unit (ECU).

In order to measure engine load, the Programmable Ignition can use a Sensym absolute pressure sensor. In fact, provision has been made to mount this sensor directly on the PC board, the sensor then being connected to the engine manifold via plastic tubing.

Alternatively, you can connect the ignition circuit to an existing manifold pressure sensor if present. This is commonly called a Manifold Absolute

BLANK

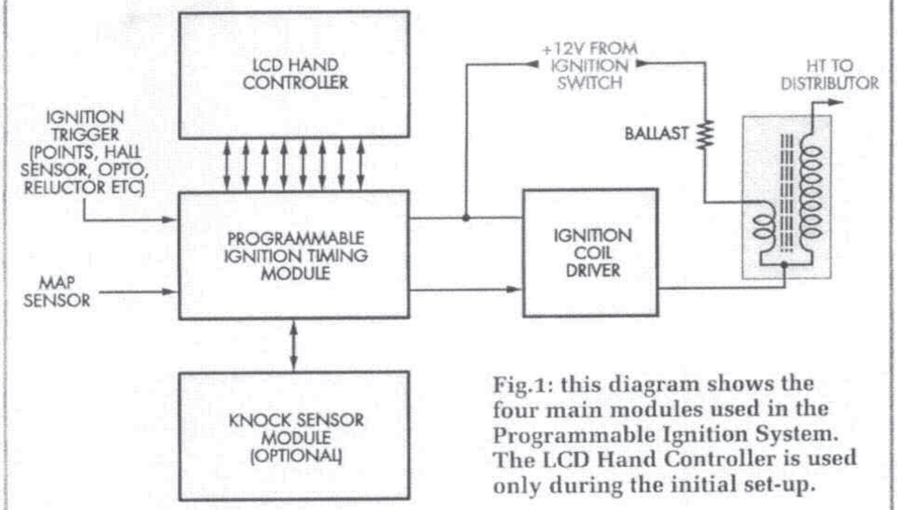


Fig.1: this diagram shows the four main modules used in the Programmable Ignition System. The LCD Hand Controller is used only during the initial set-up.

Pressure (or MAP) sensor and is found on many cars these days. You could also use a secondhand MAP sensor from an auto wrecker.

Changing the timing

A fully effective ignition system needs to increase the timing advance with increasing RPM and to alter the timing according to engine load – all with a fair degree of precision. Additionally, some means to detect detonation (knock) and retard the timing would be an advantage. In this way, the ignition can be advanced further than would otherwise be possible without knock sensing.

This latest SILICON CHIP Programmable Ignition incorporates all these features. What's more, there is an option to select between two separate ignition-timing curves using a switch. This option is ideal if you are running both petrol and gas, where a different timing curve is required for each type of fuel.

Fig.1 shows the complete system. It comes in four modules: an LCD Hand Controller, a Programmable Ignition Timing (PIT) module, an Ignition Coil Driver module and a Knock Sensor module. The first three modules are mandatory, while the fourth, the Knock Sensor module, is optional.

The heart of the system is the Programmable Ignition Timing module, based on a PIC16F88-E/P micro. It is programmed by the LCD Hand Controller and it delivers a signal to the Ignition Coil Driver. The latter, as its name suggests, then drives the ignition coil.

LCD Hand Controller

The LCD Hand Controller is similar to the one featured in our book "Performance Electronics for Cars". It was originally designed for setting up the Digital Pulse Adjuster, Digital Fuel Adjuster and Independent Boost Controller projects featured in that book.

The Hand Controller is used during the initial setting-up procedure. It plugs into the main unit and can be used while the engine is either running or stopped. It is then normally disconnected from the main unit after all adjustments have been made.

Using the Hand Controller, you can set all the initial parameters and also program the ignition advance/retard curve. Several pushbutton switches on the Hand Controller enable these changes to be made.

Knock sensor

The optional Knock Sensor module enables "pinging" to be sensed and the ignition timing retarded for a brief period. In brief, engine pinging is monitored by the Knock Sensor and the Programmable Ignition Timing (PIT) module for the first 6ms after each spark. However, at high RPM, there is less than 6ms between each firing and so knock signal monitoring is done between each spark and the start of the next coil dwell period.

When engine knock is detected, the timing is retarded for the next 10 sparks. The amount of retardation varies according to the severity of the knock signal. More details on this are given in the specifications.

Different uses

The Programmable Ignition can be used either as an interceptor or for fully mapped ignition timing. In the interceptor role, it can vary the existing ignition timing by advancing or retarding it from its current value – ie, it can be used to alter the timing signals from the car's ECU.

Alternatively, when used to completely replace the existing ignition timing, you will need to obtain the advance/retard curve for your vehicle so that the entire timing curve can be produced by the Programmable Ignition. For some vehicles, you may

Main Features

- Advance and retard adjustment over a wide range
- Plug-in LCD Hand Controller for adjustments
- Hand Controller LCD shows values and settings for adjustment
- Suitable for single-coil ignition systems with a distributor
- Can be used as a timing interceptor or as a replacement ignition
- Ignition timing mapped against RPM and engine load
- Interpolated values used for RPM and load values between sites
- Optional single map or dual timing maps
- Single map has 15 RPM sites x 15 engine load sites
- Dual maps each have 11 RPM sites x 11 engine load sites
- 1° or 0.5° adjustments
- Dwell adjustment
- Knock sensing indication with optional ignition retard
- Suits 1 to 12-cylinder engines (4-stroke) and 1 to 6-cylinder 2-stroke engines
- Two debounce settings
- High-level or low-level triggering
- Points, reluctor, Hall effect, digital signal or optical triggering
- Works with many pressure sensors (MAP sensors)
- Minimum and maximum RPM adjustments
- Minimum and maximum engine load adjustments
- Diagnostic RPM and load readings
- Add-on knock sensing unit (optional)
- Requires evenly spaced firing between cylinders. For V-twins, you will need two ignition systems and a separate trigger for each cylinder.

be able to obtain the curves from the manufacturer. For other cars, you will need to plot out the existing curve and transfer the resulting timing map to the Programmable Ignition.

Plotting out this timing curve is not hard to do and can, in fact, be done using the Programmable Ignition system itself and a timing light.

In practice, the ignition timing is mapped out in an array of either two 11-RPM by 11-engine load site maps or as a single 15-RPM by 15-engine load site map. Timing arrays (or ignition maps) are the most common method that car manufacturers use to set the ignition advance curve for both RPM and engine load.

Mapping is a way of plotting the advance curve as a series of steps rather than setting an ignition advance or retard value at every possible engine RPM and load value. Thus mapping sets the ignition advance or retard values at specified preset points for both RPM and engine load.

		RPM0	Min RPM										Max RPM
	RPM Site		RPM1	RPM2	RPM3	RPM4	RPM5	RPM6	RPM7	RPM8	RPM9	RPM10	RPM11
	Load Site	0	1000	1400	1800	2200	2600	3000	3400	3800	4200	4600	5000
Min load	LOAD1	16	16	18.5	21.5	23	25.5	29	32	36	38	42.5	44
	LOAD2	15	15	17.5	20.5	22	24.5	28	31	35	37	41.5	43
	LOAD3	14	14	16.5	19.5	21	23.5	27	30	34	36	40.5	42
	LOAD4	13	13	15.5	18.5	20	22.5	26	29	33	35	39.5	41
	LOAD5	12	12	14.5	17.5	19	21.5	25	28	32	34	38.5	40
	LOAD6	11	11	13.5	16.5	18	20.5	24	27	31	33	37.5	39
	LOAD7	10	10	12.5	15.5	17	19.5	23	26	30	32	36.5	38
	LOAD8	9	9	11.5	14.5	16	18.5	22	25	29	31	35.5	37
	LOAD9	8	8	10.5	13.5	15	17.5	21	24	28	30	34.5	36
	LOAD10	7	7	9.5	12.5	14	16.5	20	23	27	29	33.5	35
Max load	LOAD11	6	6	8.5	11.5	13	15.5	19	22	26	28	32.5	34

Table 1: these ignition advance values were measured for a 1988 2-litre Ford Telstar using a timing light and the Programmable Ignition itself.

For example, we can specify the timing advance to be 25° at 3000 RPM and 28° at 3400 RPM. However, we do not specify individual values at 3100, 3200 or 3300 RPM. Instead, the advance values at these RPMs are interpolated (ie, calculated), based on the values set for 3000 and 3400 RPM.

At 3200 RPM, the amount of advance is easily calculated because it is exactly in the middle between the 3000 RPM and 3400 RPM sites. The advance change between 3000 RPM and 3400 RPM is 3° (ie, from 25° to 28°) and half of this is 1.5°. So the advance required at 3200 RPM is simply 25° + 1.5° = 26.5°.

Another calculation is required for engine load values that are in-between the specified load sites.

For our Programmable Ignition, if you require two separate engine advance curves then you need to select the 11x11 arrays. If only one advance curve is required, you then have the option of using a 15x15 array for greater accuracy.

By the way, don't confuse the ignition timing map with the MAP (manifold air pressure) sensor. They are two completely different things.

Plotting the timing values

We used the Programmable Ignition, the LCD Hand Controller and a timing light to plot out the ignition timing values for a 1988 2-litre Ford Telstar. We'll describe exactly how this is done in some detail in a later article.

The resulting timing vs RPM values were tabled (Table 1) and then plotted using Microsoft Excel. These files will be available on our website so that you can use the tables and edit the values (just by wiping over the values and rewriting them) to suit your car's engine. It is not really necessary to use Excel though and you can just as easily use a pencil and piece of paper to draw out the map instead.

Fig.2 shows the ignition timing versus RPM and engine load from 1000-5000 RPM. Since we have 11 RPM sites, each RPM site covers a span of 400 RPM.

RPM0 is an extra site and is shown covering the range from 0-1000 RPM. The RPM0 wording is shown on a different line because it is not an actual

RPM site and cannot be adjusted. It has the same values as RPM1.

RPM0 is shown because it explains what the advance curve is below the minimum RPM1 site while the engine is being started. The same thing happens for RPM above RPM11. In this case, the advance remains at the RPM11 values.

Engine load is shown with LOAD1 as the minimum engine load while LOAD11 is the maximum engine load. LOAD1 is usually accessed when the engine is on overrun while LOAD11 is usually accessed under acceleration or when the car is climbing a hill. The load values were measured using a second hand pressure sensor from an automotive wrecker. These were then converted to load values ranging from 1-11.

The curve can be plotted in three dimensions showing RPM, load and ignition advance. If you use our Excel file, then the curve will be automatically replotted when ever a value is altered.

Using the Hand Controller

As mentioned above, the Hand Controller is used to enter the settings and to enter the ignition map. The values are displayed on the 2-line 16-character LCD screen. There are eight direction pushbuttons, a Run/View pushbutton and a Reset.

The Reset switch is recessed to prevent accidental activation. It is used to return all mapped advance or retard values to 0°. The eight direction pushbuttons alter the values and can configure the display to show the different settings or a different load site.

Finally, the Run/View pushbutton only works in the Timing mode. This mode is selected using a jumper link on the Programmable Ignition Timing Module.

RUN modes

The Timing mode has four possible display modes, selected by pressing the Run/View pushbutton. It selects one of four modes – called SITE, FULL, DIAG and VIEW – in cyclic fashion.

Each display mode shows a slightly different aspect of the mapping sites. One feature in common is that they all display the MAP and the current advance or retard value on the top line, although there is a difference in the displayed value as we shall see.

When the 11x11 maps are selected (from the settings mode), the display will show either MAPα or MAPβ, depending on which map is selected. If the 15x15 map is selected, then the display will only show MAP, without the alpha or beta symbols.

Following the MAP legend, the display shows the advance or retard value. The display format depends on whether the setting is for 0.5° or

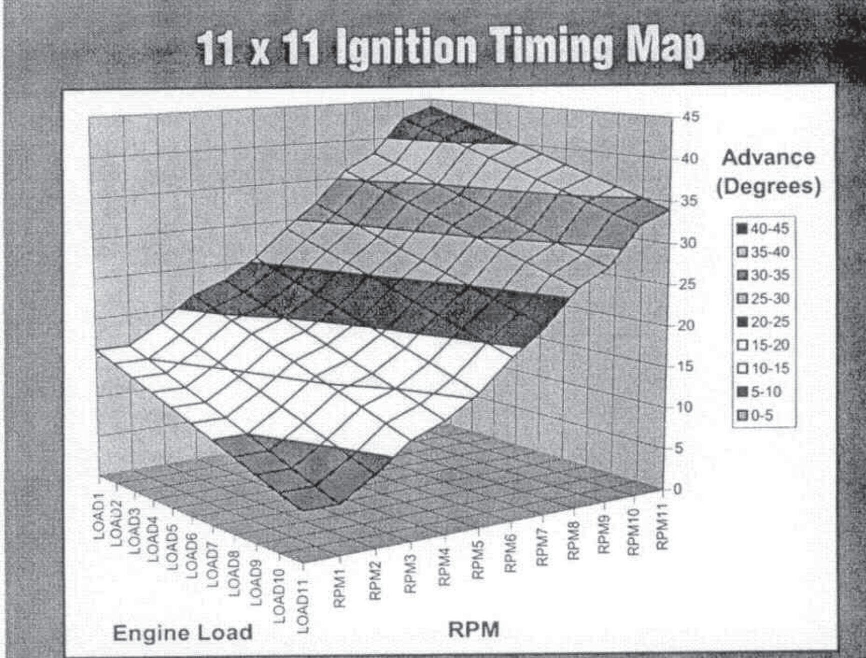


Fig.2: this 3-dimensional graph plots ignition advance against engine RPM and engine load as an 11x11 array – ie, 11 Load sites and 11 RPM sites. Note how the ignition advance increases with RPM and decreases with higher engine load. The graph here was produced for a 1988 2-litre Ford Telstar.

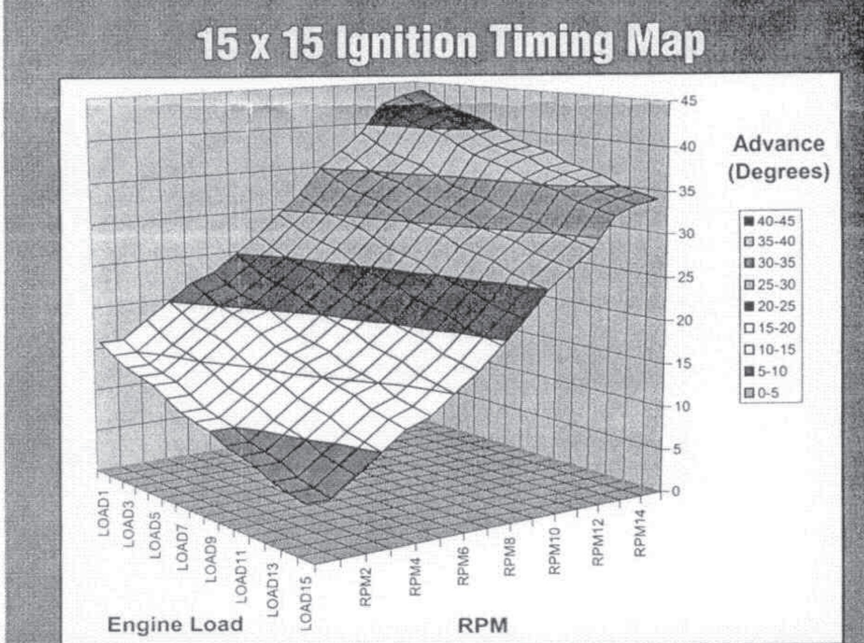


Fig.3: this 3-dimensional graph is also for a 1988 2.0-litre Ford Telstar but this time the ignition advance is plotted against engine RPM and engine load as a 15x15 map (300 RPM per site).

The LCD Hand Controller connects to the Ignition Timing Module via a standard DB25 RS-232 cable. It's used to program in the various settings and the ignition timing map(s) and can display all programmed data on a 2-line 16-character LCD module.

1° resolution. In all cases, a "-" sign indicates a retard value, while a "+" sign indicates an advance value. When there is no change in advance or retard, the value simply shows 0.0 for the 0.5° resolution setting or 0 for the 1° resolution setting.

The advance or retard value is changed using the Up (▲), Down (▼), Step Up (⇈) and Step Down (⇊) pushbuttons. The ▲ and ▼ pushbuttons increase or decrease the setting by the resolution value; ie, by either 0.5° or 1° for each switch press.

By contrast, the ⇈ and ⇊ pushbuttons change the advance/retard value by 2° on 0.5° resolution and by 4° on 1° resolution. The resulting values are stored in memory and remain there even if power is turned off, unless they are changed by the pushbuttons or by the Reset switch.

At the end of the top line, the display shows either SITE, FULL, DIAG or VIEW, to indicate the selected mode. Note that the SITE, FULL and DIAG modes are called the "Run" modes because they show what sites are accessed while the engine is running.

Site mode

The SITE mode is displayed each time the Programmable Ignition is powered up when the Run/View mode is selected with the jumper link. In this mode, the second line shows the current RPM site and the current LOAD site. These are from sites 1-11 when the 11x11 mapping is selected or from 1-15 when the 15x15 mapping is selected.

The advance or retard value is shown as the value entered at that load site. In practice, the LOAD and RPM sites only change with changes in engine RPM and engine load. In other words, this is a real time display that shows the current load and RPM sites and the current advance or retard value setting.

Full mode

Pressing the Run/View pushbutton brings up the FULL mode. In this case, the second line shows the RPM site as before (eg, RPM1) but it also shows the actual position between this site and the next. For example, with the 11x11 ignition timing map (Fig.2), each site is 400 RPM away from the next.

In practice, however, the RPM is measured in 100 RPM steps. As a result, the display shows the RPM 1 position as RPM 1;0, RPM 1;1, RPM 1;2 or RPM 1;3. These values correspond to 1000, 1100, 1200 and 1300 RPM respectively. There is no RPM 1;4 position as this becomes the RPM 2;0 site for 1400 RPM.

If you don't understand this, it will become clearer when we describe how the Programmable Ignition is set up in the forthcoming articles.

Similarly for the LOAD sites, the position within the site is shown after the semicolon (;). Note that the word LOAD is abbreviated to just LD, so that the values fit within the display line.

In the FULL display mode, the advance or retard value is the interpolated value that is calculated for the positions between each load site.

Let's go back to our earlier example and consider the RPM 6 (3000 RPM) and RPM 7 (3400 RPM) sites. At these sites, the advance is 25° and 28° respectively. This means that at RPM 6;0 the advance value will be displayed as +25.0°, while at RPM 7;0 the value will be shown as + 28.0°.

The interpolated value will be shown for RPM values between these two sites. For example, at 3200 RPM (RPM 6;2), the advance value will be +26.5°. Consequently, this is the value that will be shown at site RPM6;2.

Note that this is a simplistic example because we are ignoring the fact that the LOAD value could also be in-between LOAD sites. In that case, both the RPM and LOAD values are interpolated to give the advance or retard value.

Note also that if the advance or retard value is increased or decreased in this mode, it will be the interpolated value that is displayed rather that the site value. The site that will be changed is the next lowest RPM and LOAD site.

Having said all that, interpolation can be switched off within the settings if required.

Knock sensing

When knock sensing is set, the display shows the modified timing value after knock retard is taken into account. This means that if the display is showing +26.0° and the knock sensing subsequently introduces a 6° timing retard, the display will then immediately show +20.0°. This is the actual advance value used for ignition.

Note that engine knock detection is indicated by an exclamation mark (!) that is positioned between the RPM site value and the LOAD on the second line of the display. The (!) is shown when knock is detected, regardless as to whether the knock retard feature is on or off. The knock symbol is shown in the SITE, FULL and DIAG display modes.

Diagnostic mode

Pressing the Run/View switch again switches to the DIAG mode. This is the diagnostic mode and is very useful when it comes to determining your engine's RPM range, as well as measuring the output range from the MAP sensor.

In this mode, the second line shows the actual RPM with 100 RPM resolution and the actual LOAD value from 0-255. The advance/retard value on the top line normally shows the interpolated value in the same way as the FULL mode.

As mentioned above, interpolation can be switched off and this is useful when measuring the manufacturer's advance curve (more on this in a later article).

Pressing the Run/View pushbutton yet again switches to the VIEW mode. This is not a real-time display because the RPM and LOAD sites do not change with the engine RPM or load. Instead, you can step through each site manually using the Right (▶), Step Right (▶▶), Left (◀) and Step Left (▶▶) pushbuttons.

The ▶ and ◀ pushbuttons increase or decrease the LOAD site value. When increasing the LOAD site value and it reaches its maximum value (either 11 or 15), pressing the switch again causes the RPM site to increase by 1 and the LOAD site to return to 1. In this way,

Specifications

Timing adjustment resolution: 0.5° resolution advance and retard or 1° resolution advance and retard.

Timing adjustment range: ±60° for 12-cylinder engines, ±90° for 8-cylinder engines, ±120° for 6-cylinder engines, ±127° for less than 6 cylinders. Using less than 75% of the limit is recommended to prevent timing "drop-out" with sudden RPM changes.

Timing adjustment accuracy (above Low RPM setting): 0.2% for a 2-cylinder 4-stroke, 0.3% for a 6-cylinder 4-stroke, 0.4% for an 8-cylinder 4-stroke (note: 0.3% is equivalent to 0.12° at 40° advance or retard for a 6-cylinder engine).

Timing update: the update period is the time between successive firings.

Timing calculation period: 700μs maximum.

Timing jitter: ±5μs at 333Hz (5μs is equivalent to 0.3° for a 6-cylinder engine at 10,000 RPM).

Minimum input frequency: 0.6Hz (corresponds to 36 RPM for a 2-cylinder 4-stroke engine, 18 RPM for a 4-cylinder 4-stroke engine, etc).

Maximum input frequency: 700Hz (corresponds to 14,000 RPM for a 6-cylinder 4-stroke, 7000 RPM for a 12-cylinder 4-stroke.

Cylinder settings: 1-12 cylinders for a 4-stroke engine and 1-6 cylinders for a 2-stroke engine.

Minimum RPM setting: 0-25,500 RPM in 100 RPM steps

Maximum RPM setting: indirectly set by RPM/SITE – 0-25,500 RPM in 100 RPM steps.

Minimum load setting: 0-255 in steps of 1 (corresponds to 0-5V).

Maximum load setting: indirectly adjusted by changing loads per site (0-255 in steps of 1).

Debounce adjustment: 0.4ms or 2ms.

Dwell adjustment: 0-25.3ms in 0.2048ms steps (multiplied with voltage below 12V).

Dwell variation with supply: x1 for >12V, x2 for 9-12V, x3 for 7.2-9V, x 4 for <7.2V.

Firing edge selection: low or high.

Spark duration: 1ms.

Map settings: two 11x11 maps (MAPα and MAPβ) or single 15x15 map.

Knock input range: 0-5V (0-1.25V = no retard; 1.25-5V = progressive retard in 16 steps). 9° at 3.75V, 12° at 5V for 1° resolution; 4.5° and 6° respectively for 0.5° resolution.

Knock monitoring (requires an additional knock circuit): monitored for the first 6ms after firing. This period is reduced at higher RPM with the start of dwell. Optional 4000 RPM or 6000 RPM sensing limit. Ignition retard activation (when enabled) is set for a minimum of 10 sparks with the onset of knocking.

Internal test oscillator: 4.88Hz.

Response to low RPM setting: 0-25,500 RPM in 100 RPM steps. Typically set at around 1000 to 2000 RPM.

The Best Laid Plans Of Mice & Men

When we presented our last very popular High Energy Electronic Ignition System, in the December 2005 & January 2006 issues of SILICON CHIP, we stated that "in a future issue we would present a development of the Electronic Ignition to allow ignition timing to be altered. That project will allow the existing timing to be fully mapped on the basis of engine RPM and inlet manifold pressure".

In fact, provision was made on the PC board for the extra parts that would be required to make the system fully programmable. A new program for the microcontroller would complete the system . . . or at least, that was the plan.

It didn't work out. Instead, we have had to effectively split the original PC board into two parts and add a few more components into the bargain.

Now what was that about mice and men? It goes like this:

The best-laid plans o' mice an' men
Gang aft a-gley,
An' lea'e us nought but grief an' pain
For promised joy.

["To a Mouse" by Scottish poet Robert Burns (1759-1796)].

you can step through the entire ignition-timing map.

The same thing happens when decreasing the LOAD site value. After reaching 1, the RPM site value is decreased by 1 on the next switch press and the LOAD site goes to either 11 or 15 (depending on the MAP setting).

The ⏩ and ⏪ switches just alter the RPM sites up or down without altering the LOAD site. In this way you can check the ignition advance or retard settings for each RPM site at a particular LOAD site.

Note that the ▸, ⏩, ◂ and ⏪ pushbuttons do not operate in the SITE, FULL and DIAG modes. In these modes, the sites are only changed in response to engine RPM and load inputs.

Settings

The Settings display is invoked when jumper LK1 in the Programmable Ignition Timing Module is moved to the settings position. This display is used to set up the programmable ignition to suit your engine.

The display will initially show <SETTINGS>. The < and > brackets indicate that each setting can be selected with either the left (◂) or right (▸) pushbutton switch. The values within the settings are then changed using the ▴ and ▾ pushbuttons. These values (except for the oscillator setting) are stored in memory and do not change unless altered using the Up and Down pushbuttons.

Note that the oscillator setting is always off when power is re-applied to the Programmable Ignition.

Pressing the ▸ pushbutton brings up the Cylinder setting. You can then select cylinder values from 1-12 for a 4-stroke engine and from 1-6 for a 2-stroke engine. During this time, the top line of the display will show STROKE and then two numbers – ie, 4 and [2] for 4-stroke 2-stroke engines respectively. Directly below these on the second line is the word CYLINDER and the selected cylinder numbers (the bracketed number is the cylinder value for a 2-stroke engine).

The cylinder value is changed using the ▴ and ▾ pushbuttons. Note that a dash is shown in the two 2-stroke column when odd 4-stroke cylinder numbers are selected, as this is not a valid setting for a 2-stroke engine.

The next four settings are for adjusting the range of the RPM sites and the LOAD sites. These are crucial in insuring you get the full use of the available sites. In other words, there is not much point in having the RPM sites cover a range from 0-25,000 RPM when, for example, the engine does not run above 5000 RPM. In this case, you would only be using 20% of the available RPM sites (ie, RPM 1, RPM 2 and part of RPM3 only) for mapping the advance curve.

The first of these settings is the Minimum RPM. This sets the RPM for the RPM 1 LOAD site. The display shows SET MIN RPM X00 RPM, where the X represents a number from 0-255. Typically, this is set at the idle speed for the car but it may be set differently depending on how you want the ignition curve to operate (more on this in a later article). The settings can be changed from 0 RPM through to 25,500 RPM in 100 RPM steps.

In practice, you would use the DIAG (diagnostic) setting mentioned above to determine the minimum and maximum engine RPM range. Alternatively, you can use the idle and red-line specifications for your engine.

The second setting is for the Maximum RPM. This value of RPM is indirectly set by the value of the RPM per site (RPM/SITE) adjustment, as shown on the top line of the display. It can be set from 0-25,500 RPM in 100 RPM steps.

The second line shows the maximum RPM. This is calculated based on the minimum RPM setting and the RPM/site value. It is shown in the second line of the display as MAX RPM X00 RPM, where X is a number from 0-255. An ERROR indication is shown instead of the maximum RPM if the setting would be over 25,500 RPM.

The reason why we adjust the RPM/SITE value rather than the Maximum RPM directly is because the Programmable Ignition requires a discrete number of 100 RPM steps between each RPM site.

In practice, the RPM/SITE value is altered so that the maximum RPM is at or just over the value required. You can also adjust the minimum RPM setting to achieve the best compromise for the adjustment.

An example may help here using the 11 x 11 map. If, say, the minimum RPM is set at 1000 RPM, the RPM/SITE value can be set to say 400 RPM for a 5000 RPM maximum or to 500 RPM for a 6000 RPM maximum. Thus, if you had a red line of say 5500 RPM, you could set the RPM/site value to 500 for the 6000 RPM maximum. Alternatively, you could lower the minimum RPM value to say 800 RPM, with the RPM/site set to 500 for a 5800 RPM maximum.

The third and fourth settings are for the LOAD sites. Again, in practice, you would use the DIAG (diagnostic) mode to determine the minimum and maximum values from the MAP sensor. The maximum load values occur when the car is accelerating up a hill, while minimum load values are

Ignition Timing – A Quick Primer

A typical internal combustion engine has one or more pistons that travel up and down inside cylinders to turn a crankshaft. As a piston rises inside its cylinder during the compression stroke, a mixture of fuel and air is compressed. In petrol and gas engines, this fuel-air mixture is then ignited using a spark to drive the piston as it starts its downward stroke.

This ignition must be timed accurately to ensure maximum power and efficiency. If the mixture is fired too late in the cycle, power will be lost because the piston will have travelled too far down in the cylinder for the burning fuel to have maximum effect. Conversely, if the mixture is ignited too early, it will "push" against the piston in the wrong direction as it rises towards top dead centre (TDC).

Ideally, each spark plug is fired so that there is just enough time for the ignited fuel to apply maximum force to the piston as it starts its downward power stroke. In practice, the fuel takes a certain amount of time to burn and so the spark plug needs to be fired before the piston reaches the top of its stroke or top dead centre.

At low engine RPM, the spark only needs to occur a few degrees before top dead centre. However, as engine RPM rises, the ignition must be fired progressively earlier in order to give the fuel the same time to fully ignite – ie, the spark timing must be progressively advanced as engine RPM rises.

This timing requirement is called the "RPM ignition advance curve" and is often around 6° before TDC at idle, rising to about 40° at the engine's recommended maximum RPM (the redline).

As stated, if the spark ignites the fuel far too early, then the piston may be pushed downwards before it reaches top dead centre. However, if the ignition is only early by a small amount, then the engine will exhibit a knocking sound as the piston rattles within the cylinder. This effect is called "detonation" (also called "pinging" or "knocking") and can cause serious engine damage in severe cases.

Engine load is also an important factor when it comes to ignition timing. Under light loads, the advance timing can usually be at the maximum. However, when the engine is heavily loaded, such as when accelerating or powering uphill, the fuel takes less time to ignite because of higher fuel pressures and temperature (and because the mixture is richer). As a consequence, as engine load increases, the ignition timing must be retarded to prevent detonation.

present under very light throttle conditions and when the engine is being overrun in low gear downhill.

The Minimum Load adjustment can be set from 0-255 in steps of 1. These 0-255 values correspond to the 0-5V output from the MAP sensor. This value is set to the reading obtained in the DIAG (diagnostic) mode when the engine is being overrun.

By contrast, the Maximum Load is adjusted indirectly by changing the loads per site (LOADS/SITE) setting. This can be changed in steps of 1 from 0-255. The second display line shows the calculated maximum load (MAX LOAD) value based on the minimum load and the LOADS/SITE setting. An ERROR indication shows if the calculated maximum LOAD value is over 255.

In practice, the Minimum Load and the LOADS/SITE settings are adjusted so that they cover the range of the MAP sensor output, although they may slightly overlap the required minimum and maximum values.

Other settings that follow these mapping values are:

(1). MAPS: here you can select either the two 11x11 maps (mapα and mapβ) or the single 15x15 map. Note that any ignition values mapped into an 11x11 map will no longer be correct if the map is subsequently changed to a 15x15 array and vice versa. Instead, you have to re-enter the values.

(2). Resolution: this sets the resolution of the advance/retard adjustments and can be either 1° or 0.5°. Once ignition values have been entered into the map on one resolution setting, they will be incorrect if the resolution is changed to the alternative setting.

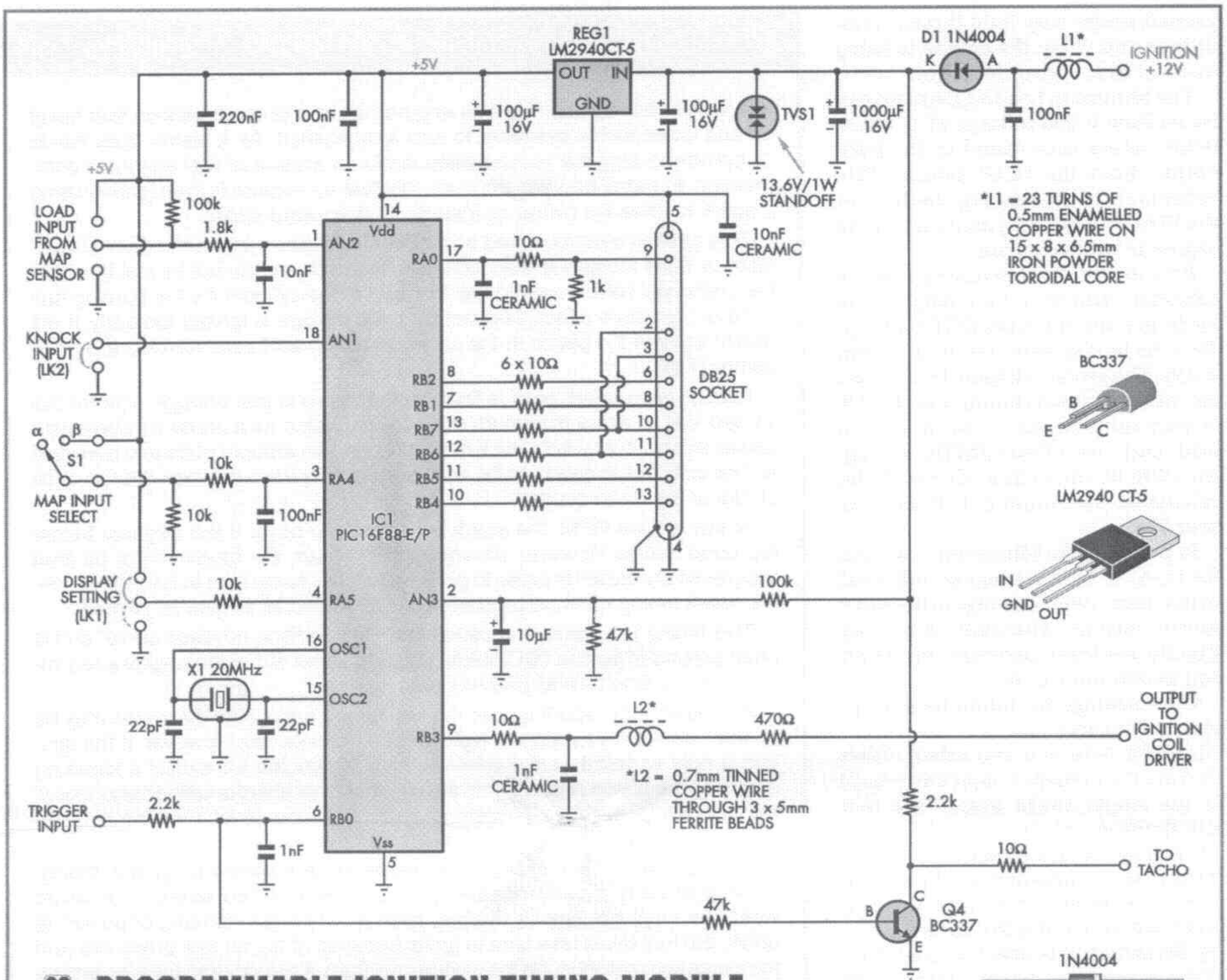
(3). Response To Low RPM setting: at low RPM, the engine speed can change quite quickly. Because the calculation for RPM can only occur between each detected firing pulse, the response to RPM changes can be too slow and can lag behind the engine. This can noticeably retard the ignition with increasing RPM. The Response To Low RPM setting is included to improve low RPM response, particularly at starting. The downside of this setting is that there is some slight ignition retardation but this is less than 1° for typical low RPM settings.

The RPM value can be set from 0-25,500 RPM in 100 RPM steps. The Low RPM Response operates for RPM below the set value (typically just below idle speed). Above this setting, the standard response to RPM occurs. By contrast, the response at higher RPM is satisfactory because there is only a short period between plug firing and the engine speed will not vary much during this time. Usually, the setting is adjusted so that it operates at engine cranking speed but stops when the engine reaches idle speed. In other cases, it may be necessary to raise this RPM limit so that the engine can rev correctly from idle.

(4). Debounce: the debounce setting affects the trigger input and its resilience to a noisy signal, as can typically occur with points bounce in older car ignition systems. Unless corrected, points bounce can upset the detection of engine RPM and affect the timing. Typically, you can use the 0.4ms debounce setting but the alternative 2ms debounce setting can be selected if the ignition appears to be erratic due to a noisy input sensor signal.

(5). Dwell: dwell is the period during which the ignition coil "charges" before each plug firing. It is alterable from between 0-25.3ms in 0.2048ms steps. We have provided an oscillator feature (see below) that allows the ignition coil to be driven by the Programmable Ignition and the spark produced by the coil monitored. The dwell is then progressively adjusted upwards from 0ms until the spark reaches its maximum voltage. The dwell is then increased slightly above the set value to ensure there is more than sufficient spark when the engine runs.

In addition, the dwell is automati-



SC ©2007 PROGRAMMABLE IGNITION TIMING MODULE

Fig.4: the Ignition Timing Module is based on a PIC16F88-E/P microcontroller. This processes the input trigger, MAP sensor and optional knock sensor signals and provides outputs to drive the Ignition Coil Driver circuit (Fig.5) and a tachometer. It also monitors the Hand Controller's switches and drives the LCD.

cally increased when the battery voltage is low – ie, to x2 for battery voltages between 9V and 12V; to x3 for voltages between 7.2V and 9V; and to x4 for voltages below 7.2V.

(6). Edge: this sets the ignition to trigger from either a low-going input signal edge or a high-going signal. In most cases, a high-going signal edge must be selected but some optical, Hall-Effect and reluctor outputs will require the low-going edge selection.

(7). Knock: this sets the KNOCK retard feature either ON or OFF and sets the LIMIT at either 4000 or 6000 RPM (these settings are all shown on the LCD). Pressing the ▲ and ▼ pushbuttons cycle the selections between these options. The LIMIT setting sets the RPM value at which knock sensing ceases. This is usually set to 4000-6000 RPM because at higher revs, the engine noise drowns out any knocking and so would either be undetectable or would cause false readings.

Note that knocking will only be detected if the separate knock sensing circuit (to be described) is added and a knock sensor is installed on the vehicle.

(8). Diagnostic: this sets the interpolation either ON or OFF. It is normally set to ON and should only be set to OFF when making ignition curve measurements using the Programmable Ignition and a timing light.

(9). Oscillator: this sets the internal oscillator ON or OFF. It's normally OFF but can be set to ON to test the ignition coil spark with varying dwell settings. The oscillation rate is about five times a second (5Hz).

Circuit details

OK, so much for all the fancy features built (or more accurately, programmed) into the unit. Let's now take a look at the circuit details.

The circuit for the Programmable Ignition can be split into three sections. First, there is the Programmable Ignition Timing circuit, as shown in Fig.4. To this is added an input trigger circuit, depending on the ignition trigger used – see Fig.6. This can be either points, optical, Hall effect or reluctor, or can be taken from the engine management unit (EMU).

Finally, a separate circuit, controlled by the Programmable Ignition Timing circuit, drives the ignition coil – see Fig.5.

The LCD Hand Controller, to be described in Pt.2, is a completely separate unit which connects to the Programmable Ignition Timing module via a DB25 cable. As stated, it's used only during the setting-up procedure, after which it is no longer required unless you wish to reprogram the system (eg, to alter the timing map).

The main circuit (Fig.4) is based on IC1 which is a PIC16F88-E/P high-temperature microcontroller. This micro processes the input trigger and MAP sensor signals and provides an output to drive the Ignition Coil Driver circuit. It also drives the LCD module in the Hand Controller and monitors the Hand Controller's switches.

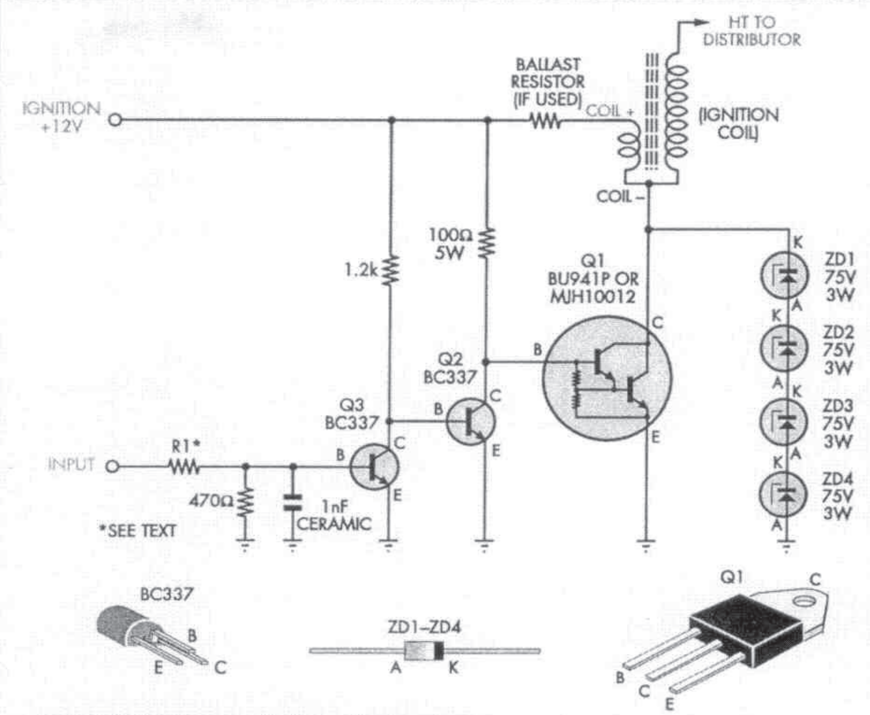
Timing signals for IC1 are provided by crystal X1. This sets the internal oscillator to run at 20MHz, which enables the software programmed into IC1 to run as fast as possible.

In operation, IC1 accepts the ignition trigger signal at its RB0 input (pin 6) and drives its RB3 output to switch the ignition coil (via the driver circuit) accordingly. As shown, the RB0 input is protected from excess voltages by a series 2.2kΩ resistor, which prevents excessive current flow in IC1's internal clamping diodes. Clamping occurs when the voltage goes below 0V or if it goes above the +5V supply (ie, the input is clamped to -0.6V or +5.6V).

The 1nF capacitor at the RB0 input shunts transient voltages and high-frequency signals, to filter false timing signals.

Transistor Q4 is also driven from the trigger input. The transistor is used to provide a tachometer output at its collector. In operation, Q4's collector is normally held high via a 2.2kΩ pull-up resistor but switches low each time the transistor turns on (ie, when the trigger input is high).

Q4's collector output can be used to drive most modern tachometers. However, an impulse tachometer (now very rare) requires a different con-



SC IGNITION COIL DRIVER (PROGRAMMABLE IGNITION)

Fig.5: the Ignition Coil Driver is based on transistors Q1-Q3. Darlington transistor Q1 switches the ignition coil, while the four series zener diodes across Q1 protect it against voltage spikes when the transistor turns off.

nection and this type should operate when connected to the ignition coil's negative terminal.

MAP sensor

The MAP sensor signal is applied to the analog AN2 input of IC1 via a 1.8kΩ resistor. A 10nF capacitor filters out unwanted high-frequency signals to prevent false readings.

In operation, the AN2 input measures an input voltage ranging from 0-5V and converts this to a digital value ranging from 0-255. This is the value that's read from the DIAG (diagnostic) display.

Note that +5V supply and ground rails are provided for the sensor. When the Sensym sensor is used, it can be directly mounted on the PC board used for the Programmable Ignition Timing Module.

The optional knock sensor signal is applied to IC1's analog AN1 input (pin 18). As before, this input accepts signal voltages from 0-5V and converts them to digital values.

Conversely, if the knock sensing circuit is not used, this input must be tied to ground using jumper link LK2 to disable the knock sensing function.

The third analog input at AN3 (pin 2) is used to monitor the +12V ignition supply. As shown in Fig.4, this supply voltage is divided down using 100kΩ and 47kΩ resistors and filtered using a 10μF capacitor before being applied to the AN3 input. This divider effectively converts the supply voltage to a 0-5V signal which is then used to determine if the dwell period should be increased to compensate for a low supply voltage.

Note that the voltage across D1 is accounted for in this measurement.

Link LK1 selects either the timing map display or the settings display. In the settings position, the RA5 input is tied to ground via a 10kΩ resistor. Conversely, when LK1 is in the timing position, RA5 is tied to 5V via the 10kΩ resistor.

Note that the RA5 input differs from the other inputs in that it cannot be directly tied to one of the supply rails otherwise the micro could latch up. The 10kΩ input resistor eliminates this problem.

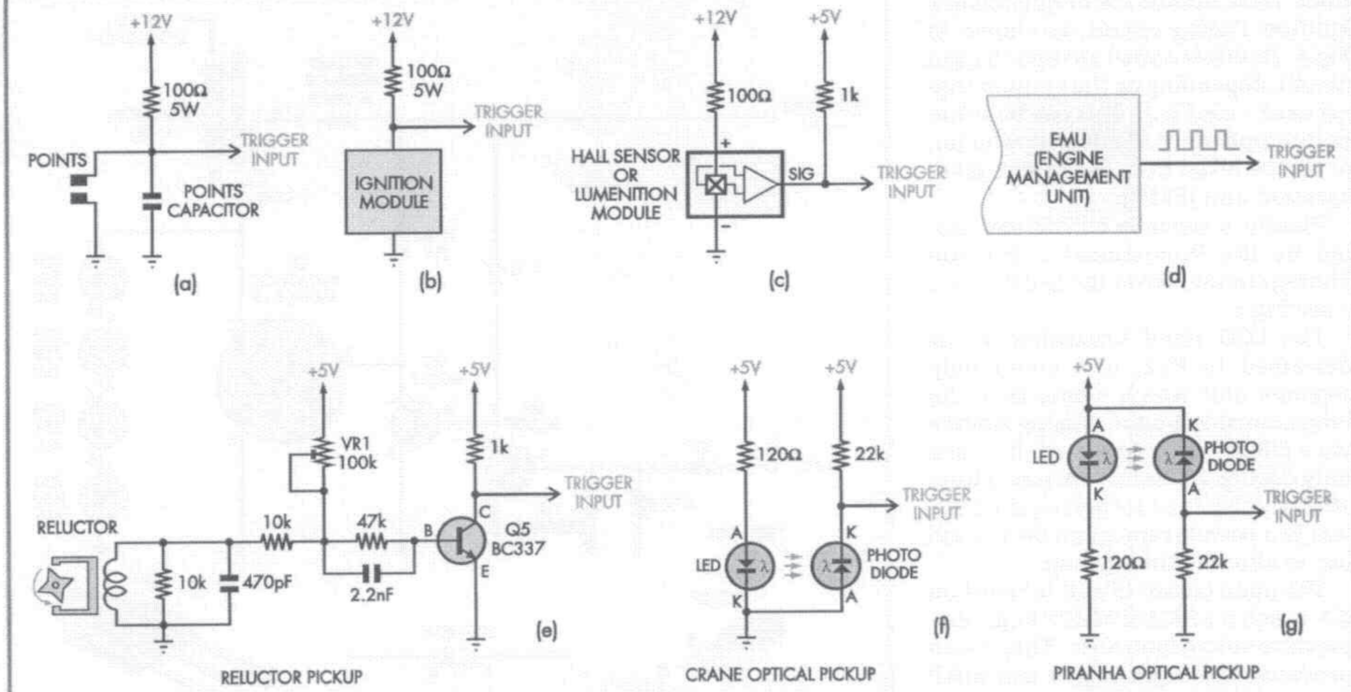


Fig.6: the seven input trigger circuits: (a) points triggering; (b) ignition module (see text); (c) Hall effect & Lumenition triggering; (d) triggering from an engine management module; (e) reluctor pickup; (f) Crane optical pickup; and (g) Piranha optical pickup.

Switch S1 is used to select between the two 11x11 timing maps. When S1 is open, RA4 is pulled low via the 10kΩ resistors and mapα is selected. Conversely, when S2 is closed, RA4 is pulled to +5V and mapβ is selected.

Note that this switch operates only when the 11x11 maps are selected using the LCD Hand Controller. It has no effect if a 15x15 map is selected.

Driving the LCD

Pins 7, 8 & 10-13 of the microcontroller are used to drive the LCD module in the Hand Controller (via a DB25 connector). The 10Ω resistors in series with these outputs act as stoppers to keep RF signals out of IC1.

In addition, the RA0 input at pin 17 monitors the switches from the Hand Controller. The associated 1kΩ resistor pulls the input voltage to 0V unless a switch is closed, at which point the line is pulled high to +5V. The 10nF and 1nF capacitors filter out RF signals.

Power supply

Power for the circuit is derived via the ignition switch. This supply is then filtered using inductor L1 and the 100nF capacitor. Diode D1 provides reverse polarity protection, after which the supply is decoupled using a 1000µF capacitor.

As a further precaution, the circuit is protected from voltage spikes using transient voltage suppressor TVS1. This clamps any high voltages that may otherwise damage following components.

Following TVS1, the supply is regulated to +5V using regulator REG1. This is a low-dropout device and is used here to ensure that a regulated +5V supply is maintained during starting when the battery voltage can drop well below 12V.

A 100µF capacitor decouples the regulator's output, while a 100nF capacitor (located close to pin 14 of IC1) shunts high frequencies to ground.

Ignition coil driver

Fig.5 shows the Ignition Coil Driver circuit. It's fairly straightforward and is based on transistors Q1-Q3.

Q1 is a Darlington transistor specifically made for ignition systems. It's capable of handling currents in excess of 10A and voltages exceeding 400V. As shown, four 75V zener diodes (ZD1-ZD4) are connected in series between its collector and emitter terminals. These protect the transistor from excess voltages by clamping its collector at 300V, which is well within its rating.

The circuit works like this: when the input signal is low (or there is no signal), transistor Q3 is off, Q2 is on (due to base current through the 1.2kΩ resistor) and Q1 is off. Conversely, when the input subsequently switches high, Q3 turns on and switches Q2 off by pulling its base to ground. As a result, Q1 turns on and current flows through the primary winding of the ignition coil.

The ignition input signal now subsequently switches low again and so Q3 immediately turns off due to the 470Ω resistor between its base terminal and ground. And when that happens, Q2 switches on and Q1 switches off, interrupting the current through the ignition coil.

As a result, the coil's magnetic flux rapidly collapses and this generates a high voltage in the secondary to fire one of the spark plugs. The 1nF capacitor on Q3's base is there to suppress any RF signals that may otherwise be injected when the current through the ignition coil is interrupted (ie, when Q1 switches off).

Resistor R1 is included to make the module more versatile. In our application, R1 is not used and is replaced with a wire link. For other applications, where a separate ignition coil driver is required, R1 will be required. Typically, a 470Ω resistor would be used for a 5V drive signal, while a 1.2kΩ resistor would be used for a 12V drive signal.

Finally, the module can also be configured to drive transistor Q1 when the input signal switches low. In this case, Q3 is left out of circuit and a link installed between the pads on the PC board for its base and collector leads. The 1.2kΩ resistor pull-up is also removed from circuit.

Trigger inputs

The Programmable Electronic Ignition is configured for the appropriate trigger input during construction. The seven possible input circuits are shown in Fig.6.

The points trigger is shown in Fig.6(a) and includes a 100Ω 5W wirewound resistor connected to the 12V supply. This resistor provides a "wetting" current for the points to ensure there is a good contact between the two mating faces when they are closed. The wetting current is sufficient to keep the contacts clean but not so high as to damage them.

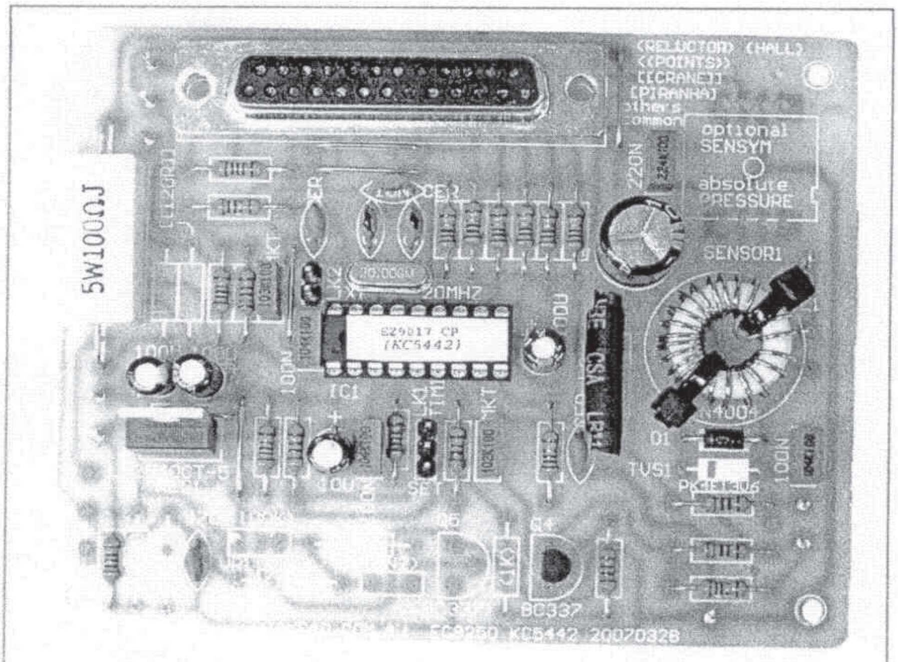
The ignition module version is shown in Fig.6(b). This is essentially the same as the points input except that a transistor inside the ignition module switches the input to ground instead.

This type of input has been included because some electronic ignition systems do not provide access to the actual trigger (usually a reluctor) and the only output is the ignition coil driver transistor. In this case the coil is replaced with the 100Ω resistor to provide the necessary pull-up to +12V when the transistor is off.

Fig.6(c) shows the Hall Effect trigger. It uses a 100Ω current-limiting resistor to feed the Hall sensor, while the 1kΩ resistor pulls the output voltage to +5V when the internal open-collector transistor is off. Conversely, the output signal is pulled to 0V when the internal transistor is on.

Note that the same circuit is used for the Lumenition optical module.

The engine management input circuit is shown in Fig.6(d) and is quite simple. Its 0-5V output signal connects to the trigger section of the main circuit in Fig.4.



This view shows the assembled PC board for the Ignition Timing Module but without the optional Sensym MAP sensor fitted.

Reluctor sensors are catered for using the circuit in Fig.6(e). These produce an AC signal and so require a more complex input circuit.

In this case, transistor Q5 switches on or off, depending on whether the reluctor voltage is positive or negative. It works as follows. Initially, with no reluctor voltage, Q5 is switched on via current through VR1 and a 47kΩ resistor. The voltage applied to Q5's base depends on the 10kΩ resistor across the reluctor coil and the internal resistance of the reluctor.

Trimpot VR1 is included to provide for a wide range of reluctor types. In practice, VR1 is adjusted so that Q5 is just switched on when there is no signal from the reluctor. The 10kΩ resistor provides a load for the reluctor, while the 470pF capacitor filters any RF signals that may have been induced.

The 2.2nF capacitor ensures that Q5 quickly switches off when the reluctor signal goes negative.

Finally, Fig.6(f) & Fig.6(g) show two different optical pickup circuits. Fig.6(f) is for a module that has a common 0V supply connection (eg, Crane), while Fig.6(g) is for a module that has a common positive supply (eg, Piranha). In each case, current for the LED is supplied via a 120Ω resistor, while the photodiode current is supplied via a 22kΩ resistor.

Software

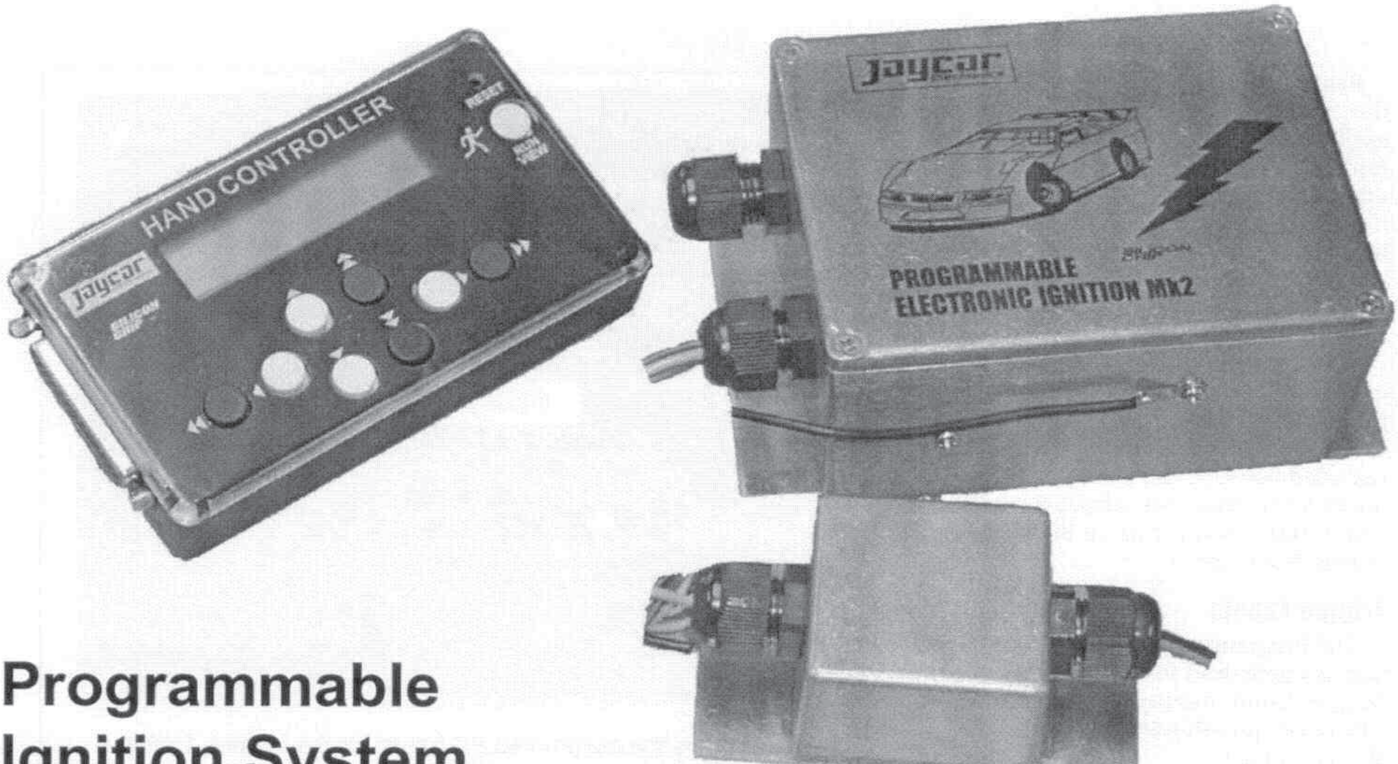
The software for the Programmable Ignition is the largest and most complex we have developed to date. In all, the final assembler code totals some 6020 lines to perform all the necessary functions, including monitoring the ignition trigger and pressure sensor signals and providing an output based on the ignition timing map.

Basically, the software includes several multiply and divide routines (some 24-bit) to calculate the timing, based on the RPM and load site. These routines are also used to calculate engine RPM and the interpolated advance/retard values and must be performed constantly to maintain the correct timing as engine RPM and load vary.

We managed to perform all the required calculations in under 1ms – fast enough for high revving engines.

A significant part of the software has also been devoted to the many functions accessible via the Hand Controller and to allow the Hand Controller to be used while the engine is running.

In the end, we used all the data memory space of the PIC16F88 to store the ignition timing maps and the adjustable parameters, along with some 97% of the program memory. SC



Programmable Ignition System for Cars - Pt2

by John Clarke

Six Versions To Build To Suit Your Car's Trigger Input.

This month, we describe the circuit for the LCD Hand Controller module and provide all the assembly details for the Programmable Ignition. There are six versions to build.

LAST MONTH, we published the circuit details for the Programmable Ignition Timing Module and its companion Ignition Coil Driver Module and described their operation in some detail. The various input trigger circuits (points, reluctor, Hall sensor, optical, etc) were also described.

LCD Hand Controller

That just leaves the LCD Hand Controller Module. Its circuit is shown in Fig.7. It comprises an LCD module, a 4017 decade counter (IC1), a DB25 socket and several pushbutton switches. This unit connects to the main circuit via a standard DB25 RS-232 cable.

Signals from the microcontroller in the Programmable Ignition Timing Module drive both the LCD module and IC1. IC1 has 10 outputs and each output independently goes high in sequence as it is clocked at its pin 14 input. A high at the reset (MR, pin 15) sets the "0" output at pin 3 high.

Each output connects to a switch. When a switch is closed, it pulls pin 9 of the DB25 socket high whenever its corresponding output on IC1 is high. This allows the microcontroller (in the Ignition Timing Module) to recognise which switch is closed.

The LCD is driven using data lines DB7-DB4. The display readings are entered via the data lines and are controlled via the EN and RS (Enable and Register Select) inputs.

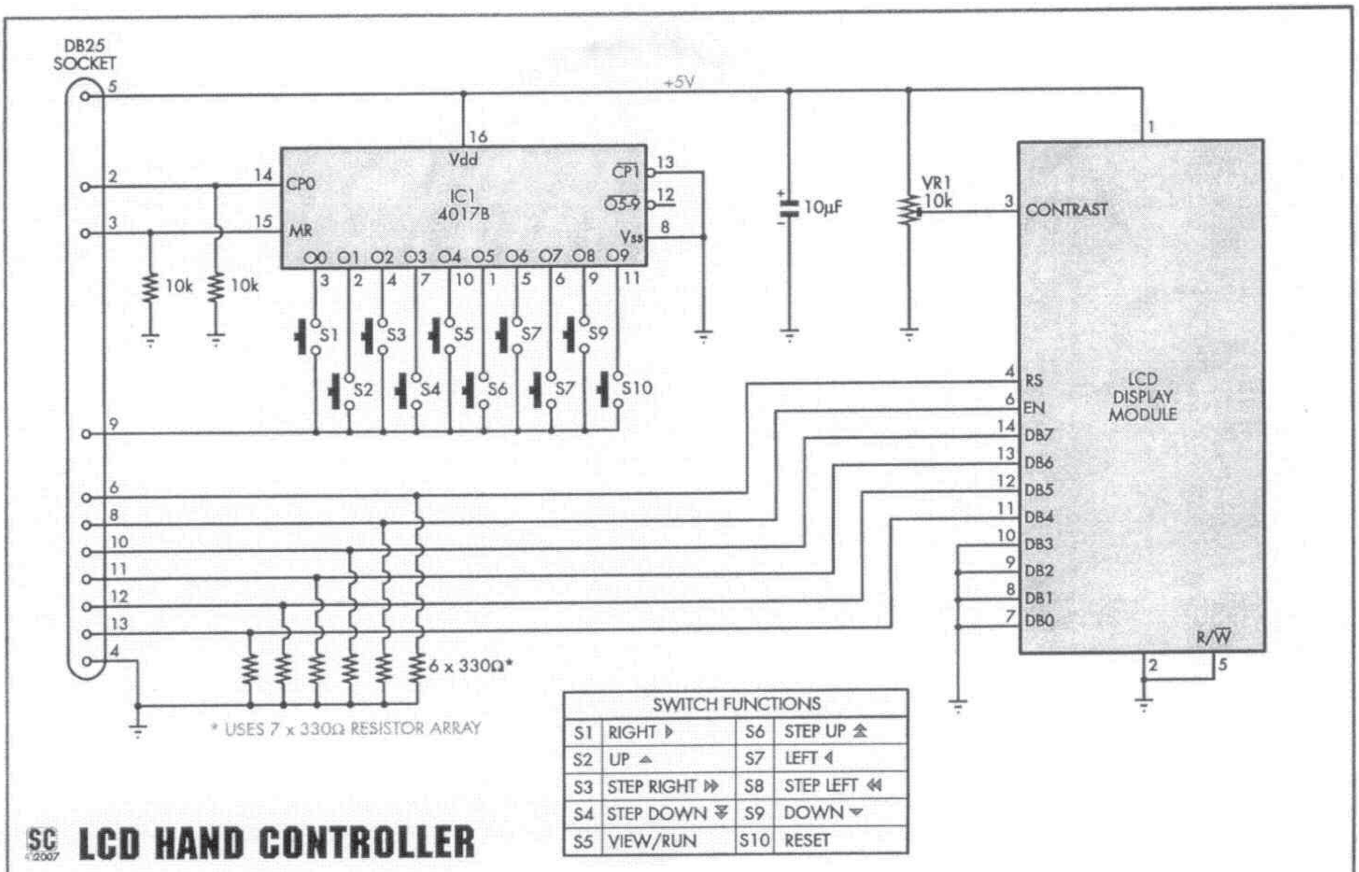
Note that the data lines and the EN & RS lines are all connected to ground via 330Ω resistors. These resistors allow the LCD module to be driven without the signals being corrupted by interference from the car's ignition.

Finally, trimpot VR1 is used to adjust the display contrast.

Construction

OK, that completes the circuit description. Let's now build all the modules for the unit.

As shown in the accompanying diagrams, the Programmable Ignition system is built on three PC boards – one for the Programmable Ignition Timing Module (code 05104071, 103 x 82mm); one for the Ignition Coil Driver Module (code 05104072, 40 x 39mm); and one for the LCD Hand Controller (code 05104073, 115 x 65mm). The Programmable Ignition Timing Module board is housed in a diecast aluminium case measuring 119 x 93 x 57mm, while the Ignition Coil Driver board goes into a much smaller diecast



SWITCH FUNCTIONS

S1	RIGHT ▶	S6	STEP UP ⏫
S2	UP ▲	S7	LEFT ◀
S3	STEP RIGHT ⏩	S8	STEP LEFT ⏪
S4	STEP DOWN ⏬	S9	DOWN ▼
S5	VIEW/RUN	S10	RESET

SC ©2007 **LCD HAND CONTROLLER**

Fig.7: the circuit for the LCD Hand Controller is quite simple. It uses 10 switches, an LCD module, a 4017 counter (IC1), a DB25 socket, a 10μF capacitor and a few resistors. Trimpot VR1 sets the display contrast.

case measuring 51 x 51 x 32mm.

The LCD Hand Controller board goes into a 120 x 70 x 30mm plastic case with a clear lid.

Before installing any parts, check each PC board for etching defects by comparing it against a printout of its pattern (you can download the relevant board files from the SILICON CHIP website). Check also that all the holes have been drilled and that the hole sizes for the larger parts are correct.

Ignition timing module

There are six different component layouts for this board, one for each different trigger input. It's just a matter of choosing the one that's applicable to your car.

For example, if your car has a reluctor distributor, follow the reluctor version overlay diagram – see Fig.10. Similarly, if it has a Hall effect or Lumenition pickup module, use the layout of Fig.11, etc.

It's not difficult to recognise the different sensor types. Reluctor distributors have a coil and a magnetic ring that has as many points (or protrusions) as the number of engine cylinders. By contrast, Hall effect distributors include a metal vane that passes through a gap in the Hall sensor itself. Lumenition triggers are similar to Hall effect sensors and so the overlay diagrams for these trigger types are the same – see Fig.9.

Start construction by installing PC stakes at the external wiring points, then solder in all the wire links. That done, install the resistors, using Table 1 as a guide to select the values. In addition, it's also a good idea to check each resistor using a digital multimeter (DMM) to make sure you have the correct resistor for each position.

Next, install the IC socket for the microcontroller, making sure that it's oriented with its notch at the lefthand end, as shown. Don't install the microcontroller (IC1) at this stage though – that step comes later.

Diode D1 and TVS1 are next on the list. Note that D1 must be oriented as shown, while TVS1 can be installed either way around. Follow these with the transistor(s) and REG1, taking care to ensure that these parts are oriented correctly.

Trimpot VR1 should now be installed if you are building the reluctor version (Fig.10). It should be oriented with its adjusting screw to the left.

The link headers for LK1 and LK2 can be installed now. LK1 is a 3-way header while LK2 is a 2-way header. Place a jumper shunt over two of the three pins for LK1 and another jumper shunt onto both pins for LK2.

Now for the capacitors. Several types are used on the board: ceramic, MKT and electrolytic. **The ceramic capacitors are all shown on the overlays in yellow, so that you don't get them confused with the MKT types.** Be sure to orient each electrolytic capacitor with the polarity shown.

Once the capacitors are all in, install the crystal (X1). Note that the crystal's metal case is earthed using a short wire link. This link is soldered

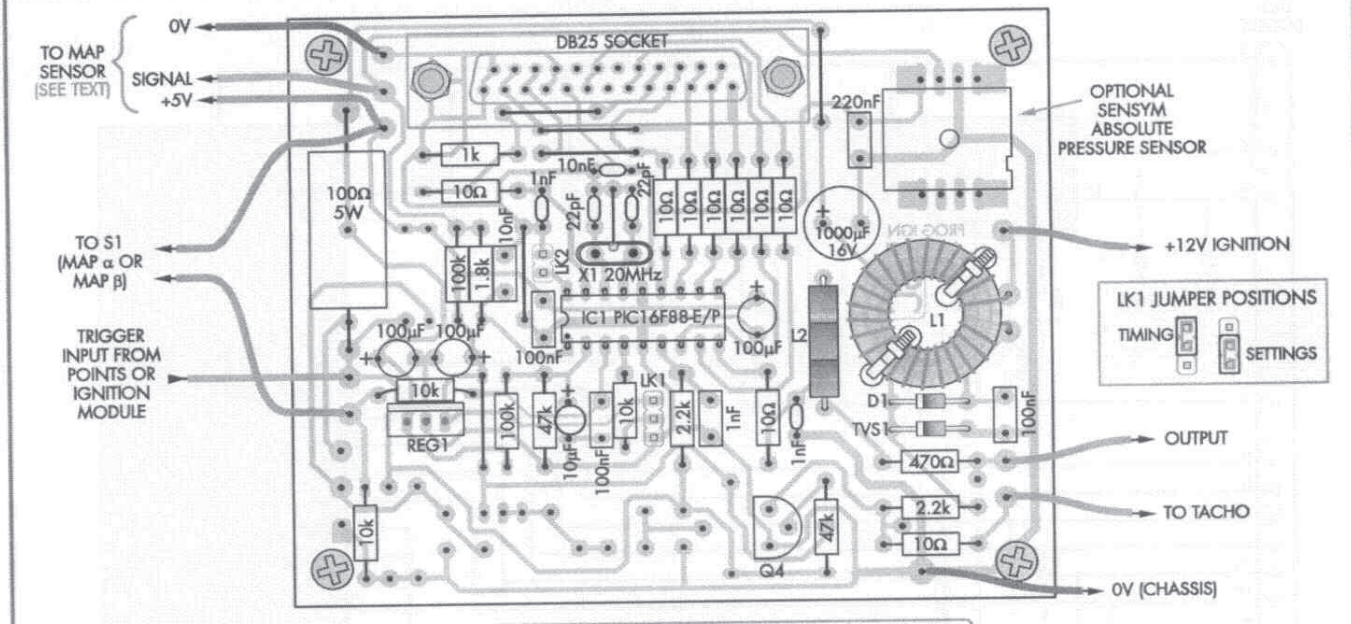


Fig.8: this is the points version. Secure all wiring leads to the board using cable ties and cover the connections to the PC stakes with heatshrink tubing or silicone, to prevent them coming loose.

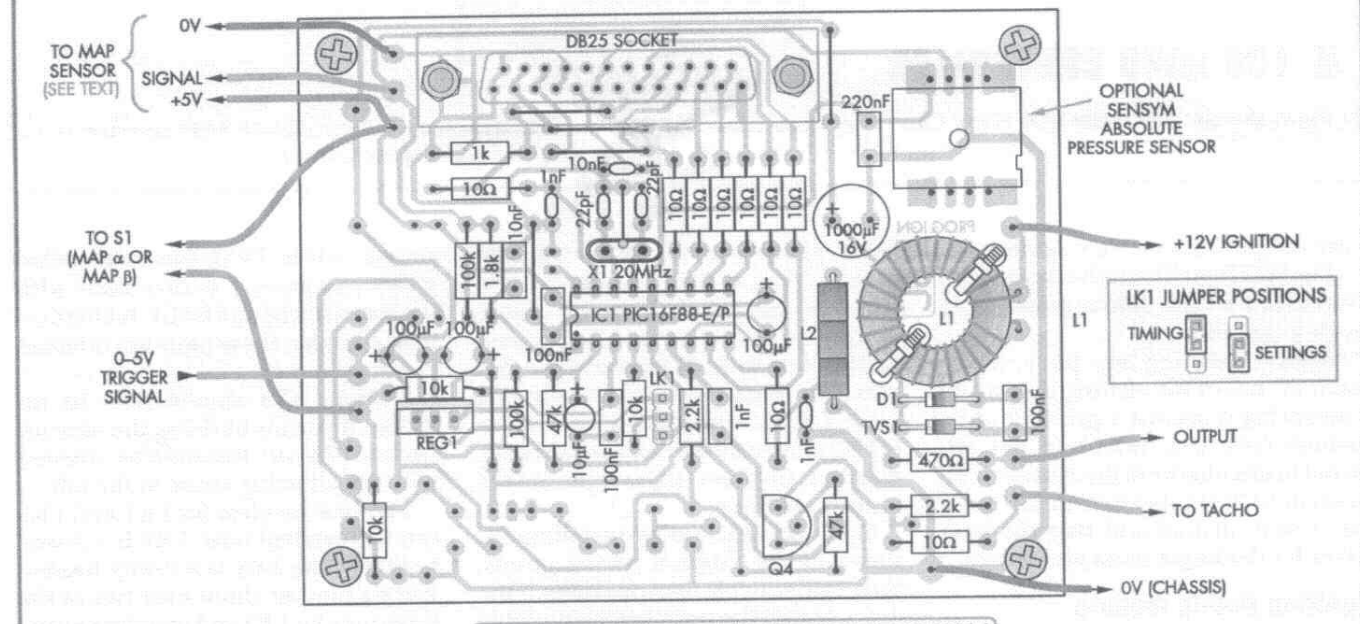


Fig.9: the engine management trigger version requires no additional input conditioning circuitry. In this case, the ECU trigger signal goes straight to pin 6 of IC1 via a 2.2kΩ resistor.

to the case and runs to a pad on the PC board between the two 22pF ceramic capacitors.

Sensym pressure sensor

If you are using the Sensym absolute pressure sensor (eg, if you car doesn't already have a MAP sensor or you are not using a seconhand MAP sensor), then this can be installed now. Note the orientation notch on the sensor – this goes towards the righthand edge of the PC board. If you get the Sensym sensor's orientation wrong, it will not be powered but no damage will result from doing this.

Inductors

Inductors L1 & L2 are next on the list. First, L2 is made by passing a 0.7mm tinned copper wire link

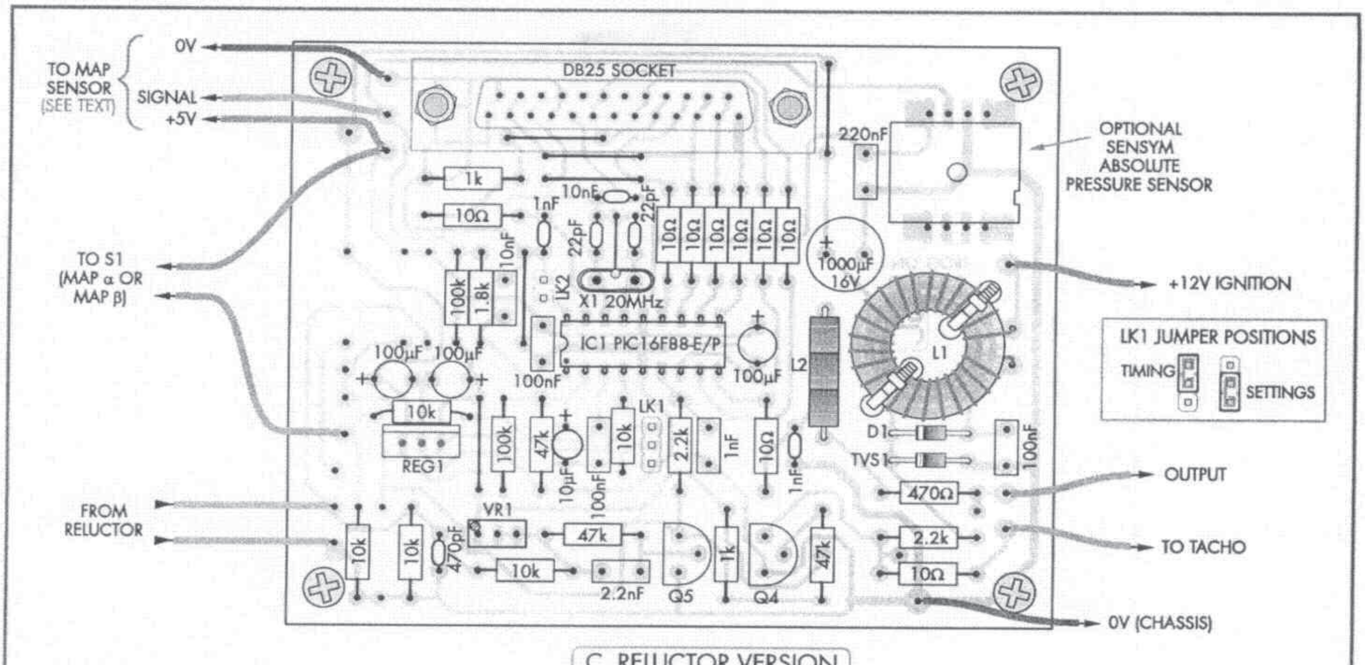


Fig.10: follow this parts layout diagram if your car's distributor has a reluctor pickup. The Sensym pressure sensor is used only if there is no external MAP sensor (applies to all versions).

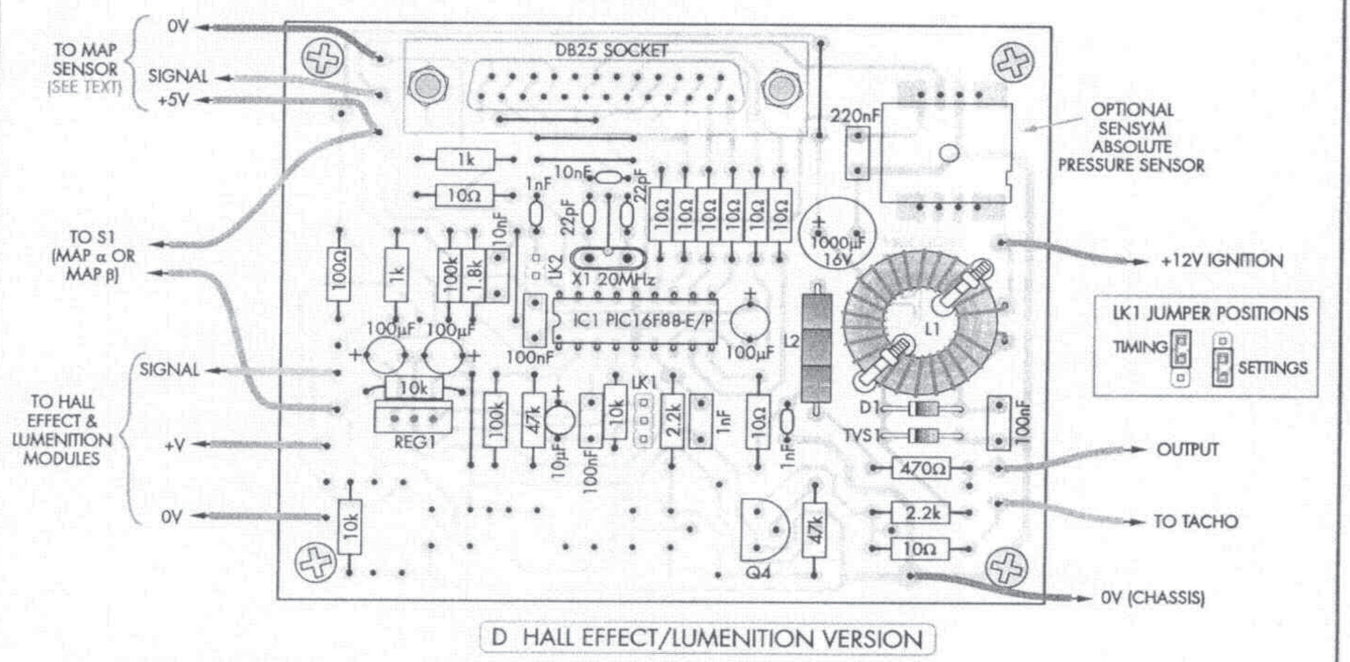
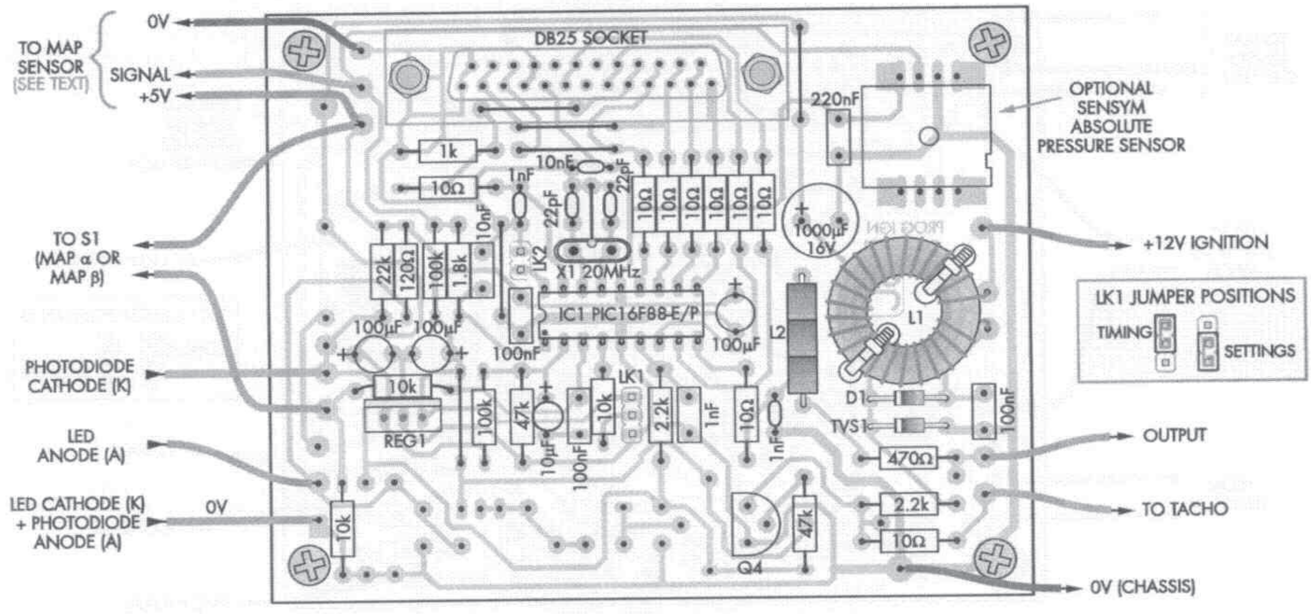


Fig.11: this is the layout to follow if the distributor uses a Hall Effect device or a Lumenition module. Take care with component orientation during assembly.

through three ferrite beads. A length of the 4mm heatshrink tubing is then slid over the three cores and shrunk down to hold everything in place, after which the assembly can be soldered to the board.

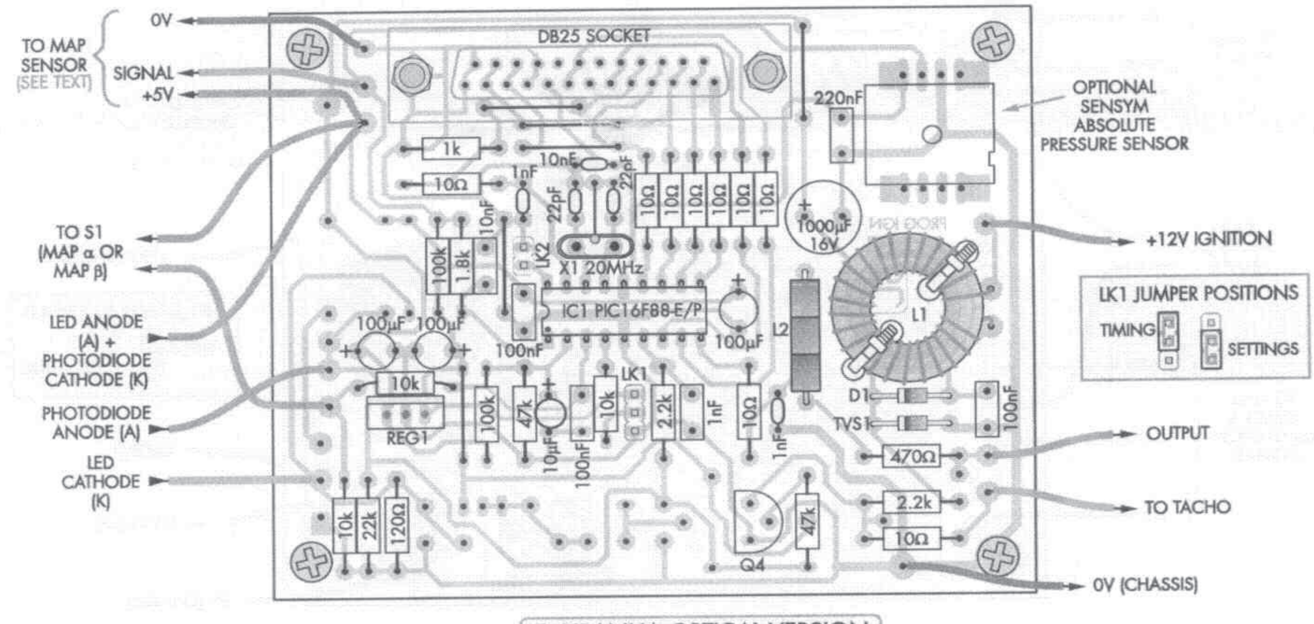
Inductor L1 is much larger. It's made by winding 23 turns of 0.5mm enamelled copper wire through a 15 x 8 x 6.5mm powdered-iron toroidal core. **These turns should be evenly spaced around the core, as shown on the overlays.** That done, the wire ends are stripped of insulation and soldered to the PC pads. The toroid is then secured to t he board using two plastic cable ties.

Finally, the DB25 socket can be installed in position. Before doing this though, two D-connector nut extenders must to be attached to the



E CRANE OPTICAL VERSION

Fig.12: build this version if your distributor has been fitted with a Crane optical pickup. Make sure that inductor L1 is firmly secured, to ensure reliability (all versions).



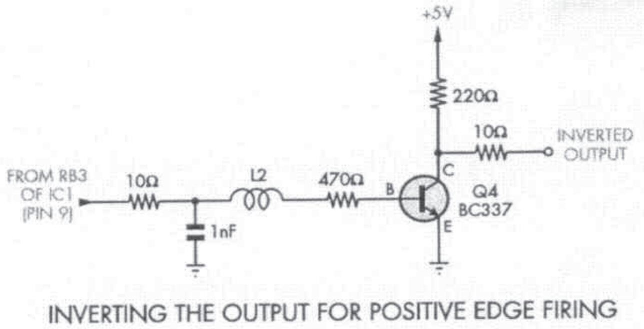
F PIRANHA OPTICAL VERSION

Fig.13: the Piranha optical pickup version is almost identical to the Crane version but note the different locations for the 22kΩ and 120Ω resistors.

PC board. These are simply passed through their two mounting holes and secured using spring washers and nuts on the underside of the board. **In addition, the righthand extender is fitted with a Nylon washer to prevent the spring washer and nut from shorting to nearby tracks. Don't leave this washer out!**

By contrast, the lefthand extender makes contact with the ground track on the PC board, so that the shell of the socket is earthed when it is installed. That way, when the DB25 lead is connected, its shield will also be earthed.

The DB25 socket can now be secured in place using a second set of nut extenders and its pins soldered to the PC pads. Note that you may need to cut down the extender threads so



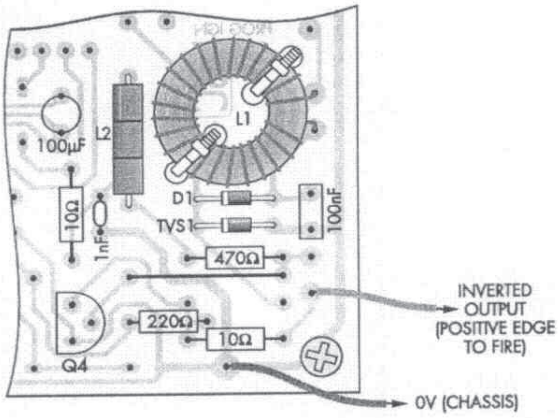


Fig.14: these diagrams show the modifications required to invert the output from the Ignition Timing Module.

the nuts sit flush with the socket's mounting flange.

Inverting the output

In normal operation, the RB3 output from the Programmable Ignition Timer Module goes high in order to turn on transistor Q1 (via Q3 & Q2) in the Ignition Coil Driver. This in turn allows current to flow through the primary of the coil.

Conversely, when RB3 goes low, Q1 switches off, the current through the coil is interrupted and the coil "fires" the relevant spark plug. So a low-going signal at the Ignition Timing Module's output normally causes the Ignition Coil Driver to fire a plug via the coil.

However, there may be some applications where the output from the Programmable Ignition Timing Module needs to be inverted; ie, so that a low output "charges" the coil and a high-going output causes the plug to fire. This may be the case if you connect the Programmable Ignition Timing Module to a different ignition coil driver.

In this case, an inverted output can be provided using the tachometer driver transistor (Q4). The necessary changes to the circuit and to the PC board layout are shown in Fig.14. The only extra parts required are a 220Ω resistor and some tinned copper wire for the link.

Housing

Having completed the board assembly, the next step is to install it in its metal diecast case. Fig.15 shows the assembly details.

The first step is to position the board inside the case and mark out its four mounting holes. That done, remove the PC board and drill the mounting holes to 3mm. Deburr each hole using an oversize drill bit, then secure a 6mm-long tapped spacer to each mounting point using an M3 x 15mm screw inserted from the outside of the case.

You will also have to drill a hole in one end of the box to accept a cable gland for the various external leads (ie, +12V lead, trigger signal leads and signal output lead). An additional hole for a second cable gland will also be required if you are using an external MAP sensor (see Fig.15).

Next, a 3mm hole must be drilled through the side of the box adjacent to the GND (0V) PC stake. This mounting hole is used to terminate an earth wire from the PC board via a crimped eyelet connector. A second wire terminated in an eyelet connector is also

Table 2: Capacitor Codes

Value	µF code	IEC Code	EIA Code
220nF	0.22µF	220n	224
100nF	0.1µF	100n	104
10nF	.01µF	10n	103
2.2nF	.0022µF	2n2	222
1nF	.001µF	1n0	102
470pF	NA	470p	471
22pF	NA	22p	22

Table 1: Resistor Colour Codes

	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❑	2	100kΩ	brown black yellow brown	brown black black orange brown
❑	3	47kΩ	yellow violet orange brown	yellow violet black red brown
❑	1	22kΩ	red red orange brown	red red black red brown
❑	7	10kΩ	brown black orange brown	brown black black red brown
❑	2	2.2kΩ	red red red brown	red red black brown brown
❑	1	1.8kΩ	brown grey red brown	brown grey black brown brown
❑	1	1.2kΩ	brown red red brown	brown red black brown brown
❑	3	1kΩ	brown black red brown	brown black black brown brown
❑	2	470Ω	yellow violet brown brown	yellow violet black black brown
❑	1	120Ω	brown red brown brown	brown red black black brown
❑	1	100Ω	brown black brown brown	brown black black black brown
❑	9	10Ω	brown black black brown	brown black black gold brown

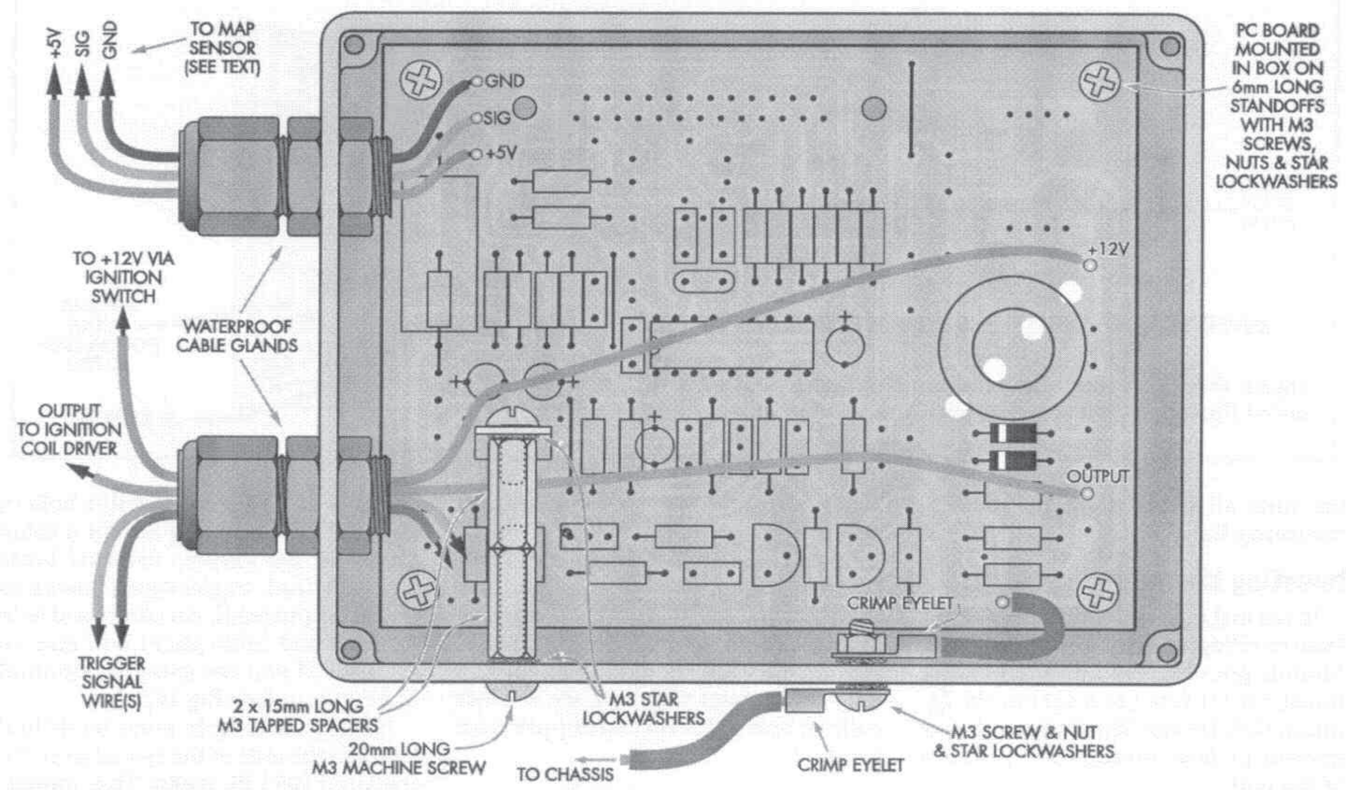
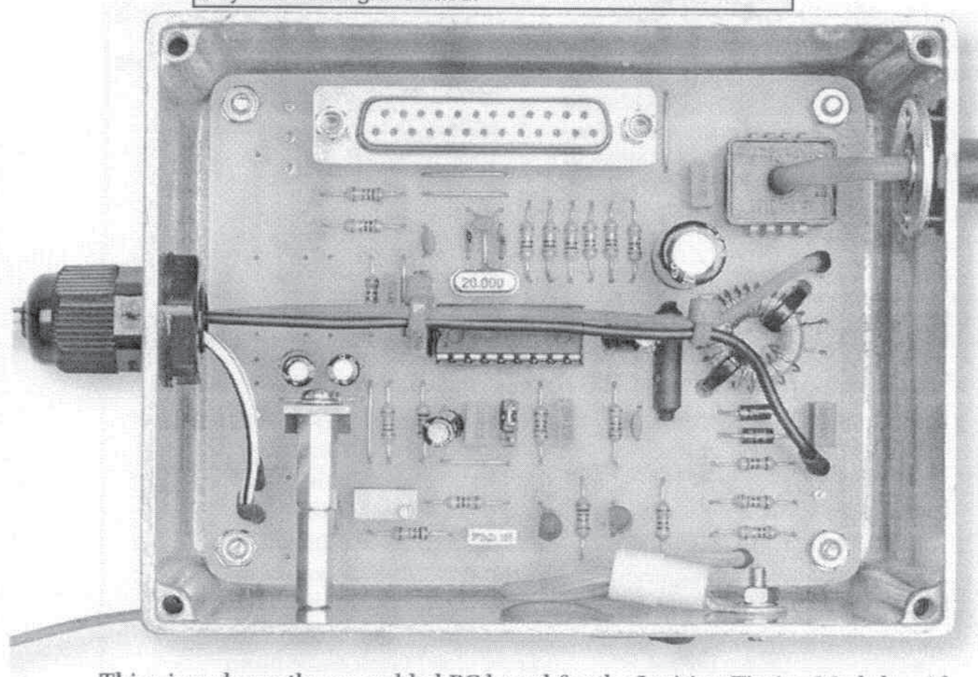


Fig.15: this diagram shows the final assembly and external wiring details for the Ignition Timing Module. Note how the 0V (ground) rail on the PC board is connected to one side of the case, with a lead then run from this point to the vehicle's chassis. Use cable ties to help secure the leads, both inside and outside the case.

Note that this is an early Silicon Chip prototype, that has only one cable gland fitted.



This view shows the assembled PC board for the Ignition Timing Module with the optional internal Sensym MAP sensor fitted (ie, when there is no existing external MAP sensor or you are not using a secondhand MAP sensor). Make sure that the unit is ruggedly built (ie, so that no leads can come adrift).

attached to the outside of the case to make the chassis connection, with the entire assembly secured using a M3 x 9mm screw, nut and star washer – see Fig.15.

Another 3mm hole is drilled to allow the metal tab of regulator REG1 to be secured to the case using two M3 x 15mm tapped metal spacers. This arrangement serves a dual purpose: (1) it mechanically secures the regulator to prevent its from breaking; and (2) it provides heatsinking for the regulator tab.

The two spacers are secured to REG1's tab using an M3 x 20mm screw, while an M3 x 9mm screw secured the spacers to the side of the case.

Note that star washers must be used under each screw head, to prevent the assembly from shaking loose.

Hose adapter

If you are using the on-board Sensym pressure sensor, then a hose connection will be required from the sensor to a chassis-mount flange (or through-piece) on the side of the box. This piece serves as both an anchor

Details for some MAP sensor pin outs can be found here too:
www.diy-efi.org/gmecm/component_info/sensors.html

Manifold Pressure Sensor Options

IN ORDER TO utilise the vacuum advance feature provided by the Programmable Ignition System, some means of monitoring manifold pressure is required.

There are several options available here. The simplest option is to use the MAP (manifold air pressure) sensor that's already installed on your car (if it has one). This sensor would normally be used to detect manifold pressure for the car's own Engine Management Unit, to control the timing.

If your car does not have a MAP sensor, then you can easily obtain one to do the job. There are different sensors to suit normally aspirated engines and to suit turbocharged engines.

Normally aspirated engines do not boost the air pressure for the fuel mixture and so a 1-bar (one atmosphere, 100kPa or 15psi) sensor is all that is required. These sensors measure the air pressure compared to a vacuum and output a voltage close to 4V for atmospheric pressures and close to 0V for a vacuum.

Turbo engines boost the air pressure above atmospheric and consequently a 1-bar sensor is inadequate. This is because the output from a 1-bar sensor would not change for pressures above 1-bar. There is also a possibility that the sensor could be damaged if the pressure went too far beyond its rating.

In this case, a 2-bar sensor should be adequate for most applications. However, if the boost is greater than 2-bar, a 3-bar sensor will be required instead.

One option is to use an on-board Sensym sensor that covers from 0-1 bar or from 0-2 bar, as specified in the parts list. This device is best used at temperatures ranging from 0-85°C and so the Programmable Ignition Timing Module should be mounted inside the cabin rather than in the engine bay.

Alternatively, most automotive wreckers can sell you a MAP sensor quite cheaply. These are available from various models of Holden, Honda, Toyota, Subaru and others. Details of the Holden type 1-bar, 2-bar and 3-bar MAP sensors and the Motorola 2.5-bar MAP sensor are available at this web site:
http://www.pgmfi.org/twiki/bin/view/Library/MapSensor

Typically, the 1-bar Holden sensors are designated with a 039, 460 or 883 code. 2-bar sensors have a 886, 012, 539 or 609 code and 3-bar sensors have a 749 code. The A, B and C labels refer to the positioning of the Ground, Signal and +5V terminals.

point and as a 3mm-to-5mm adapter.

This is necessary because the sensor's hose connection is 3mm in diameter while a standard automotive vacuum tube requires (at least) a 5mm fitting to enable it to stay in place without air leaks.

A 15mm round brass spacer is used as the adapter. The 3mm-diameter hose from the sensor is pushed inside the spacer at one end (ie, the end inside the case), while the external vacuum tube is fitted over the spacer at the other end (outside the case).

Note that it will be necessary to enlarge the hole at one end of the spacer slightly to accept the 3mm (ID) hose. Silicone sealant can be used later, when fitting the hoses, to ensure that the connections are air-tight.

Fig.16 shows how the adapter is fitted. First, a brass nut is soldered to one end of the adapter, after which the adapter is pushed through a 5mm hole in the side of the case. It is then clamped in position using a 20mm OD washer and a couple of M3 x 6mm machine screws that go into tapped holes in the washer (or you could use M2 x 10mm screws and nuts).

Alternatively, you can do away with the adapter altogether and pack the inlet on the Sensym sensor out with several layers of heatshrink tubing so that the 5mm hose is a tight fit. That way, the 5mm (ID) vacuum hose that runs to the engine manifold can simply pass through a hole in the case and

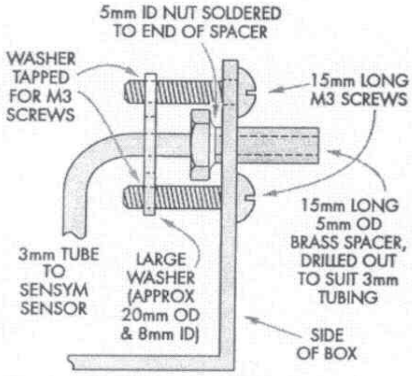


Fig.16: a simple adapter made from a brass spacer can be used to connect the 3mm outlet on the Sensym pressure sensor to a standard 5mm vacuum hose.

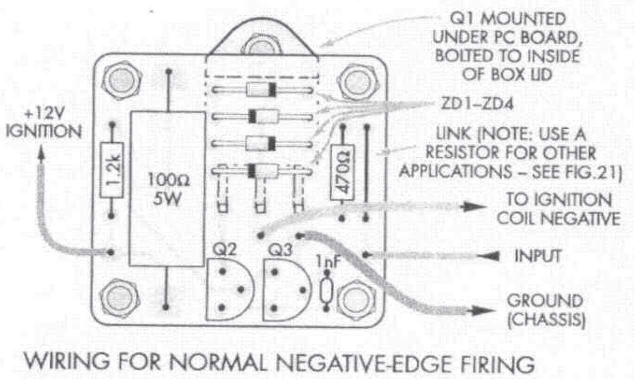
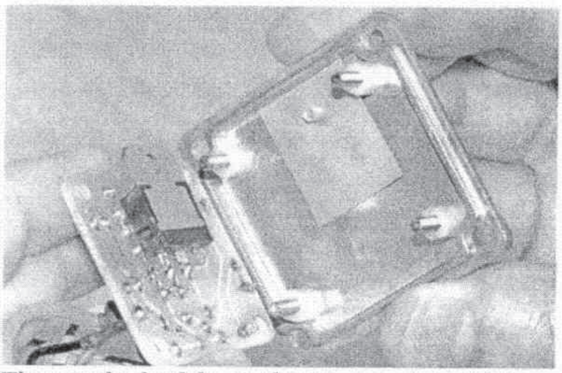


Fig.17: this is the parts layout for the Ignition Trigger Module. Note the different orientations for ZD1-ZD4.



The metal tab of the Darlington transistor (Q1) must be insulated from the case using a TO-218 insulating washer and a Nylon screw and nut.

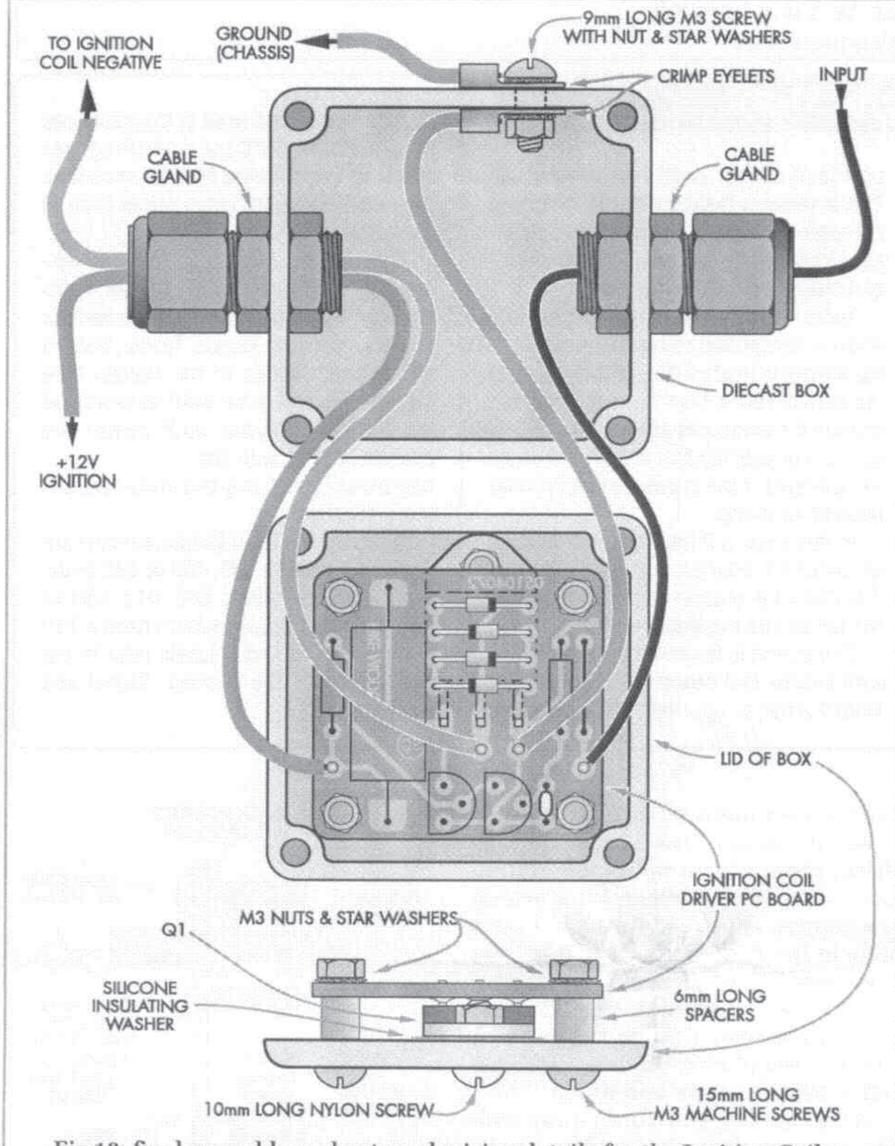
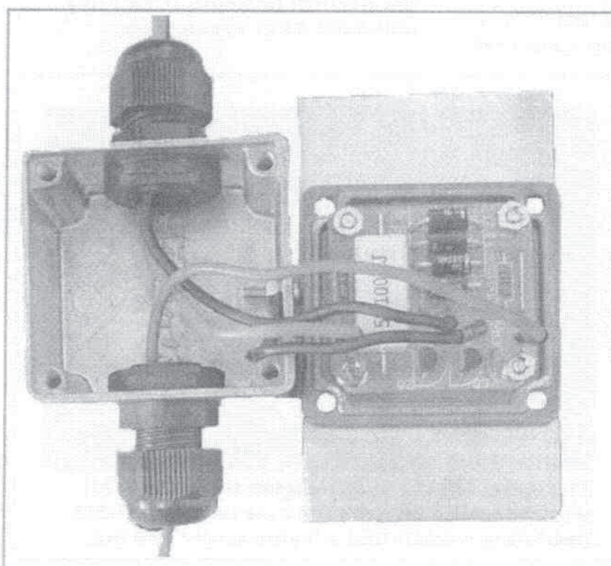


Fig.18: final assembly and external wiring details for the Ignition Coil Driver. After assembly, use a multimeter (set to a low ohms range) to confirm that the metal tab of Darlington transistor Q1 is properly isolated – ie, it must not be shorted to the case.



This is the view inside the Coil Driver Module. Note the use of a separate cable gland for the trigger input lead. As with the timing module, this unit must be ruggedly built to ensure reliability.

go straight to the Sensym pressure sensor.

As before, silicone sealant can be used to ensure an airtight fit but be careful not to block the sensor inlet with the sealant.

Once all the holes have been drilled in the case, the PC board can be fitted and the assembly completed as shown in Fig.15. Be sure to use automotive wiring for all external connections. These leads should all be secured using cable ties and the connections to the PC stakes covered with heatshrink tubing. This is necessary to prevent the leads from vibrating and coming adrift.

Wiring the pressure sensor

There are three options when it comes to wiring the pressure sensor:

(1) If you are using an existing MAP sensor, connect the signal lead only. **DO NOT connect the +5V and 0V supply leads** (the sensor will already have supply connections).

(2) If you are using an external (eg, secondhand) MAP sensor that you've added to the vehicle, then connect all three leads (ie, signal, +5V and 0V).

(3) If you are using the on-board Sensym sensor, do not make any external connections (the second cable gland can be deleted).

Ignition Coil Driver

Fig.17 shows the assembly details for this small PC board.

Begin by installing the wire link, then install the 1.2kΩ and 470Ω resistors. The 100Ω 5W resistor can then go in – it should be mounted all the way down onto the PC board, so that it cannot vibrate and break its leads.

Zener diodes ZD1-ZD4 are next on the list. Be sure to orient them as shown (two face in one direction and two in the other, so take care here). Follow these with transistors Q2 & Q3 and the 1nF ceramic capacitor.

Transistor Q1 is mounted on the underside of the PC board. This device is installed with its leads bent up through 90°, so that they go through matching holes in the PC board from the track side (ie, the metal tab of the device faces away from the board – see photo).

Push the leads through their holes until the metal tab is exactly 6mm below the underside of the PC board, then lightly solder one of the leads. This will allow you to make any adjust-

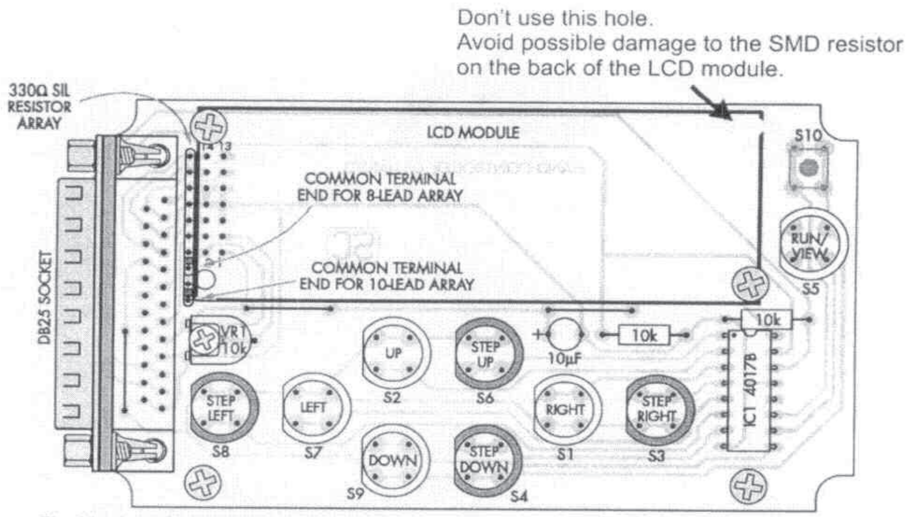
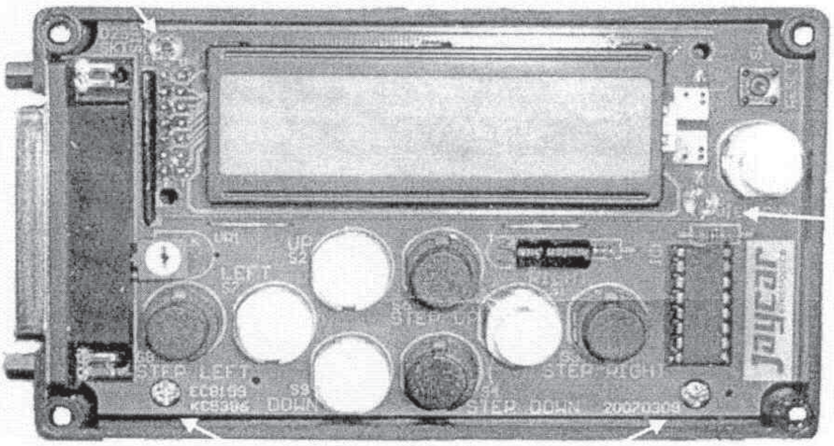


Fig.19: the LCD Hand Controller PC board is easy to assemble. Install the three links frst and note that the switches, IC and 10µF electrolytic capacitor are polarised. The LCD is connected via a 14-way DIL pin header.



The PC board mounts inside the case on four M3 x 12mm spacers as shown in Fig.19. Note how the 10mF capacitor is mounted on its side, so that it clears the front panel.

ments as necessary before completing the soldering.

Finally, complete the board assembly by installing PC stakes at the four external wiring points.

Once completed, the Ignition Coil Driver PC board can be installed in its diecast case – see Fig.18. As shown, the board in mounted on the lid of the case on 6mm tapped spacers and secured using M3 x 15mm screws, nuts and star washers. Transistor Q1 (on the underside of the board) is fastened to the lid for heatsinking.

The first step is to mark out all the mounting holes on the lid. Drill these holes to 3mm, then carefully deburr them using an oversize drill. In particular, make sure that Q1's mounting hole is perfectly smooth and free of any metal swarf that could puncture its insulating washer.

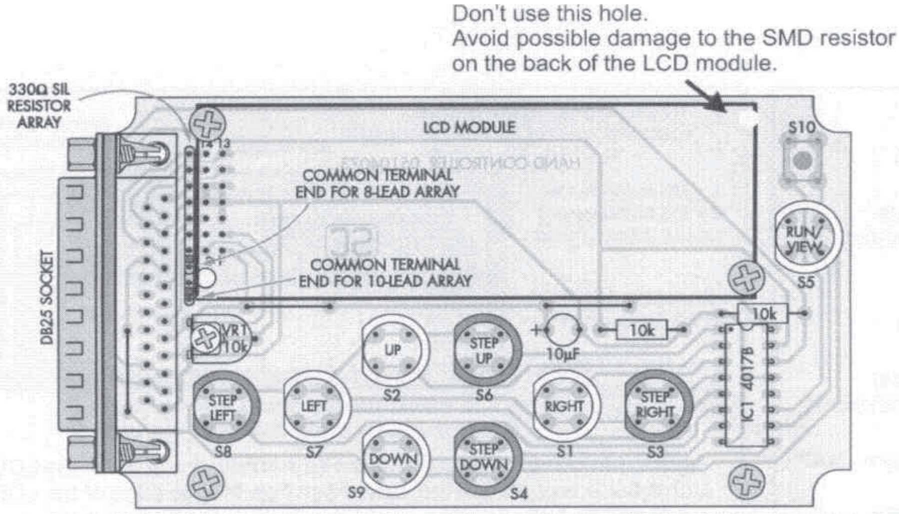
Note too that Q1's mounting hole should be chamfered (use an oversize drill bit). This is necessary to avoid sharp edges around the circumference of the hole, to prevent arcing through the insulating washer (due to the high voltages present on the transistor tab).

Once the holes have been "cleaned up", fit the four tapped spacers to the board mounting positions and secure them using the M3 x 15mm screws.

That done, install transistor Q1's Nylon mounting screw and insulating washer (see photo), then slip the board into position and secure it using M3 nuts and star washers.

Don't leave the star washers out – they are necessary to ensure that the nuts don't shake loose due to vibration.

Transistor Q1 can now be secured by installing its nut and tightening the Nylon screw (use a pair of needle-nose pliers to hold the nut in position while you "start" the screw). **Finally, use your multimeter (set to a low ohms range) to confirm that Q1's metal tab is indeed electrically isolated from**



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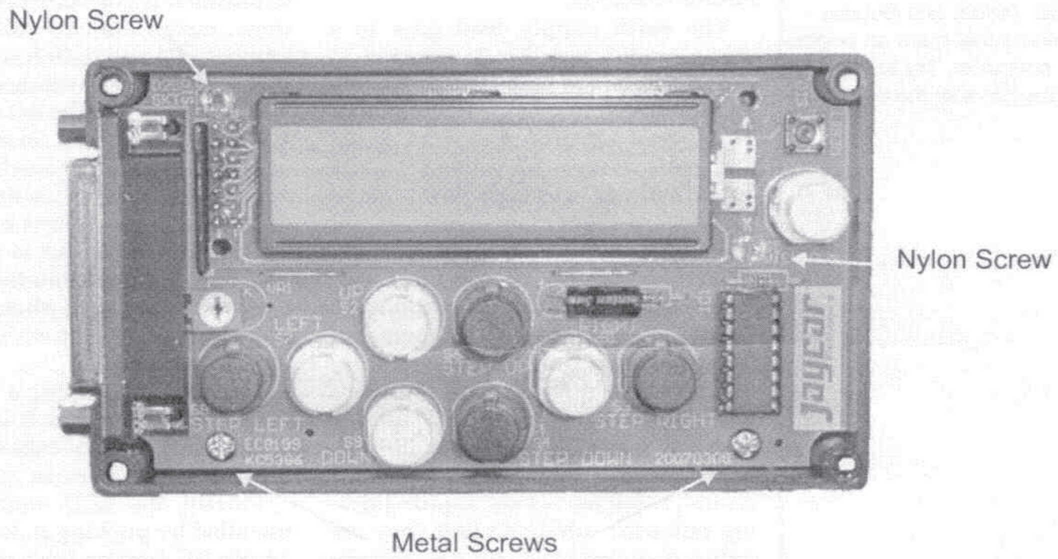

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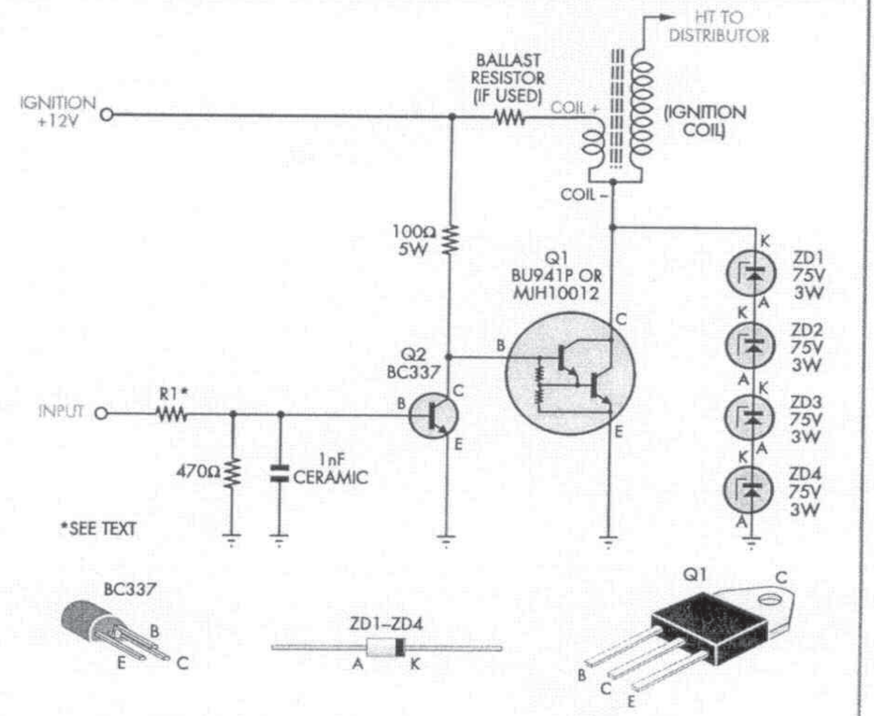
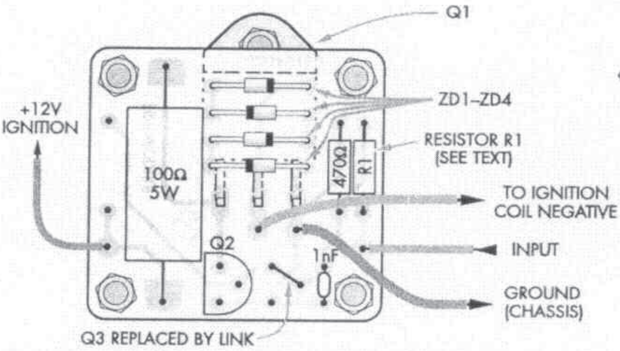
Inverting The Firing Sense Of The Ignition Coil Driver



MODIFIED IGNITION COIL DRIVER (TO INVERT THE FIRING SENSE)

Fig.21: this modified Ignition Coil Driver circuit can be used to "fire" a plug when the input signal goes high.



MODIFIED WIRING FOR POSITIVE-EDGE FIRING

Fig.22: this is the modified parts layout. Use a 470Ω resistor for R1 for a 5V input signal and a 1.2kΩ resistor for a 12V input signal.

THE IGNITION COIL DRIVER can be used on its own for other applications; eg, as a replacement coil driver in an existing system. However, in some cases, it may be necessary to change the "trigger sense" of the circuit.

The standard set-up has the coil "charging" when the input signal is high and then "firing" a plug on a negative edge input signal. To invert this level sense, transistor Q3 and the 1.2kΩ resistor are deleted and a link installed between the pads normally used for Q3's base and collector leads.

This effectively bypasses Q3 and the input now drives Q2 via a base resistor (R1) – see Fig.21. Fig.22 shows the revised parts layout for the PC board. Use a 470Ω resistor for R1 when it is driven by a 5V input signal and a 1.2kΩ resistor when driven from a 12V signal.

With this arrangement, the coil "charges" when the input signal is low and "fires" a plug when the signal goes high.

modifications. That earlier circuit is identical to the one described here except that it didn't include the six 330Ω terminating resistors.

This means that all you have to do is add these six resistors between the relevant pins on the LCD module (pins 4, 6, 11, 12, 13 & 14) and ground. These will have to be mounted on the track side of the PC board. The ground connections are best made at pins 7-10 of the LCD module.

Testing

OK, now for the smoke test, starting with the Programmable Ignition Timing Module.

First, apply +12V to the supply input and connect the case to the 0V rail. That done, use your multimeter to check that there is 5V (±0.1V) between pins 14 & 5 of IC1's socket. If this is correct, switch off and install IC1, making sure it is correctly oriented.

Next, connect the RS-232 DB25 lead between the Programmable Ignition Timing Module and the LCD Hand Controller and apply power. You should be greeted with some characters on the LCD. If there are none, or if the display is faint or the contrast is poor, adjust VR1 on the LCD Hand Controller board for best results.

If there is still no display, recheck the parts placement on both PC board assemblies. Check also that the DB25 cable is correct – each pin should be connected through to the same socket pin on the opposite end of the lead.

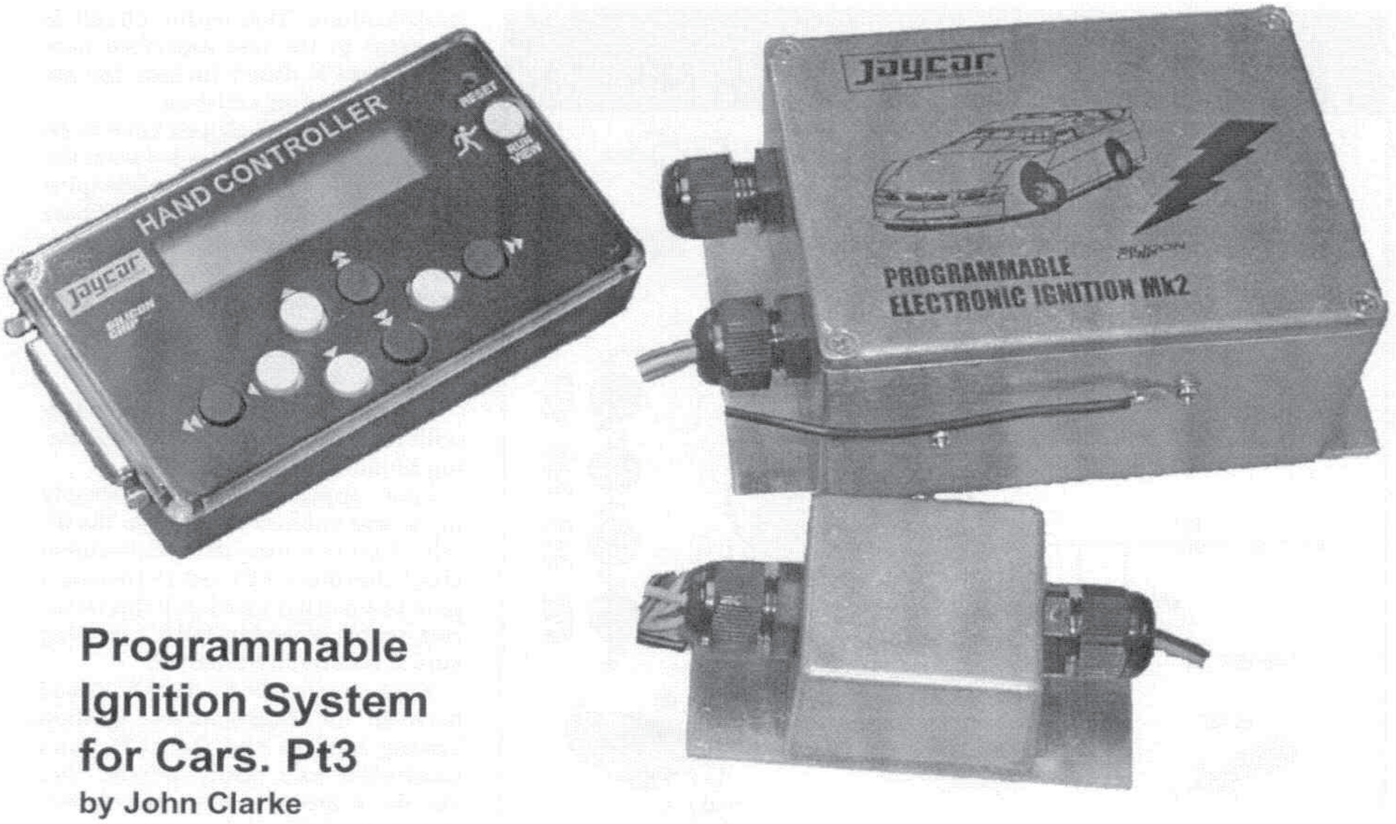
Assuming all is well, the display shown on the LCD will depend on the position of jumper shunt LK1. Remember that the Settings position will show the settings mode (used when changing parameters), while the Timing position will show the RPM and Load site values against the timing values.

The initial timing values are all set to 0° advance. Check that you can change the values using the switches on the LCD Hand Controller.

Converting your distributor

Finally, note that if you have a distributor with points, you can convert it to a Hall effect pick-up instead, to make it maintenance-free. The details on how to do this were published in our January 2006 issue.

That all for this instalment. Next month, we will describe how the unit is set up and installed in a car. SC



Programmable Ignition System for Cars. Pt3

by John Clarke

In Pt2 , we described how to build all the modules that comprise the Programmable Ignition System. This month, we describe the installation and setting up procedures and show you how to plot the ignition timing.

AS MENTIONED in Pt.1, the Programmable Ignition System can either be used as a complete ignition system or as an interceptor.

Whether it behaves as an interceptor or not depends on the input signal that's applied to the unit. In most cars, the ignition system will already provide ignition advance with respect to RPM and engine load. This applies not only to cars that have full or partial engine management but also to older cars that simply have mechanical RPM and vacuum advance systems.

When used as an interceptor, the Programmable Ignition simply modifies the existing ignition timing. By contrast, when it's used as a complete ignition system, we dispense with any existing timing system that may exist and re-map the timing using the Programmable Ignition Timing Module.

If you intend using the unit as an interceptor, then there's no real need to know what the engine's existing timing map is for RPM and engine load. That's because we are simply using the unit to modify the existing timing values at various engine RPM and load sites.

Why would you want to do this? Well, you may want to advance the timing at some sites to gain power and/or retard the timing to prevent detonation (ping) at certain trouble spots within the RPM and engine load map.

Note that although the original timing curve does not have to be known for interception, you do need to know the RPM and engine load range. This is necessary to ensure that the full mapping range is utilised with the Programmable Ignition System (more on this later).

Conversely, if the unit is used as a replacement ignition, it will be easier to program in a timing map if the original engine timing is known. That way, the Programmable Ignition can initially duplicate the original timing which can then be adjusted as necessary in a similar manner to an interceptor – eg, to extract better performance and/or to prevent detonation.

Warning!

Programming an incorrect timing map into the Ignition Timing Module could result in serious engine damage. Do NOT modify your car by fitting this device unless you know exactly what you are doing.

Also, be sure to install this ignition system in a manner that does not compromise safety. It must be ruggedly built and correctly installed to ensure that no leads or components can come adrift.

Finally, make sure that the device does not compromise the operation of other systems controlled by an existing engine management unit – eg, ABS, traction control, stability control, air-bag control, etc.

In some cases, full timing information will be available from the car's manufacturer or from a workshop manual. Usually, however, there will be no information available.

The solution is to actually measure the timing advance against changes in RPM and engine load. This is easy to do in cars with a mechanical vacuum advance mechanism, as this operates independently of engine RPM.

Plotting the timing values in cars that use engine mapping and a MAP sensor for vacuum measurement is only slightly more difficult. It's done by externally altering the pressure sent to the MAP sensor or actuator. The exact procedure is described in the panel headed "Plotting The Original Ignition Timing Values".

Cars that utilise Mass Air Flow (MAF) sensing of engine load are much more difficult when it comes to mapping ignition advance. That's because the engine will have to be run with varying degrees of load throughout the RPM range and this can only be achieved on a dynamometer.

Interceptor or replacement?

Note that the Programmable Ignition System should be used only as an interceptor on cars that already have an engine management system. That's because the manufacturer's timing map will have been carefully designed for your engine. Furthermore, the timing would have been mapped against air inlet temperature, engine temperature and the air-fuel ratio to provide the best performance in all conditions.

By using the Programmable Ignition System only as an interceptor in such cars, the original timing variations according to fuel ratio, temperature, RPM and load will be retained.

By contrast, we do advocate using the Programmable Ignition System as a complete replacement in older cars and Go-carts and on engines that do not currently include RPM or vacuum advance.

Many old cars provide both RPM and vacuum advance by mechanical means. Because of their age, the RPM advance system is now likely to be worn and sticky in its operation, while the vacuum actuator will often be leaky or may have failed altogether. Most drivers do not notice if a vacuum actuator has failed because when it fails, it remains at the maximum engine load position. As a result, power under load is retained.

Our experience

During our tests, we eliminated the original mechanical RPM and vacuum advance systems in a 1988 Ford Telstar and used the Programmable Ignition System to provide the timing advance instead. As a result, the engine became far more responsive to throttle changes and was more willing to rev than before.

There are a couple of reasons for this improved performance. First, the flying weight system in the distributor that provides RPM advance is fairly sluggish to respond to RPM changes. By contrast, the Programmable Ignition System provides "instantaneous" changes to the timing map.

Similarly, the vacuum actuator that moves the distributor's trigger firing point is slow to respond compared to using a pressure (or MAP) sensor with the Programmable Ignition System.

Installation

Typically, the Ignition Timing Module is best mounted inside the cabin of the car; eg, somewhere under the dashboard. This allows the Hand Con-

Timing Problems With Reluctor Triggers

In some cars, when using the Programmable Ignition, you may find that the ignition trigger exhibits a type of stiction effect, with the timing initially failing to advance from about 0-5°. This effect is due to the coil firing just before the trigger signal (due to the advance setting) and the resulting high-tension signal within the distributor then interfering with the normal operation of the trigger sensor.

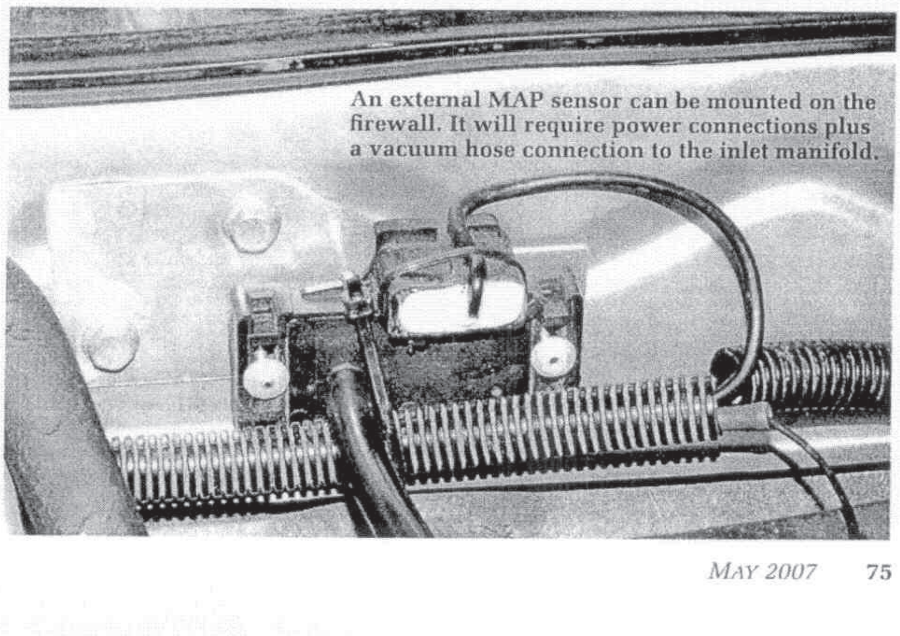
Reluctor triggers are the most likely to be affected in this way. Hall Effect, optical, engine management and points triggers are unlikely to be affected.

In some cases the effect may be dialled out by careful adjustment of VR1. Also, make sure the high-tension lead and the reluctor leads are spaced well apart and only intersect at right angles if they do need to cross.

If this does not solve the problem then you can avoid programming low values of advance into the Programmable Ignition. This can be done in one of two ways. First, the static timing can be set to say 10° of retard (eg, –10°) so that you need at least 10° of advance from the Programmable Ignition to get 0° timing. Of course, the entire timing map would have to be changed to include this extra 10° for all values.

An alternative method is to set the static timing to greater than the maximum amount of advance in the timing map. This value would then be subtracted from required timing value for each map site in order to determine the retard setting required for each site in the Programmable Ignition.

For example, if the static timing is +40° and the timing map value is 22°, the programmable ignition map setting would be -18° (22° - 40° = -18°).



An external MAP sensor can be mounted on the firewall. It will require power connections plus a vacuum hose connection to the inlet manifold.

Plotting The Original Ignition Timing Values

IT'S QUITE EASY to plot the timing advance values for an existing ignition system by using a timing light. In fact, there are several ways to go about this.

Typically, most cars only provide timing marks that show Top Dead Centre (TDC) and up to about 10° or 12° before TDC using a scale on the engine block. These marks are ideal for setting up the ignition timing at idle but are not sufficient to measure advance at higher RPM values. This is because the advance will go beyond the 10° or 12° timing mark.

One way round this is to make up an extended timing scale to directly indicate the advance at higher RPM values. Another option is to use a timing light that includes advance adjustment.

Yet another option is to use the Programmable Ignition System and a spare ignition coil and spark plug. This system can shift the timing light's stroboscopic flashing so that it is delayed by as many degrees as the advance. That way, you can use the existing engine timing marks.

Fig.23 shows how to set this system up. Note that **the coil shown here is not the ignition coil used in the car** but a separate one that independently fires the timing light. If you do not have a spare coil, they are readily available from automotive wreckers or you could temporarily borrow one from another car (just about any single output ignition coil can be used).

The spark plug is necessary to provide a spark gap for the coil to discharge. This is important because if the coil's high tension output is left open, there is the risk that the coil will internally breakdown and suffer permanent damage.

The Ignition Timing Module takes its signal from the car's trigger sensor or existing ECU output but note that this signal must include the timing advance (not always the case with trigger sensor information). If the trigger signal does not include the timing advance, then be sure to use the output from the ECU.

Before actually plotting out the timing values, there are a number of adjustments that must first be made to the Ignition Timing Module, as follows:

Reluctor adjustment

If your car uses a reluctor pick-up, then VR1 (on the Ignition Timing Module) must first be adjusted. Begin by setting VR1 fully clockwise and measure the voltage at pin 6 of IC1. If the voltage is close to 0V, wind VR1 anticlockwise several turns until the voltage at pin 6 of IC1 goes to +5V. When it does, wind VR1 anticlockwise about two turns more and leave it at this setting.

If the voltage at pin 6 of IC1 is +5V when VR1 is wound fully clockwise, then rotate VR1 fully anticlockwise and wind it clockwise until the voltage goes to +5V. As before, wind VR1 on by an extra two turns (clockwise this time).

Initial settings

Now for the programmed settings.

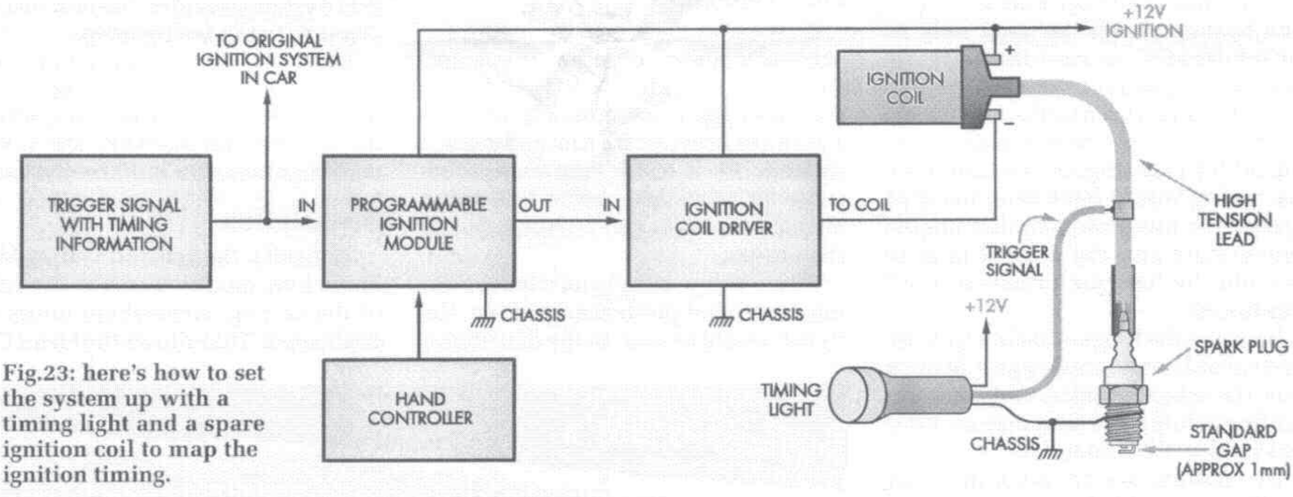


Fig.23: here's how to set the system up with a timing light and a spare ignition coil to map the ignition timing.

troller to be easily attached and used while someone else does the driving (this should be done on a racetrack or some other closed road).

It is also best to mount the Ignition Timing Module in the cabin if the Sensym pressure sensor is used. This helps keep the sensor cool.

Alternatively, the Ignition Timing Module can be mounted in the engine bay if you cannot find room for it in the cabin. Make sure it is well away from the exhaust manifold though, to prevent excessive heat exposure. It can be mounted using suitable brackets to the chassis.

The big disadvantage of mounting the unit in the engine bay is that it is much harder to connect the Hand Controller for driving. In some cases, it may be possible to feed the connecting lead through a window and under the rear of the (closed) bonnet. Alternatively, it may be possible to temporarily feed the connecting lead through the firewall (not so easy) or through an air vent (easier).

Note that the lid of the Ignition Timing Module must be left off when the Hand Controller is connected. This also allows jumper LK1 to be easily changed, to select either the settings or timing display modes. **Note that**

		RPM0	Min RPM										Max RPM
	RPM Site		RPM1	RPM2	RPM3	RPM4	RPM5	RPM6	RPM7	RPM8	RPM9	RPM10	RPM11
	Load Site	0	1000	1400	1800	2200	2600	3000	3400	3800	4200	4600	5000
Min load	LOAD1												
	LOAD2												
	LOAD3												
	LOAD4												
	LOAD5												
	LOAD6												
	LOAD7												
	LOAD8												
	LOAD9												
	LOAD10												
Max load	LOAD11	6	6	8.5	11.5	13	15.5	19	22	26	28	32.5	34

Table 1: this table shows the interpolated advance values vs RPM for the high load site (in this case, LOAD11). These values are measured with the vacuum advance line disconnected and plugged – see text.

Here's the step-by-step procedure:

(1) Install jumper LK1 in the settings position.

(2) Set the number of cylinders for your car, the edge sense to HIGH and the diagnostic setting to "No Interpolation".

(3) Set the dwell to 0ms and set the oscillator to ON.

(4) Increase the dwell value until the timing light fires reliably. Note that the dwell value does not change until the Up switch on the Hand Controller is released.

(5) Move LK1 to the timing position and press the Reset switch on the Hand Controller so that all the timing values for the selected map return to 0.

If you now start the engine and aim the timing light at the flywheel timing marks you should see the amount of advance. If this does not seem correct, then change the edge sense to low in the settings mode (ie, temporarily move LK1 back to the settings position). If the strobing is erratic, try selecting the 2ms debounce option (again found in the settings mode).

Note that with this strobe set-up, the timing light will fire for every spark firing rather than just for cylinder 1. This will make the visible contrast of the timing mark a little less than it otherwise would be. You can compensate for this by dabbing some white paint on the flywheel marker.

Checking the advance

Having gone through all these initial adjustments, the next step is to disable any vacuum advance by removing and plugging the rubber hose that connects to the vacuum advance pressure sensor (or MAP sensor. The timing advance at idle should be set according to the manufacturer's specifications.

For the Ford Telstar, the initial timing is 6° BTC (before top centre) and this should be indicated by aiming the timing light at the timing marks. In this case, the Ignition Timing Module can now be programmed (using the Hand Controller) for a timing advance of -6.0° (retard). When this is done, the timing light should now show the timing to be at exactly TDC on the flywheel marks.

Plotting the RPM advance values from here is straightforward. It's just a matter of running the engine at specific RPM values and adjusting the "retard" value programmed into the Ignition Timing Module until the timing light shows TDC in each case. The programmed values then represent the timing advance (in degrees) for each selected RPM value.

For example, let's say that the programmed value necessary for the timing light to show TDC is -22° when the engine is doing 3400 RPM. This simply means that, in this particular case, the standard ignition has a timing advance of 22° at that engine speed.

OK, so how do we actually do this? Simple – just select the timing display mode (using LK1) and then select DIAG so that the RPM is displayed. You can now plot out the advance versus RPM values by increasing the engine RPM in suitable steps (eg, 1000 RPM) all the way to the red line and adjusting the programmed retard value so that the timing is shown at TDC. Keep a record of these advance values as you proceed.

This RPM versus timing advance is generally the high-load map because the vacuum advance line is disconnected and plugged. However, it is not the high load map for turbo-boosted engines (see below).

The recorded timing information can now be plotted out on a graph and the interpolated values transferred to the individual RPM sites. This is done as follows:

(1) Decide whether you want the two 11x11 maps or the single 15x15 map and select this in the settings mode.

(2) Select either 1° or 0.5° resolution.

(3) Set the Minimum RPM and Maximum RPM values to suit the range of the engine. The Minimum RPM value is simply the idle speed, while the Maximum RPM value is the engine red line. The idle speed can be measured by setting the display to DIAG, so that it shows RPM.

When setting the Maximum RPM, adjust the RPM/SITE value so that the Maximum RPM is at or just over the value required. You can also adjust the Minimum RPM setting if necessary (see Pt.1).

The Minimum RPM value becomes the RPM1 site. The RPM step value for each site is shown in the Maximum RPM settings display. If this is 400 RPM, for example, then the RPM2 site will be 400 RPM higher than the Minimum RPM setting. Similarly, the next RPM site will be 400 RPM higher again and so on up to the final RPM site which will be equal to (or slightly higher than) the Maximum RPM value.

You should now have a timing table

. . . continued next page

LK1 should be placed in the settings position when the Hand Controller is subsequently disconnected.

By contrast, the Ignition Coil Driver must be mounted in the engine bay. It can be secured to the chassis using suitable brackets and should be located close to the ignition coil. If you are using a separate MAP sensor, then this can be mounted on the firewall.

Make sure that there is a good connection between the metal cases of both units and chassis. If necessary, you can run separate earth leads to ground (bolt them to the chassis via crimp eyelet connectors).

Once you've made the connections, use your multimeter (set to its ohms range) to confirm that the metal cases are correctly grounded. You should get a reading of zero ohms between each metal case and ground.

Fig.15 in Pt.2 last month shows the external wiring details. Note that all wiring between the Ignition Timing Module and the Ignition Coil Driver should be run using automotive wire and crimp automotive connectors. Similarly, use automotive wire and crimp connectors for the connections to the ignition coil, the +12V supply and to chassis.

The +12V supply should be taken

Plotting The Original Timing Values – Continued

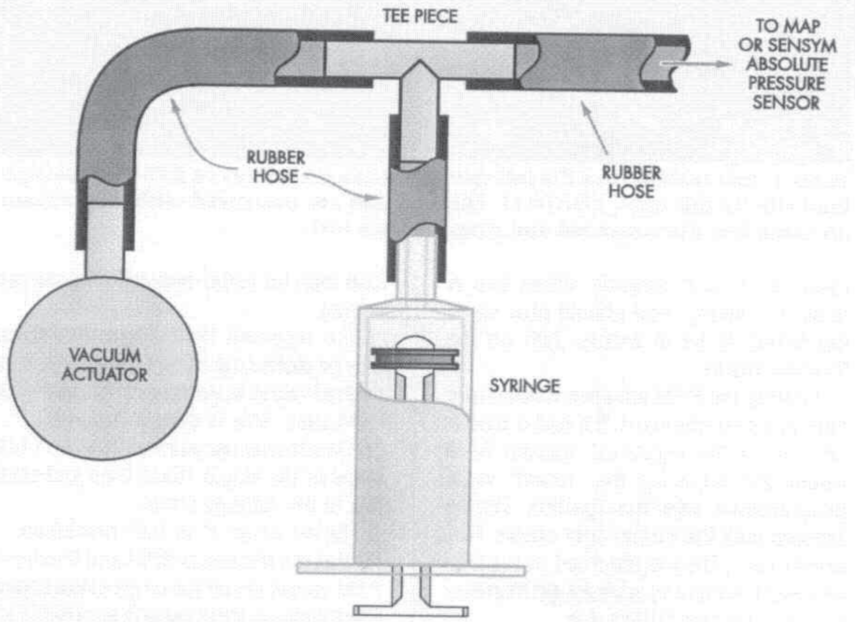


Fig.24: here's how to check the LOAD values in a car with a mechanical vacuum actuator. The syringe is used to vary the pressure.

that is similar to the one shown in Table 1. Note that we have included RPM0 on a different line because it is only there to show that the advance setting remains the same for RPM values below the Minimum RPM site (RPM1).

Finally, you may wish to recheck the advance values assigned to each RPM site. For example, for the table shown, you would recheck the advance at 1000, 1400, 1800, 2200, 2600, 3000, 3400, 3800, 4200, 4600 and 5000 RPM.

Vacuum advance

Having determined the RPM site advance values, you now need to plot the LOAD values.

First, let's assume that you have a car with a mechanical vacuum actuator. In this case, you will need a T-piece in order to connect this existing vacuum actuator (via a hose) to the MAP sensor used with the Programmable Ignition System.

Note, however, that a T-piece is not required if your car is fitted with an existing MAP sensor. In this case, the same signal from the MAP sensor is used both for the existing ignition and for the Ignition Timing Module.

In either case, it will be necessary to feed a MAP sensor signal to the Ignition Timing Module. If you are using the Sensym sensor, then a vacuum hose has to be connected to this.

The T-piece does not have to be anything too complex. You can buy these at an automotive shop or make your own.

As shown in Fig.24, a syringe is used to vary the pressure. However, be careful not introduce excessive pressure into the MAP sensor as it may be damaged.

For 1-bar sensors, the syringe should be pressed all the way in before connecting it to the vacuum hose. That way, you can only "draw" a vacuum by pulling on the syringe plunger (and not increase the pressure). The maximum value is typically around 200 but could be as high as 230 and is equivalent to a 4-4.5V output from the sensor.

If you are using a 2-bar sensor, first check the LOAD value at normal atmospheric air pressure. At 2-bar, this value will be about 100 greater. Do not increase pressure above this increased value (ie, the atmospheric plus 100 value).

In this case (ie, for a 2-bar sensor), the syringe should be inserted into the hose with the plunger set half-way down. If you cannot get a sufficient pressure range with this, then you will have to do the pressure changes in two steps: (1) for vacuum, insert the syringe when the plunger is fully in and draw out the plunger for vacuum; and (2) for boost pressure measurements, insert the syringe nozzle into the hose with the plunger fully drawn and apply boost pressure by pressing on the plunger.

During this process, be sure to always monitor the sensor output level by setting the Hand Controller to DIAG mode (the second line shows the pressure sensor LOAD value). If the value stops increasing as you apply more pressure, then stop immediately. This indicates that you have reached the maximum pressure that the sensor can detect and any further increases could damage it.

Plotting vacuum advance

Let's assume that your car uses a vacuum actuator and you have made the necessary vacuum hose connections using the T-piece. The vacuum advance plot can

from the fusebox. Be sure to choose a connection point that delivers +12V only when the ignition on. In addition, **make sure that this +12V rail DOES NOT drop to 0V when the ignition is switched to START**, otherwise the engine will never start.

In our case, we used twin-core shielded cable to connect between the Ignition Timing Module and an external MAP sensor mounted on the firewall (see photo. Alternatively, you can use automotive cable.

Note that the MAP sensor must be wired with the correct polarity so double-check the wiring and voltages before making the final connection to the this sensor. If you are using an existing MAP sensor, then you won't need to make the supply connections, since these will already be present (see panel on page 73 last month).

A toggle switch will need to be mounted on the dashboard if you want to be able to select between two 11x11 maps. The wires for this are connected to the S1 terminals on the Ignition Timing Module PC board. If you just want one map (either an 11x11 or a 15x15), then switch S1 is unnecessary.

Adjusting VR1

If you are using a reluctor pickup

now be made at a fixed RPM setting that coincides with an RPM load site value.

However, do not to choose the idle load point because the engine RPM will alter as vacuum advance is applied and you need to be able to adjust the throttle to maintain the fixed RPM setting. Choose the RPM2 site value instead (1400 RPM in our example).

It's now just a matter of plotting the RPM advance against the pressure sensor LOAD reading, as shown on the Hand Controller's display. To vary the LOAD reading, just vary the position of the syringe plunger. Be sure to adjust the throttle to compensate for pressure changes, to maintain engine RPM at the RPM2 site value.

In practice, the vacuum advance value will stop increasing beyond a certain minimum pressure value. This value should be recorded as the minimum load. Similarly, it will also cease changing at a certain maximum pressure value and this should be recorded as the maximum load value. Enter these two values into the Minimum LOAD and Maximum LOAD settings.

Remember that the maximum load value can only be changed by increasing the LOADS/SITE value. In our example below, the LOADS/SITE value is 40 and it ranges from a minimum of 151 (which becomes LOAD1) through to a maximum of 191 (LOAD11).

You can now insert the load timing values into a table as shown in Table 2.

Note that the voltage output from electronic pressure sensors (including MAP sensors) usually decreases with increasing vacuum (lower pressure). This means that the minimum load (maximum vacuum) gives the lowest value on the DIAG display and so this becomes the minimum load site (LOAD1).

If, for some reason, the pressure readings are reversed (ie, the value increases with decreasing vacuum), then the load site numbering will have to be reversed so that the maximum load becomes LOAD1.

	RPM Site	RPM0	Min RPM RPM1	RPM2	RPM3	RPM4	RPM5	RPM6	RPM7	RPM8	RPM9	RPM10	Max RPM RPM11
Value	Load Site	0	1000	1400	1800	2200	2600	3000	3400	3800	4200	4600	5000
151	LOAD1			18.5									
155	LOAD2			17.5									
159	LOAD3			16.5									
163	LOAD4			15.5									
167	LOAD5			14.5									
171	LOAD6			13.5									
175	LOAD7			12.5									
179	LOAD8			11.5									
183	LOAD9			10.5									
187	LOAD10			9.5									
191	LOAD11	6	6	8.5	11.5	13	15.6	19	22	26	28	32.5	34

Table 2: the LOAD site values are all made at a fixed RPM setting but do not use the RPM1 value. Choose the RPM2 or RPM3 rev value instead.

	RPM Site	RPM0	Min RPM RPM1	RPM2	RPM3	RPM4	RPM5	RPM6	RPM7	RPM8	RPM9	RPM10	Max RPM RPM11
	Load Site	0	1000	1400	1800	2200	2600	3000	3400	3800	4200	4600	5000
Min load	LOAD1	16	16	18.5	21.5	23	25.5	29	32	36	38	42.5	44
	LOAD2	15	15	17.5	20.5	22	24.5	28	31	35	37	41.5	43
	LOAD3	14	14	16.5	19.5	21	23.5	27	30	34	36	40.5	42
	LOAD4	13	13	15.5	18.5	20	22.5	26	29	33	35	39.5	41
	LOAD5	12	12	14.5	17.5	19	21.5	25	28	32	34	38.5	40
	LOAD6	11	11	13.5	16.5	18	20.5	24	27	31	33	37.5	39
	LOAD7	10	10	12.5	15.5	17	19.5	23	26	30	32	36.5	38
	LOAD8	9	9	11.5	14.5	16	18.5	22	25	29	31	35.5	37
	LOAD9	8	8	10.5	13.5	15	17.5	21	24	28	30	34.5	36
	LOAD10	7	7	9.6	12.5	14	16.5	20	23	27	29	33.5	35
Max load	LOAD11	6	6	8.5	11.5	13	15.5	19	22	26	28	32.5	34

Table 3: once you've completed Table 2, the rest of the table can be filled in by adding or subtracting the RPM advance steps to the RPM2 LOAD site values. This is the result for a 1988 2-litre Ford Telstar.

This is because the lowest value must be entered as the minimum load site.

Completing the table

Because the vacuum actuator advance system provides the same advance curve at all RPM values, it's quite easy to complete the table. In our example, the advance increases by 1° for each decreasing LOAD site. Table 3 shows the result.

MAP sensor

If your car has an existing MAP sensor, then the load advance will have to be plotted for each RPM site. The table then may not have a consistent change between LOAD sites but its value will be dependent on the ignition mapping.

Programming

The Ignition Timing Module can now be programmed with the timing map. This is done using the VIEW setting, to enable stepping through all the map sites.

Normally, the distributor would be adjusted so that the trigger sensor delivers a firing signal at TDC and the timing map entered on this basis. Alternatively, you can set the distributor to deliver a firing signal at a preset advance or retard value. The entered advance values would need to be adjusted to account for this initial advance or retard setting of the distributor.

Make sure that the distributor's rotor is still within its range for firing with the values set in the programmable ignition. If you do not change the settings much beyond the original ignition timing curve, then the rotor will remain within range to allow the spark to bridge the gap within the distributor cap to fire the spark plugs.

Finally, don't forget to set the interpolation back to "on" after plotting the ignition timing.

to trigger the Ignition Timing Module, the first thing to do is to adjust trimpot VR1. That's done as set out in the accompanying panel headed "Plotting The Original Ignition Timing Values" (see text immediately following "Reluctor adjustment").

If you have plotted the RPM advance curve (see panel), then most of the parameters within the Ignition Timing Module will have already been set. You will, however, need to set the dwell for the ignition coil.

Conversely, if none of the parameters have been set, then you will have to start from scratch. The various settings were detailed in the first article in March 2007.

The first step is to place jumper LK1 in the settings position. That done, set the number of cylinders for your car, then set the edge sense to high (or to low if you know it should be this setting). The diagnostic setting should then be checked to ensure it is set for "interpolation on".

Next, decide whether you want the two 11x11 maps or the single 15x15 map and select this in the map setting. Follow this step by selecting either the 1° or 0.5° resolution and set the debounce to 0.4ms.

Note that the latter may need to be

Using An Existing Coil Driver Module

IN SOME CASES, it may be possible for the output from the Ignition Timing Module to drive an existing ignition module (or coil driver) instead of using the SILICON CHIP Ignition Coil Driver.

There are a few things to sort out before doing this, however. First, you must find out the voltage sense used for the trigger signal. This can easily be determined if the trigger signal is produced by the ECU. For other triggers, the sense may need to be determined by trial and error.

Initially, you should set the Ignition Timing Module's EDGE setting set to LOW. If it doesn't work, try reducing the 470Ω output resistor in the Ignition Timing Module to 220Ω in order to drive the original coil driver module.

If it still doesn't work, try changing the EDGE setting to HIGH. In addition, the Ignition Timing Module output must be inverted for positive edge firing by taking the drive from transistor Q4 – see Fig.14 in last month's article.

ECU trigger signal

What if you are using the trigger signal from an existing ECU (or engine management unit)?

In this case, the output may normally be at +5V, with a low signal then applied to the ignition module to "charge" the coil and a high-going signal subsequently used to fire a plug. Alternatively, the signal sense could be completely reverse to this.

Generally, it's easy to determine the voltage sense by measuring the voltage from the ECU when the engine is idling, using a multimeter set to read DC. The meter will show the average voltage of the trigger signal and so a normally low output will give a voltage below 2.5V and a normally high output will give a voltage above 2.5V.

If the measured voltage is less than +2.5V, then the plugs fire on the low-going signal edges (ie, the ECU's output goes to +5V to "charge" the coil). In this case, the EDGE setting in the Ignition Timing Module should be set to LOW.

Conversely, if the voltage is greater than +2.5V, it means that the coil charges when the ECU output goes to 0V and the plugs fire on the high-going signal edges. In this case, the EDGE setting in the Ignition Timing Module should be set to HIGH. In addition, the signal output from the Ignition Timing Module must be inverted (by taking the output from transistor Q4), as shown last month in Fig.14.

set to 2ms if there are problems. This higher debounce period is usually required only for points triggers.

Dwell setting

Now for the dwell setting. First, attach an *external* spark plug to the HT lead from the coil and connect the plug's metal thread to chassis (ground). You can use a heavy-duty lead with alligator clips at either end to make this connection.

Now set the dwell to 0ms and set the internal oscillator in the Ignition Timing Module to on. That done, increase the dwell until the spark plug appears to give its best spark.

Note that the dwell value will not change until the Up switch on the Hand Controller is released, so be sure to release the switch each time you make a change. Stop increasing the dwell when the spark appears to have reached its maximum intensity.

Once you've finished, switch off the ignition and reconnect the HT lead correctly so that the car will run. The internal oscillator will automatically be off when power is re-applied.

MAP sensor & RPM ranges

If you intend using the unit as an interceptor (ie, to modify the timing output from an existing system), then you will need to know both the existing pressure (MAP) sensor and RPM ranges. This means that the Ignition Timing Module should be set up so that it initially makes no changes made to the timing.

The range over which the existing MAP sensor works can be found by monitoring the LOAD value in the DIAG display mode. First, record the maximum load value by checking the LOAD reading with the ignition on but without the engine started. This should be done only for normally aspirated engines when the barometer shows 1013hPa of atmospheric pressure (ie, the standard pressure at sea level).

If you are at a higher altitude, then add another 3% to the reading for every 300m above sea level to compensate for the loss in air pressure. Alternatively, vary the reading by the percentage that your local air pressure differs from 1013hPa. Increase the reading for lower air pressure and decrease it for higher air pressure.

For turbo engines, the maximum reading from the pressure sensor is found at maximum boost.

The minimum load value can be found by driving the car downhill, with the engine being overrun (eg, by shifting to a lower gear than normal). Note, however, that some cars tap the vacuum line for the vacuum measurement before the butterfly valve that's located within the air inlet throat. In this case, vacuum measurement is not available on a fully-closed throttle because the butterfly valve is also closed. What's more, just slightly opening the throttle in this case will cause the vacuum to reappear.

Once you've measured the minimum load value, enter it into the settings as the Minimum LOAD. That done, enter the Maximum LOAD by altering the loads/site value so that it is equal to or a little over the value previously measured.

You now need to set the minimum and maximum RPM values to suit the range of the engine. Just set the Minimum RPM value to the idle speed and the Maximum RPM value to the engine red line.

Note that the idle speed can be measured using the Programmable Ignition System, with the display set to DIAG to show the RPM.

When setting the Maximum RPM, adjust the RPM/SITE value so that the maximum RPM is at or just over the value required. You can also adjust the minimum RPM setting to achieve the best compromise for the adjustment.

Testing

The Programmable Ignition System should now be ready for it first real test. If you are using it as an interceptor, make sure that all the initial timing map values are zero. You can ensure this by pressing the Reset button on the Hand Controller and waiting one second so that RESET is shown on the display. This will clear all the timing values to zero but only for the map selected.

If you want to clear both the alpha and beta maps, then you will need to use switch S1 to select the alternative

Disabling Original Ignition Systems

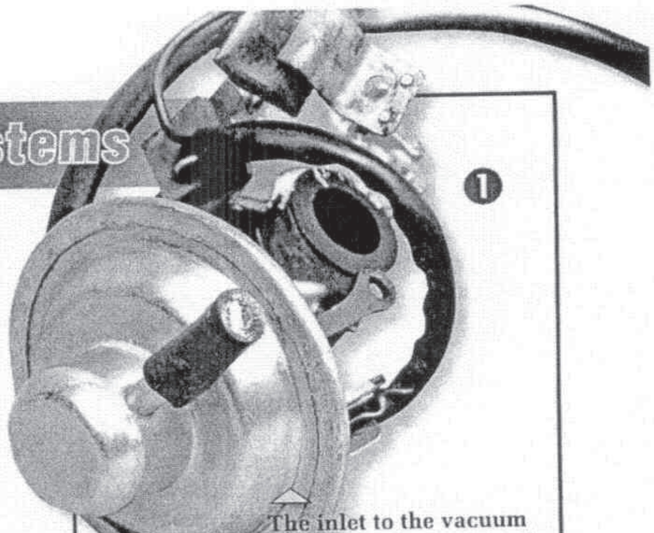
IF YOUR CAR already has a fully electronic ignition, it can be disabled quite easily. Just disconnect the trigger sensor from the existing ignition and connect it to the Ignition Timing Module instead.

Note that with some ignition systems, you will not be able to find a suitable trigger signal that does not also include timing information. In this case, you can only use the Programmable Ignition System as an interceptor.

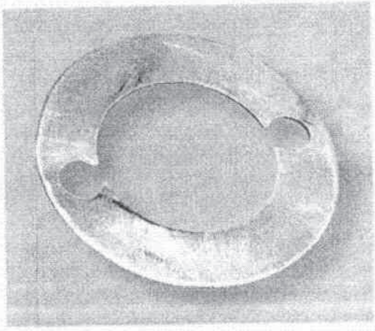
To disable a mechanical advance system, you first need to remove and disassemble part of the distributor. Make sure you turn the engine to TDC for cylinder 1 before removing the distributor.

The distributor must be stripped down to give access to the mechanical weights, so they can be locked in place. We used an aluminium plate to lock the weights to the minimum advance position. The vacuum actuator hose is disconnected (to set the advance to the maximum load setting) and the inlet to the actuator is plugged.

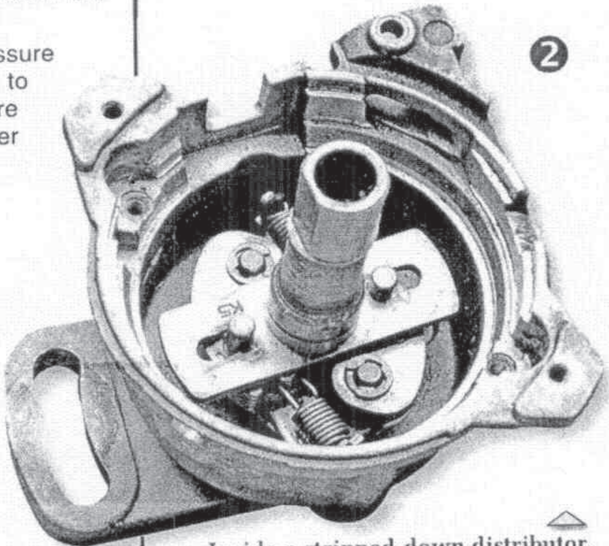
The vacuum hose is then connected to the manifold pressure sensor that's used with the Programmable Ignition System (eg, to an external MAP sensor or the on-board Sensym sensor). Be sure to reinstall the distributor with its rotor pointing towards the cylinder 1 high-tension terminal on the distributor cap.



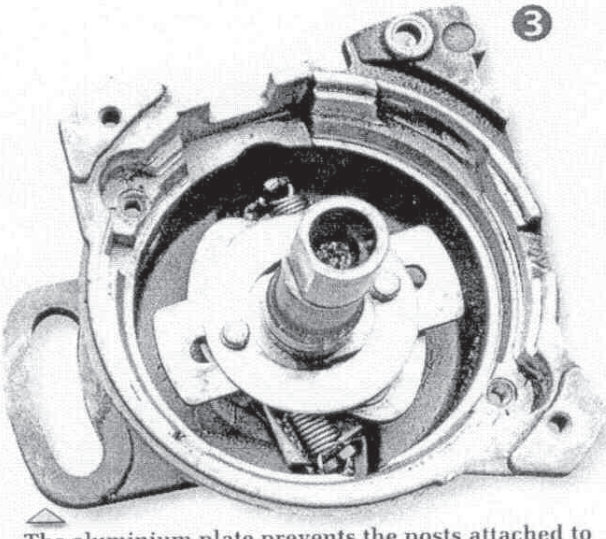
The inlet to the vacuum actuator is disconnected and plugged.



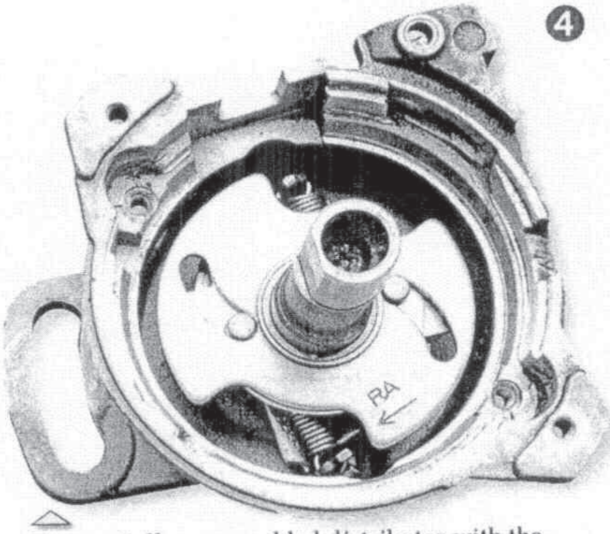
Left: you can use a simple aluminium plate like this to lock the mechanical timing weights inside a distributor. It simply slides over the distributor cam and the timing weight posts, as shown in the photos.



Inside a stripped-down distributor, showing the timing weight posts.



The aluminium plate prevents the posts attached to the weights from sliding in their slots as the RPM increases, thus locking them in position.



The partially reassembled distributor with the advance plate back in position. Because the weights are locked, the advance plate is now also locked.

Programmable Ignition Software: How It Works

THE CIRCUIT DESCRIPTION in Pt.1 details many of the functions of microcontroller IC1 and explains its pin assignments. However, it doesn't explain what goes on inside the microcontroller, so let's take a closer look at this.

As we've already seen, the trigger signal is applied to IC1's RB0 input and the RB3 output subsequently switches off the ignition coil via the driver circuit to fire a spark plug. We'll assume here that a positive signal edge at the RB0 input is the trigger point for turning off the ignition coil.

Alternatively, this could be set for negative edge triggering instead by selecting the EDGE LOW setting via the LCD Hand Controller.

If the Programmable Ignition is set for no advance or retard, the RB3 output will go low and turn off the ignition coil (to fire a plug) at the instant the RB0 input goes high. However, we also need to "charge" the coil so that there is sufficient energy stored in it at the point of "firing" so as to provide a spark. The duration required to fully charge the coil (to provide maximum spark energy) is called the "dwell" period.

In order to provide this dwell period, we need to predict when the coil is going to "fire" the next plug. Based on this prediction, we can then determine when to start "charging" the coil (ie, the start of the dwell period).

Fig.25 shows the waveforms associated with this. The top waveform is the trigger signal applied to RB0 and the positive-going edges are the firing points. The RB3 output on the waveform below this initiates the dwell period before firing occurs at the positive edge of RB0.

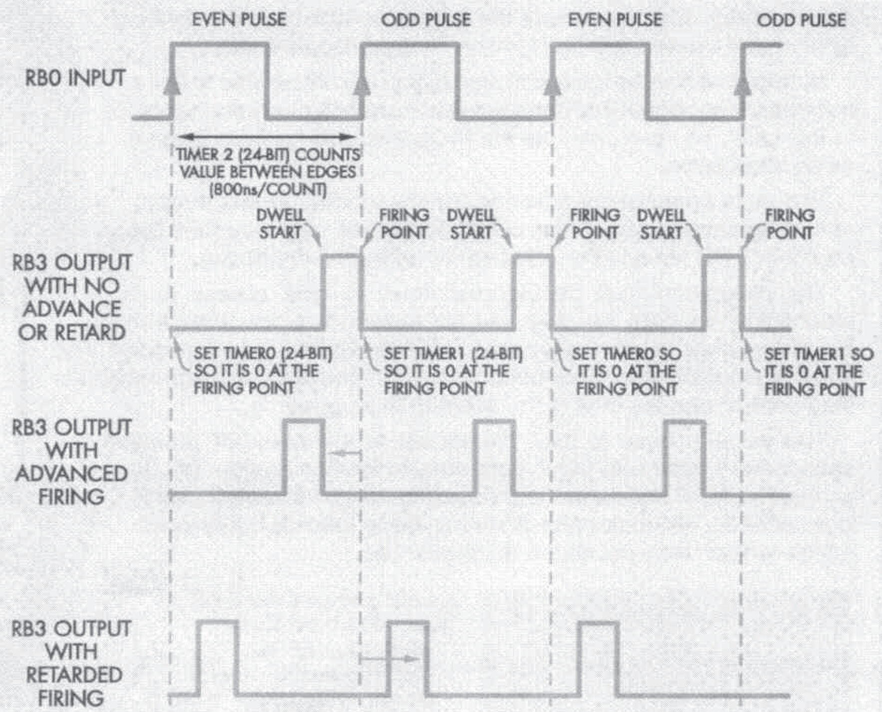


Fig.25: the top waveform in red represents the trigger signal applied to the RB0 input of the microcontroller in the Ignition Timing Module. The green waveforms show the three possible RB3 output signal conditions.

To predict the next firing point, we use a timer (Timer2) that counts up by one for each 800ns between the positive edges of RB0. This count value then becomes the predicted count for Timer2 to indicate when the next firing will occur. This is true when the engine is running at a constant RPM. However, when the engine is increasing in speed, the firing point will occur somewhat earlier than the previous Timer2 count value.

Conversely, the firing point will lag behind the previous Timer2 count value when the engine is slowing down. These changes are not significant since the engine RPM value cannot quickly change

map and press the Reset button again. Of course, this only applies if the two 11x11 maps have been selected. The 15x15 map is fully reset to zero using just the Reset switch, regardless of switch S1's position.

Now try to start the engine. If it refuses to start, then the edge setting (for the input trigger signal) may need to be set to low rather than high.

Assuming that it does start, check that it runs properly when the throttle is quickly pressed to increase the revs. If it falters, then the dwell period may need increasing a little. Additionally, the response to the low-speed RPM setting may need to be increased by a few hundred RPM above the idle speed for best "take-off" acceleration.

Altering the timing a little from its standard setting can sometimes smooth out the idle speed if it tends to be rough. It needs to be tested by both advancing and retarding the existing value to find the optimum setting. This setting becomes the cranking advance as well.

These two settings (for cranking and idle) may not be compatible because the idle advance setting may make the engine hard to start. If necessary, the cranking timing can be made independent of the idle timing by lowering the minimum RPM setting to below idle but above the cranking speed. This will set the RPM1 sites for cranking only. Cranking RPM can be measured on the DIAG display during starting.

Both the off-throttle and cruising settings can generally be advanced further to improve fuel economy. However, too much off-throttle and cruising advance can produce poor engine response if extra throttle is suddenly applied for acceleration.

Any pinging (detonation) problems at high loads can be solved by reducto any extent between successive input trigger signals.

The dwell period can be initiated before the next firing by doing some calculations using the Timer2 count value. If, for example, the required dwell for the coil is 4ms, we can calculate that this period is equal to a count of 5000. This is because 4ms requires counting 5000 of the 800ns count periods. We can then start the dwell at a count of 5000 before the next expected firing point.

Initiating the dwell start and switching off the coil to fire a plug requires another counter. At every positive signal edge on RB0, this second counter (Timer0) is set at a value so that it will reach a count of zero at the next expected firing position. Before it reaches zero, the counter is checked every 204.8μs to see if it has reached the value to start the dwell period. If this value has been reached, RB3 goes high and remains high until the counter reaches zero, at which point RB3 goes low to fire the plug.

In order to advance or retard the firing point, instead of setting Timer0 to fire at the next expected RB0 positive edge we either fire before this for advance or later than this for retard. The dwell is also shifted to start earlier as the timing advances or later as the timing retards.

We need to make some calculations in order to set Timer0 to a value that will give the correct amount of advance or retard in degrees. As we know, the Timer2 value provides us with the count between firing pulses. Firing pulses occur twice per engine revolution for a 4-cylinder 4-stroke engine and three times per engine revolution for a 6-cylinder 4-stroke. So for a 4-cylinder 4-stroke engine, we divide the Timer2 count by 180 because plug firings are 180° apart, with two pulses per 360° engine revolution. This gives us the count per degree.

For the 0.5° resolution setting, we divide by 360 instead of 180 to get the number of counts per 0.5°. Similarly, for a 6-cylinder engine, we divide by 120 for the 1° resolution setting because there are three firing pulses per 360° engine revolution. The number of degrees of advance or retard required is then multiplied by the count per degree value. This is then either added to the Timer2 value to retard the timing or subtracted from the Timer2 value to advance the timing.

Timer0 is then set so that it reaches a count of zero at this altered Timer2 value. In this way, RB3 is controlled by Timer0 to set the dwell and fire a plug (when Timer0 is zero) at the required advance or retard setting.

Well, that's basically how the system works but in practice it's a bit more complicated that that. In reality, there are two timers: Timer0 and Timer1. Timer0 is used to decide when to drive RB3 high (for the dwell) and low (to fire the plug) between each of the even-numbered positive edges from RB0.

By contrast, Timer1 is used to drive RB3 high and low between each of the odd-numbered RB0 positive edges.

The reason we need two timers is because one of them might still be in use, determining when to drive RB3, when the next positive edge from RB0 occurs. If only one timer was used, it could not be made ready for the next firing sequence, as this would affect the current firing position. The only alternative is to use two timers, as described.

Note that the firing point is calculated from the previous RB0 positive edge and may not exactly match the current RB0 edge when there is no advance or retard adjustment. This can happen when the engine revs are changing.

In this case, we fire the coil when the RB0 output goes high. In addition, when the timing is set to retard, the firing point is recalculated when the next RB0 positive edge occurs. If the timing is set to advance, the plug will also be fired at the positive RB0 edge if it has not already fired.

Another calculation made within the microcontroller is for the engine RPM value. This calculation first divides the Timer2 count value by 16 and the result is then divided into 93,750/cylinder for a 4-stroke engine. The result is a value for the number of "100 RPM" increments.

For example, lets assume that Timer2 has a count of 37,500 and we are running a 4-cylinder engine. The 37,500 is then divided by 16 to give a result of 2343. Dividing this value into 93,750/4 gives a value of 10. This is the number of "100 RPM" increments which in this case is equivalent to 1000 RPM.

This calculation is correct because with a Timer2 count of 37,500, the period between pulses is 30ms because each count represents 800ns (800ns x 37,500 = 30ms). A 30ms period is 33.333Hz or 2000 pulses per minute. Since the engine is a 4-cylinder 4-stroke, there are two pulses per revolution and so the engine speed is 1000 RPM.

Calculations are also required to convert the RPM and pressure sensor values to site values. These calculations are based on the size of the map selected (11x11 or 15x15) and the minimum and maximum RPM and load values. Further calculations perform the interpolations for the advance and retard values between both the RPM and load sites.

ing the advance. Note that with the 11x11 map, there are 121 individual adjustments that can be made at the various RPM and engine LOAD sites. You will probably not need to alter too many of these. Just adjust those sites that need to be changed to eliminate pinging (reduce the timing value) or to provide more power under load (increase the timing value).

In practice, the vehicle can be driven with the Hand Controller connected if you wish to fine-tune the adjustments (get someone else to do the driving). However, it's important to note that the Programmable Ignition will work best when the Hand Controller is in the settings mode, as selected using link LK1 on the Ignition Timing Module.

The microcontroller then does not spend time updating the LCD module and this allows its program to be solely devoted to updating the timing. As a result, any responses to manifold pressure changes and RPM changes will not be hampered by display updates.

The Hand Controller can be disconnected when all the settings have been entered. **Note that it should only be connected or disconnected with the power to the Ignition Timing Module switched off.** SC