LED Tachometer With Dual Displays, Pt.1

A responsive and accurate tachometer is essential for motoring enthusiasts. This new unit features a bright 4-digit display plus a 32-LED circular bargraph. The LED bargraph responds rapidly to changes in RPM while the digital display shows accurate RPM readings with a steady throttle.

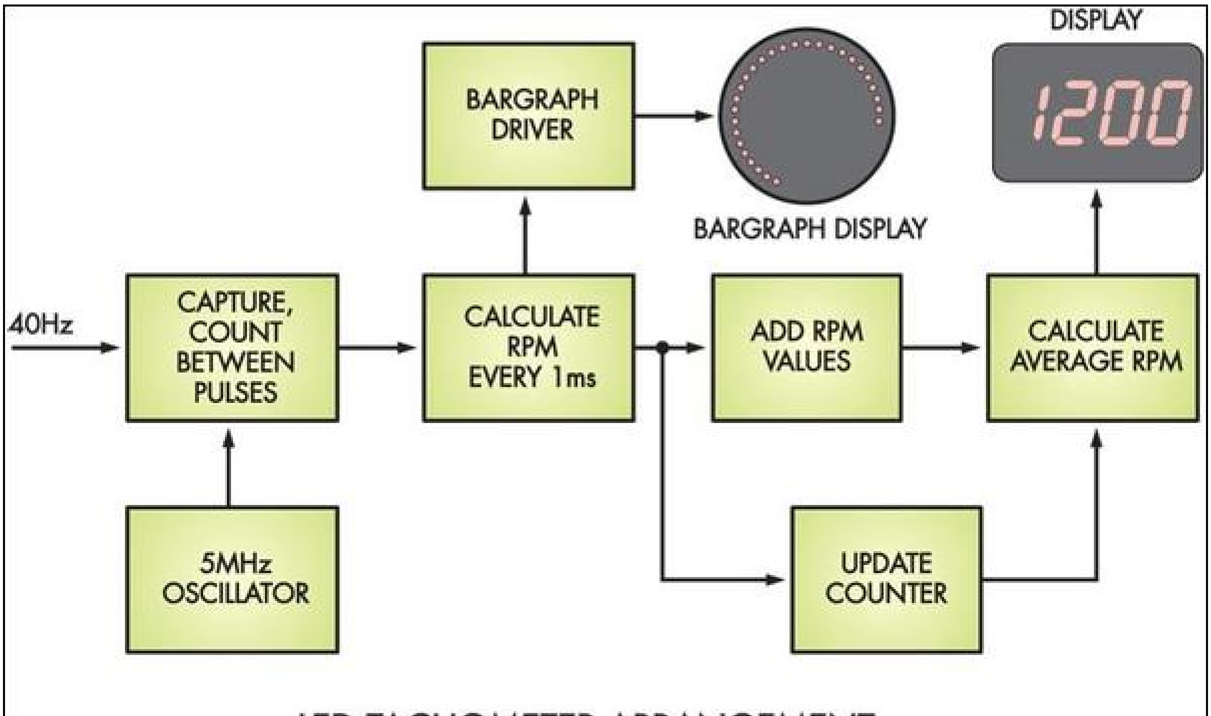
By John Clarke

igital tachometers might be accurate but they don’t respond like an analog instrument. This new SILICON CHIP tachometer combines the best features of analog and digital instruments: blip the throttle and the LED bargraph rapidly responds to the change in engine revs while the true RPM will be shown on the 4-digit display with up to 1 RPM resolution.

A gear shift light and a rev limiter output are standard features and it can operate with virtually any car or motorcycle (except magneto ignition). Its vast array of optional setting adjustments makes this tachometer a truly versatile instrument. For performance cars and motorcycles, this versatility includes the ability to display engine RPM above 10,000 RPM.

The circular display section of the tachometer has been made as small as is practical and it can be installed within the instrument cluster of your car if there is sufficient space available. Alternatively, it can be housed in a cylindrical case and mounted using a suitable holder on the dashboard, windscreen or instrument cluster. The main electronics part of the tach-ometer needs to be mounted under the dashboard (or within a side cover in a motorcycle).

The LED bargraph is arranged in a 76mm diameter circle that covers a 286° span. Most of the 32 LEDs are green except for the extreme clockwise end which uses five red LEDs to indicate the "red line" RPM. You can increase the "red line" indication to as many as 10 LEDs.



LED TACHOMETER ARRANGEMENT

Fig:2: that Silicon Chip LED Tachometer is more complicated than the basic unit and includes both digital and bargraph LED displays.

During calibration, the red line RPM can be selected, as well as the number of red line LEDs. The tachometer then automatically calculates the RPM increments required to light each LED.

The shift light RPM can also be entered into the tachometer during the setting up procedure. If you do not want the shift light LED to operate, you can enter an RPM setting higher than the engine will reach.

The rev limiter output from the tach-ometer can be used to prevent the engine from over-revving if say, you miss a gear. However, the limiter action is very abrupt and is not suitable for normal speed or RPM restriction. The limiter output controls an external cutout circuit that works by "killing" the ignition or interrupting fuel to the injectors. We will discuss these options in Pt.2, next month.

Setting up the tachometer is easy as we use the digital display to show the options and the current settings, while you set the number of cylinders and lots other settings using pushbutton switches.

Basic digital tachometer

Fig.1 shows the basic arrangement for a typical digital tachometer. It comprises a counter, a timer and a digital display. For a 4-cylinder 4-stroke engine, there are two sparks or firing pulses per engine revolution. A 40Hz pulse signal from the engine therefore corresponds to 1200 RPM (40 x 60/2).

If we want the display to show 1200, we can do this in several ways. First, we can wait 30 seconds so that the counter reaches a count of 1200 but this is far too long to be practical.

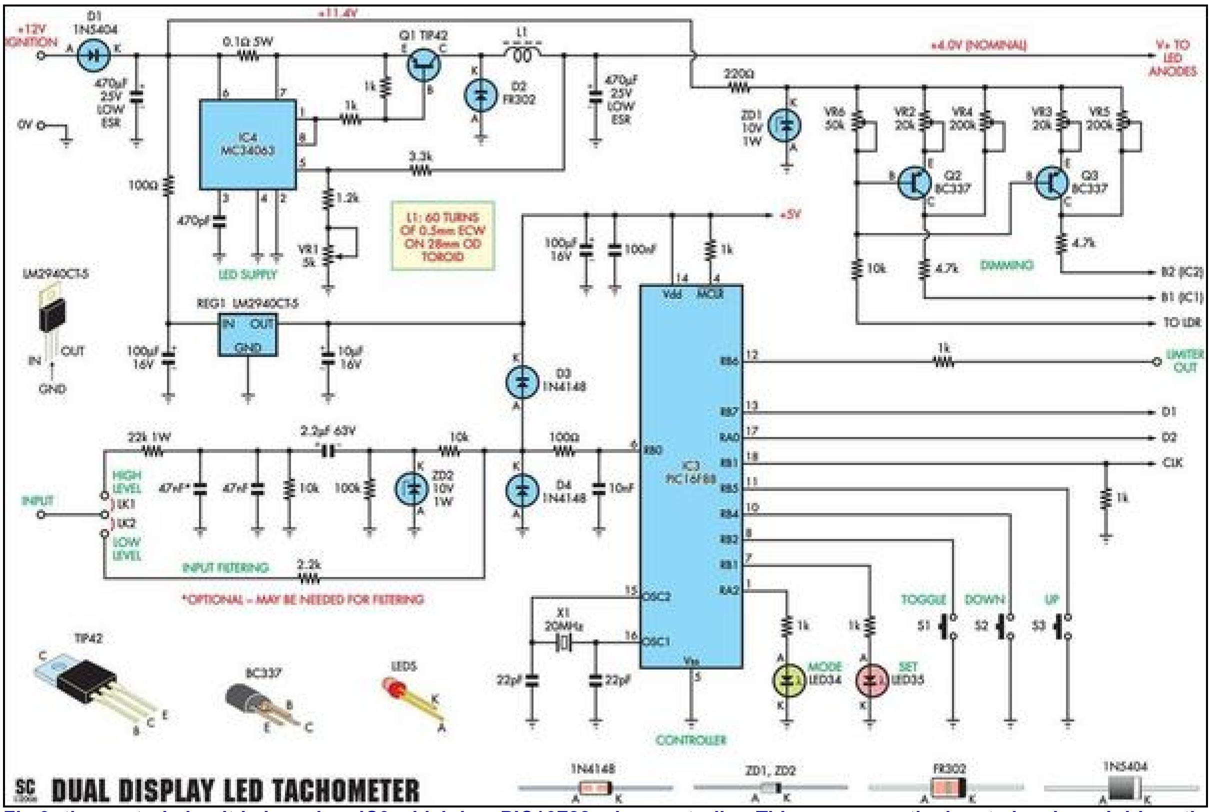


Fig.3: the control circuit is based on iC3 which is a PIC16F88 microcontroller. This processes the input signals and drives the display circuit of Fig.4.

A more practical method is to count the incoming signal over a 300ms period. This would allow the counter to reach 12 after 300ms. The display would then show a 12 and two more zeros could be added after the 12 to make it display 1200. These last two digits will always be set at zero and so the resolution is only 100 RPM. The resulting 300ms update time (ie, three times a second) is probably fine for a digital display because we would not be able to read it if it changed at a much faster rate. (We described a digital tachometer along these lines in the August 1991 issue).

However, if we add a multi-LED bargraph to the tachometer, then the 300ms update period would prevent the bargraph from rapidly responding to changes in engine revs; a quick blip of the throttle would probably not even be registered. The other problem with the 300ms update period is that it only has 100-RPM resolution and so the increments on the circular display would not be very precise.

Main Features

- Fast 32-LED circular bargraph
- Dot or bargraph option
- 4-digit display
- Gear shift indicator LED
- Limiter signal output
- Display from 0-9999 RPM or above 10,000 RPM (optional)
- Two display options for RPM above 9999 RPM
- Options for 1 RPM, 10 RPM or 100 RPM display resolution
- Automatic display dimming in low ambient light
- Set-up for 1, 2, 3, 4, 5, 6, 8, 10 & 12-cylinder 4-stroke engines and 1, 2, 3, 4, 5 & 6-cylinder 2-stroke engines
- Selectable red line RPM
- Selectable shift light RPM
- Selectable limiter RPM
- Selectable number of red line LEDs
- electable display update period
- Selectable RPM hysteresis for LED bargraph
- electable limiter minimum on time

The solution

Clearly, a tachometer with a bargraph that has many steps will need a much faster and more accurate means of measuring RPM. Fig.2 is the solution. Essentially, we have a high-speed oscillator running at 5MHz and this frequency is counted and then captured for the period between firing pulses. For a 40Hz input we would have 40 firing pulses every second and the counter would count up to 125,000 (5,000,000/40) between pulses. The value of 125,000 may not appear to be of much use but if we divide this number into 150 million we get the correct 1200 RPM reading for a 4-cylinder 4-stroke engine. The resolution is 1 RPM.

We can use a different numerator for the division calculation for each type of engine. For example, for a twin cylinder 4-stroke engine we use a value of 300 million for the numerator. In this case, a 40Hz signal would give a reading of 2400 RPM.

The RPM calculations are repeated every 1ms and a new RPM reading will be obtained if the captured count value is different from the previous count. The actual rate at which the RPM is updated is dependent on the time period between the firing pulses. For the 40Hz signal, we have an RPM update 40 times per second or once every 25ms. This is 12-times faster than the RPM measurement described in Fig.1. At higher RPM, the update time is even quicker. With a 100Hz signal (equivalent to 3000 RPM for a 4-cylinder 4-stroke engine), the RPM reading is updated every 10ms or 100 times per second.

Note that because the calculation of RPM is made every 1ms, the new RPM value is available almost as soon as the counter value has been captured. The resulting RPM value is sent to the bargraph driver to display the latest reading.

Twin-cylinder motorbikes

One small problem with this method of RPM measurement is that it does not work with engines that have uneven firing between cylinders. It would measure two different RPM readings because of the uneven spacing between successive firing pulses. This is mainly a concern with twin-cylinder 4-stroke engines with cylinder separations of less than 180°, such as from Harley Davidson, Ducati and Moto Guzzi.

To prevent this reading problem, we have included setting selections for these engines that count between four successive firing pulses. Because the spacing is constant (in engine rotational degrees) between an even number of firings, it prevents erratic RPM measurements.

We also set the tachometer to count between four successive firing pulses for engines with six cylinders and over. This is to provide a sufficient count value, especially at high RPM, to ensure a high-resolution calculation.

For the 4-digit display, the fast updates are not required and so the update is slowed down to a more readable rate as set by the update counter. Between display updates, each RPM calculation is added together and the total is averaged before being displayed. The display update period is one of the tachometer settings that can be adjusted. Typically, a 200ms update (five times a second) is satisfactory, however update times from 0-510ms can be set, in 2ms steps.

Circuit description

The circuit can be divided into two sections which correspond to the control board and the display board. The control section includes microcontroller IC3 and the LED display power supply involving IC4, inductor L1 and transistor Q1. The display section incorporates the 32-LED bargraph, the four 7-segment displays, the shift LED, the LDR and the display drivers (IC1 & IC2).

The control section of the circuit is shown in Fig.3. IC3 is the microcontroller that drives the data and clock lines for the display driver ICs. It also accepts the tachometer signal from the engine and performs the calculations required to display the RPM. Calibration and option settings are set using switches S1-S3, while LED34 and LED35 show the display status. IC3 operates at 20MHz, as set by the crystal X1.

The ignition signal from the engine can be obtained from the car's Engine Control Unit (ECU), from a reluctor, Hall effect trigger or points, or via an ignition coil connection for cars that have a distributor. Two separate inputs are provided, a high level input for connecting to high-voltage signals such as from an ignition coil and reluctor and a low-level input for a low-voltage source such as the ECU.

The high-level signal is fed via an attenuation network consisting of a 22kΩ resistor, two 47nF capacitors and the 10kW resistor to ground. The resulting signal is coupled via a 2.2µF capacitor (to remove any low-frequency or DC voltages that may be present) and limited by 10V zener diode ZD2. The signal is then applied to pin 6 input of IC3 via a 10kW limiting resistor.

By contrast, the low-level input is applied to pin 6 via a 2.2k7Omega; resistor and 100Ω resistor. Diodes D3 and D4 limit the signal swing to between -0.7V and +5.7V. IC3's pin 6 input also incorporates its own protection diodes and these are protected from excessive current by the 100Ω resistor.

Display section

Fig.4, the display section, mainly involves IC1 & IC2 which might just have been designed for our very purpose. Each M5451 IC can drive up to 35 LEDs and a dimming control is included. Serial data is fed in at pin 22 of each IC and the clock is fed into pin 21. The serial data comes from the microcontroller (IC3) on the control board and this selects which LEDs are to be lit and which are not.

IC1 & IC2 are run at 5V (at pins 1 & 20), while the LEDs have their own adjustable high-current supply. Pin 19 (BRC) is the brightness control input and it requires 750mA in order fully drive the LEDs; lower current reduces the LED brightness. A 1nF capacitor at each pin prevents oscillations.

We have provided separate dimming control for each IC so that they can be adjusted to provide the same apparent brightness. The light dependent resistor (LDR1) controls the brightness.

Power

There are two power supply circuits, one to provide 5V for the ICs and the already mentioned LED supply which operates in switchmode to minimise heat dissipation. It comprises IC4, transistor Q1 and inductor L1 – see Fig.3.

IC4 is an MC34063 DC-DC converter which runs at around 40kHz to switch transistor Q1 on and off. Each time Q1 switches on, current builds through L1 until it reaches a peak of about 3A, as detected by the voltage drop across the 0.1Ω resistor between pin 6 & 7. When the current reaches 3A, Q1 switches off and the charge within L1 is allowed to continue to flow via diode D2. The resulting supply is filtered with a 470µF low-ESR capacitor.

Voltage feedback is provided via the 3.3kΩ resistor to pin 5 and the 1kΩ resistor in series with trimpot VR1. The feedback voltage at pin 5 is maintained at 1.25V for regulation of the output. It means that with the addition of the resistive divider, the output voltage can be higher than 1.25V. VR1 allows adjustment of the output from 1.8V up to 4V.

The incoming 12V supply from the car's battery is fed via diode D1 which provides protection again reversed polarity and the supply is filtered with the 470μF capacitor. The cathode side of the diode also supplies the 5V regulator REG1, an LM2940CT-5. This is a low dropout regulator intended for automotive use, with input protection against supply transients. The 100Ω series resistor supplying REG1 limits peak currents into the transient protection circuitry.

Dimming

As mentioned display drivers IC1 and IC2 include dimming inputs. The dimming control circuitry comprises LDR1 and transistors Q2 & Q3, along with the associated trimpots. This circuit is operated from a 10V supply derived from the 220Ω dropping resistor and zener diode ZD1. Q2 and Q3 act as voltage followers where the emitter voltages are 0.7V above the base voltage. The emitter voltages therefore "follow" the voltage across the LDR.

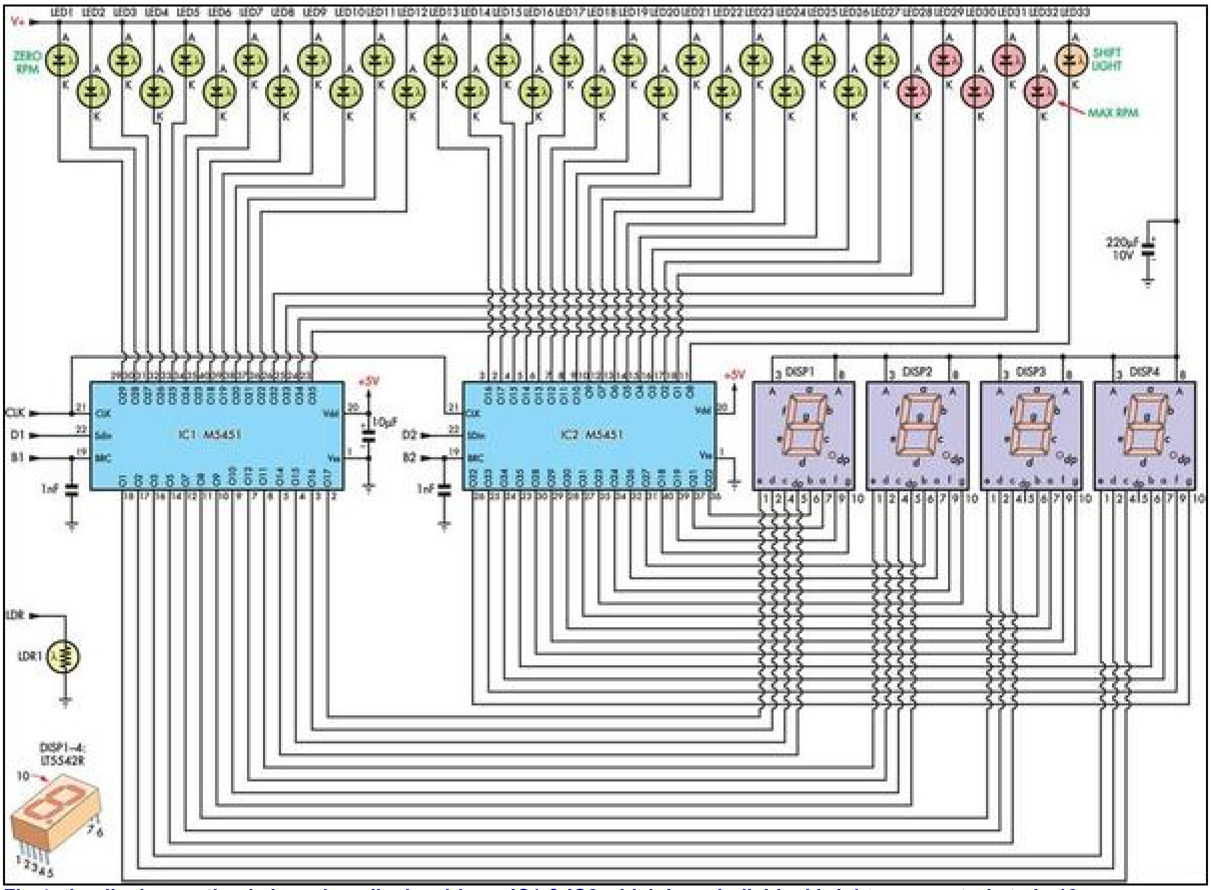


Fig.4: the display section is based on display drivers IC1 & IC2 which have individual brightness control at pin 19.

With high ambient light, the LDR is a low resistance and the voltage across the LDR is about 1V. The emitters of Q2 and Q3 are at 1.7V. This fixes the voltage across trimpots VR2 and VR3 at 10V - 1.7V, or 8.3V. The resistances of VR2 and VR3 therefore set the current through the collectors and emitters of Q2 and Q3. This in turn sets the brightness for display drivers IC1 and IC2 respectively.

In low ambient light, the LDR resistance rises and so the emitter voltage rises. Current sources Q2 & Q3 therefore drop their collector current because there is less voltage across VR2 and VR3 and so the displays dim. Trimpots VR4 and VR5 shunt Q2 and Q3 to set the minimum current flow into IC1 and IC2 when the LDR is in darkness, which results in Q2 and Q3 being fully switched off. Trimpot VR6 is included to adjust the threshold where the LDR starts dimming.

The individual adjustments of dimming current for IC1 and IC2 are included to allow balancing the display brightness for each driver. Balancing is required because there may be variations in the current drive between IC1 and IC2 with dimming current.

Construction

The Digital Tachometer has two PC boards. The control PC board is coded 05111061 and measures 117 x 101mm. It is housed in a small instrument case measuring 140 x 110 x 35mm. The display PC board is coded 05111062 and is 89mm in diameter.

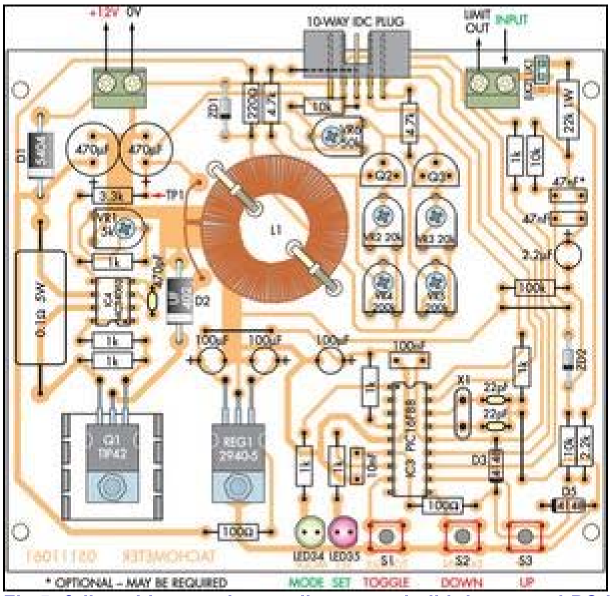


Fig.5: follow this parts layout diagram to build the control PC board. Take care with component orientation and note that IC3 goes in the socket.

Fig.5 shows the component overlay for the control board while Fig.6 shows the components on both sides of the display board. While it is a single-sided board (ie, copper pattern on one side only), it does have components on both sides.

Begin construction by checking the PC boards for any shorts between tracks, for breaks in the tracks and for correct sized holes. Some components such as the screw terminals and the 3A diodes will require hole sizes that are larger than the standard 0.9mm required for most other components. Also, the mounting holes for both PC boards, the REG1 and Q1 mounting holes and the cable tie holes (for securing L1) need to be 3mm in diameter.

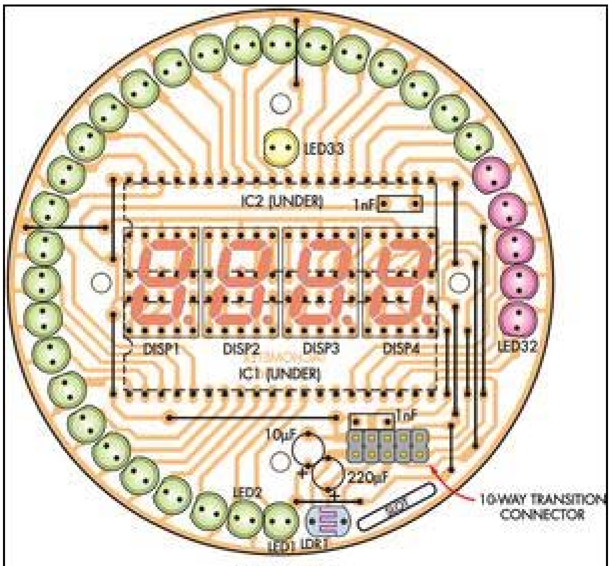
Starting with the control PC board, you can install the low-profile components such as the resistors, links and ICs. Use Table 1 to select the resistors and check each value with a digital multimeter. IC3 is installed in a socket – make sure it goes in with the correct orientation.

The diodes can go in next, making sure that the orientation of each is correct. That done, install transistors Q2 and Q3, the trimpots and the switches. The 10-way IDC plug can then be installed, as well as the two 2-way screw terminal connectors.

Next, install the capacitors but note that the 47nF capacitor marked with the asterisk should be left out of circuit for the moment.

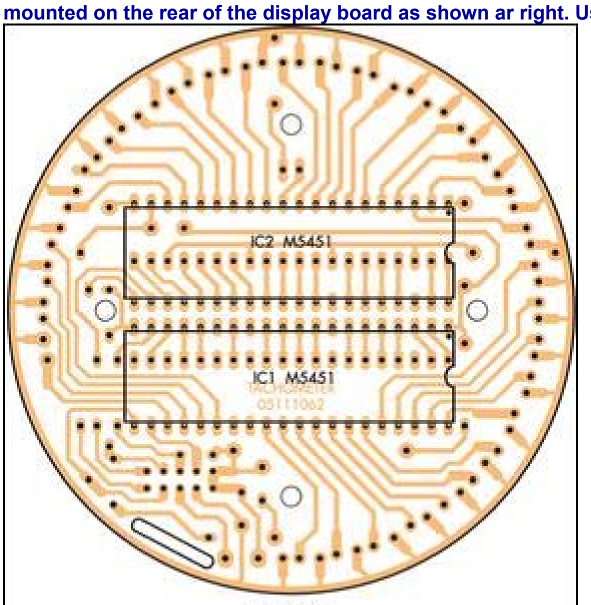
Both transistor Q1 and the regulator REG1 are mounted horizontally and secured with an M3 screw and nut to the PC board. Q1 is also mounted on the small heatsink. The leads can be bent using pliers before each component is inserted into the PC board holes.

Next, install the 3-way pin header, the crystal and the two LEDs (take care to orient these correctly). We used a red LED for LED35 and a green LED for LED34.

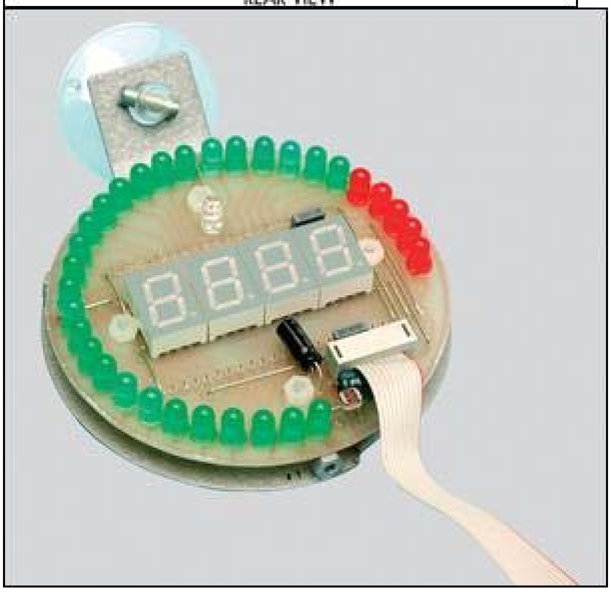


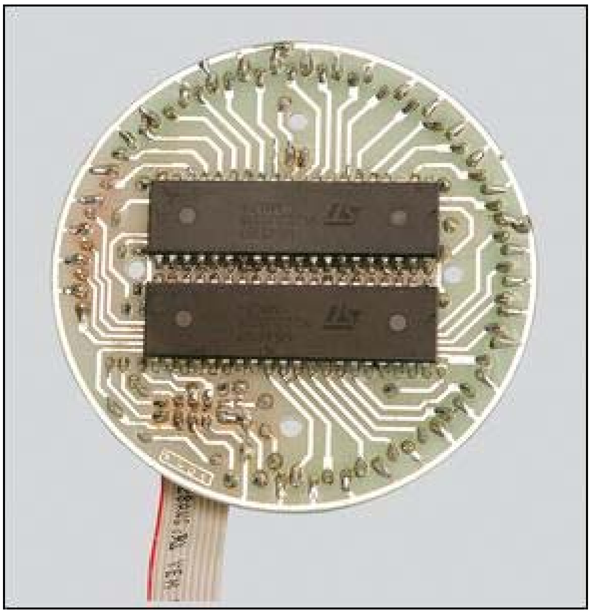
FRONT VIEW

Fig.6: Here's how to assemble the display PC board. The 7-segment displays and the LEDs all sit flush against the board, while the LDR should be mounted so that its face is level with the tops of the LEDs. The two display driver ICs (IC1 & IC2) are mounted on the rear of the display board as shown ar right. Use soldering iron with fine tip to solder their pins to the PC pads.



REAR VIEW



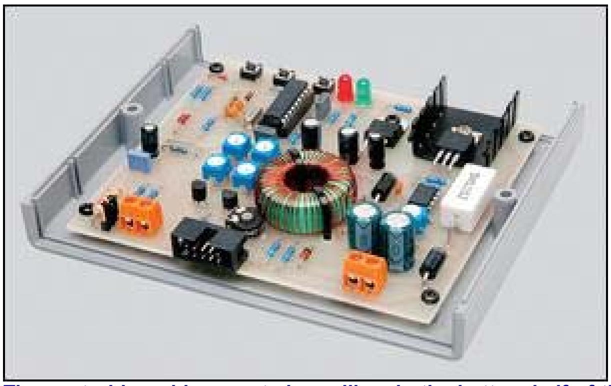


Winding inductor L1

Inductor L1 is wound on a 28mm powdered iron core using 0.5mm en-amelled copper wire. Neatly wind on the 60 turns and twist the wires together to prevent the windings loosen-ing, then secure it in position on the board using two cable ties. That done, strip the insulation from the ends of the wires using a utility knife and solder them to the PC board.

The board can now be mounted in the small instrument case and secured with four M3 x 6mm screws. You will need to cut holes in the rear panel for the IDC socket and for the cable entry for the screw terminal points.

Display PC board



The control board is mounted on pillars in the bottom half of the case and secured using four screws. The mode & set LEDs (towards the rear) are used during the setting up procedure.(details next month)

The commonly-available display LEDs used for the tachometer are suitable for inside a car provided the sun does not shine directly on the display. However, they are not bright enough when operating in direct sunlight. For this you will need sunlight-readable 7-segment displays and high-intensity LEDs. The parts list has the details.

Begin the assembly by installing all the wire links. Keep these straight and tight so that they will not short against each other. That done, install the 7-segment LED displays with the decimal points at the lower righthand side of each display.

Next, install the two 1nF capacitors and the two electrolytic capacitors. The latter both lie on their sides (see photo) and must be oriented as shown (the 220µF capacitor lies adjacent to the 10-way IDC connector).

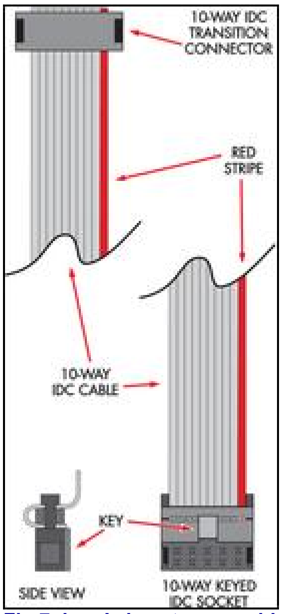


Fig.7: here's how to assemble the IDC lead.

Now install all the LEDs, taking care to orient these correctly. These all sit flush against the PC board. We used green LEDs for all except the red line LEDs and the shift light LED. Note that you can use any number of red LEDs for the red line from 0-10 – it's your choice. The LDR should be installed at the same height as the LEDs.

IC1 and IC2 are installed on the rear of the PC board. Before installing them, make sure that the displays have been soldered in correctly and that there are no shorts between pads. Now place the ICs in position and solder each pin using a fine-tipped soldering iron.

The next job is to make up an IDC lead using a 10-way IDC (insulation displacement connector) and the key-ed IDC socket – see Fig.7. The cable is inserted into the IDC which is then squeezed together using a vice or clamp. Install the transition connector on the display PC board.

That's all for this month. In Pt.2, we'll finish the construction, describe the test and set-up procedures and give some hints on installation.

Parts List

1 PC board, code 05111061, 117 x 101mm

1 PC board, code 05111062, 89mm diameter

1 small instrument case, 140 x 110 x 35mm

1 LDR with 10kΩ light resistance (Jaycar RD3480 or equivalent) (LDR1)

1 20MHz parallel resonant crystal (X1)

1 right-angle 10-pin IDC header

1 10-way IDC line socket

1 10-way IDC PC board transition connector

1 3-way pin header

1 jumper shunt for 3-way header

2 2-way PC board mount screw terminals (5.08mm pin spacing)

1 powdered iron core 28mm OD x 14mm ID x 11mm (Jaycar LO-1244)

1 TO220 heatsink 25 x 29.5 x 12.6mm

3 SPST micro tactile switches vertical mount 0.7mm actuator (S1-S3)

2 50mm cable ties

1 18-pin DIL IC socket

1 500mm length of 0.7mm tinned copper wire

1 1m length of 10-way IDC cable

1 3.5m length of 0.5mm enamelled copper wire

2 M3 x 10mm screws

4 M3 x 6mm screws

2 M3 nuts

2 PC stakes

Extra hardware for Display

3 M3 brass nuts

6 M3 x 12mm Nylon screws

6 M3 Nylon nuts

3 M3 x 12mm countersunk screws

1 90mm female stormwater fitting (90mm ID x 21mm)

1 40mm suction cap (with 5mm diameter x 15mm locking pin)

1 90mm diameter neutral-tint 1.5mm display filter and with display masking (cut for a tight fit inside the 90mm PVC pipe)

1 90mm diameter piece of 0.5mm galvanised steel

1 piece of 25 x 42mm x 1mm aluminium

4 M3 tapped 6mm long Nylon spacers

Semiconductors

2 M5451B7 (PDIP40 package) (IC1,IC2)

1 PIC16F88-I/P microcontroller programmed with ledtacho.hex (IC3)

1 MC34063 DC-DC converter (IC4)

1 LM2940CT-5 low dropout TO-220 3-terminal 5V regulator (REG1)

1 TIP42C PNP transistor (Q1)

2 BC557 PNP transistors
(Q2,Q3)

4 common anode 12.5mm red 7-segment displays (LTS542R or equivalent) (DISP1-DISP4). Note: for sunlight readable displays use the Agilent 16mcd @ 20mA HDSP-H151 from Farnell Cat. 100-3141 or 264-313 (www.farnellinone.com.au).

28 green 5mm LEDs (LED1-LED27, LED34). Note use >400mcd @ 20° angle and @10mA for sunlight readability.

6 red 5mm LEDs (LED28-LED32, LED35). Note use >400mcd @ 20° angle and @10mA for sunlight readability.

1 high intensity 5mm orange LED (LED33)

1 10V 1W zener diode (ZD1)

1 1N5404 diode (D1)

1 FR302 100V 3A fast recovery diode (D2)

2 1N4148 switching diodes (D3,D4)

Capacitors

2 470µF 25V low ESR PC electrolytic

1 220µF 10V PC electrolytic

2 100µF 16V PC electrolytic

2 10µF 16V PC electrolytic

1 2.2µF 63V PC electrolytic

1 100nF MKT polyester

2 47nF MKT polyester

1 10nF MKT polyester

2 1nF MKT polyester

1 470pF ceramic

2 22pF ceramic

Resistors (0.25W 1%)

1 100kΩ 1 1.2kΩ

1 22kΩ 1W 5% 7 1kΩ

3 10kΩ 1 220Ω

2 4.7kΩ 2 100W

1 3.3kΩ 1 0.1Ω 5W

1 2.2kΩ

Trimpots

1 50kΩ horizontal mount trimpot (code 503) (VR1)

2 20kΩ horizontal mount trimpots (code 203) (VR2,VR3)

2 200kΩ horizontal mount trimpots (code 204) (VR4,VR5)

1 5kΩ horizontal mount trimpot (code 502) (VR6)

Table 2: Capacitor Codes

Value	µF Code	EIA Code	IEC Code
100nF	0.1µF	104	100n
47nF	.047µF	473	47n
10nF	.01µF	103	10n
1nF	.001µF	102	1n0
470pF	NA	471	470p
22pF	NA	22	22p