Part 1: By JOHN CLARKE

LED Strobe and Tachometer

This versatile LED Strobe and Tachometer can be used to observe and measure the RPM of rotating machinery. It offers three different measurement methods and the readout is via a 2-line 16-character LCD module.

IT's easy to measure the speed of rotating machinery with this versatile project. It uses three different 'contactless' sensing methods, making it ideal for checking the RPM of objects such as rotating shafts, fans and model aircraft propellers.

In addition, the strobe feature allows rotating machinery to be effectively 'frozen' for close visual inspection. The strobe is based on a high-brightness white LED and can also be used to provide basic stroboscopic speed measurement. Alternatively, speed measurements can be made using either an infrared reflective optical pickup or a slotted disc/photo-interruptor pickup.

Strobing

Many people consider strobes as just a party effect, for use in discos and other venues. A typical disco strobe flashes at about four times a second and the strobing effect makes people appear to move in a jerky manner. That's because, in the dark, you only see each person's position when the

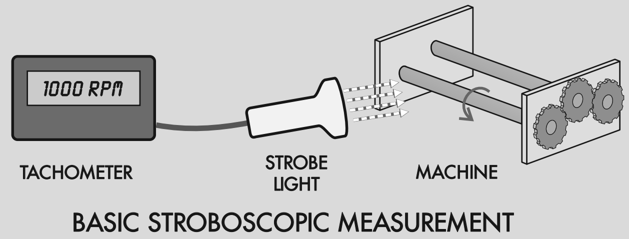


Fig.1: using a strobe light to measure rotational speed. The strobe flash rate is manually adjusted until the machine appears to stop (see text) and the result read from the LCD.

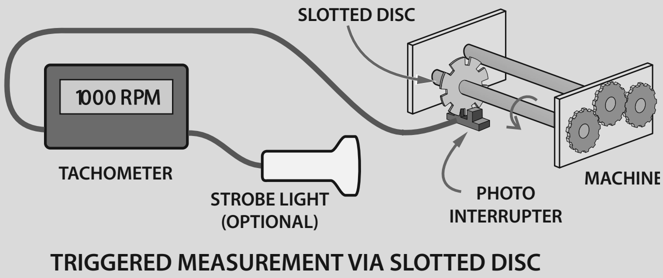


Fig.2. A signal is sent to the 'tacho' from a sensor attached to the machine. The sensor can be an optical or Hall effect trigger that is interrupted by a rotating vane of magnet

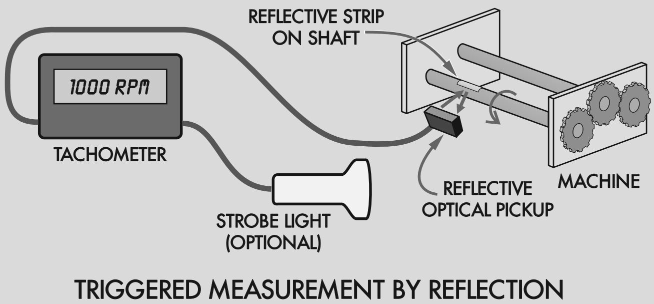


Fig.3: this triggered measurement technique uses the tacho to count the pulses from a reflective optical pickup.

Warning!

Flashing lights, particularly in the lower frequency range from about 5Hz (300 RPM) and upward can induce seizures in people subject to photosensitive epilepsy. Flashing lights can also trigger a migraine attack. It is recommended that people prone to these effects avoid stroboscopic lights.

strobe flashes. The intermediate positions between flashes are not seen.

Strobing rotating machinery gives much the same effect, depending on the strobe frequency and the RPM of the rotating part. If the strobe is set to flash at a rate of once per revolution, then the rotation will appear to stop. The reason for this is simple – the machine will be in the same position each time the strobe flashes.

In fact, the effect is so convincing that it can be dangerous. **You must be alert to the fact that the machine must not be touched, since it is still actually moving and could cause serious injury.**

Other strobe effects also become apparent as the strobe frequency drifts out of step with the rotational frequency. For example, if the strobe flashes slightly faster than the rotational speed of the machine, then the machine will appear to rotate slowly backwards. Conversely, if the strobe flashes at a slightly slower rate than the rotational speed of the machine, the machine will appear to rotate slowly forward.

On a roll

One area where this is often apparent is in western movies, where the wheels of a stage coach initially appear to slowly rotate backwards and then stop while the stage coach is still moving. That happens because movies are shot at a rate of 24 frames/sec and this has the same effect on the wheels spokes as a strobe.

Initially, the wheel spokes are travelling too slowly to keep up with the strobing effect of the frame rate. Then, as the speed increases, the wheels appear to stop, before finally appearing to rotate forwards.

If we know the number of spokes in the wheel, we can even calculate its rotational speed when it appears to be stopped. For example, if the wheel has eight spokes, then its speed is equal to 1440 (the number of film frames per minute) divided by eight, or 180 RPM.

Similarly, the rotational speed of any machine can be measured by setting the strobe rate so that the motion appears to stop. Note, however, that you have to set it to the highest speed at which the machine appears to stop, since the same effect will also occur if strobing takes place at 1/2-speed or 1/3-speed, or 1/4-speed...

You also have to take into consideration the number of blades on a fan or propeller, or the number of marks on a shaft. For example, if there are two blades on a prop, then the prop will also appear to stop if strobed at twice the rotational speed. The solution to this problem is to place a single mark on the shaft or a propellor.

Fig.1 shows how the unit is used with a strobe to measure machine rotation. Note that if the strobe is set at twice the speed of the machine, there will appear to be two reference positions, each 180° apart. However, if the strobe is set at half rotational speed, there will be one reference position, but it will appear dimmer than when the strobe is set at the correct speed.

Photo-interruptor

Fig.2 shows another way to measure rotational speed. In this case, a trigger signal is sent to a tachometer from a sensor attached to the machine. This sensor could be either an optical trigger or Hall effect trigger that is interrupted by a rotating vane or magnet.

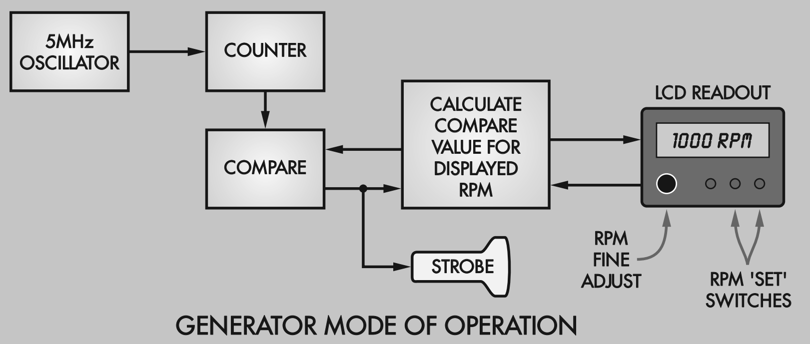


Fig.4(a): this is the block diagram for the generator operating mode. The Up and Down 'RPM Set' switches and a fine adjust pot on the tachometer set the stroboscope's flash rate, while the LCD shows the corresponding reading in RPM,

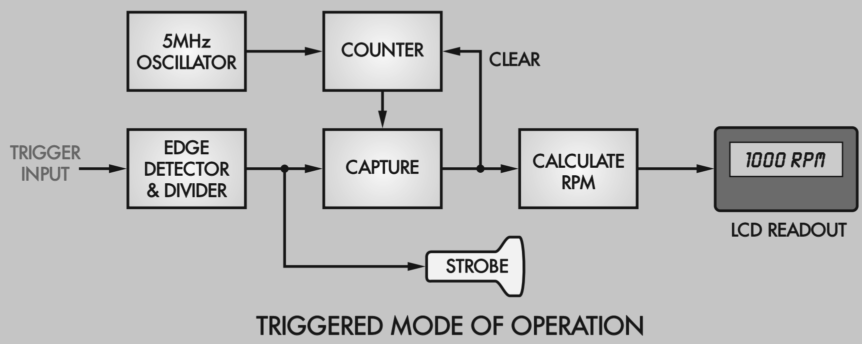


Fig.4(b): the triggered mode of operation. In this mode, the counter counts the number of pulses from a 5MHz oscillator between each successive external trigger signal. This value is used to calculate the RPM, which is then displayed on the LCD.

Main Features

- RPM and frequency readout on LCD panel
- Generator or triggered strobe
- Can be triggered via slotted disc or reflective light
- Adjustable flash period
- Fine frequency adjustment in generator mode
- Wide frequency range
- 1 RPM resolution
- Divider options when triggering
- Triggering indicator
- Readout averaging

As the shaft rotates, it sends a series of pulses to the tachometer. The tachometer measures the frequency of these trigger signals and calculates the RPM for display on the LCD. As an option, the strobe can also be fired in synchronisation with the sensor.

The more rotating vanes used on the trigger, the greater the number of pulses generated for each rotation of the shaft. As a result, the unit can be set to a division ratio from 1 to 8, so that the displayed reading is correct. For example, if there are eight pulses per rotation, the division ratio is set to eight to get the correct reading.

A 0.5 divider has also been included. This can be used if the sensor is being triggered by a shaft that runs at half the speed of the shaft we want to measure.

For divisions from 2 to 8, you also have the option of firing the strobe on any one of the trigger signals. For example, if there are eight pulses per rotation, you can have the strobe fire either on the first pulse, the second pulse, the third pulse or on any other pulse up to the eighth pulse.

In addition, the pulse edge can be selected so that the strobe fires when the pulse signal goes high or when it goes low. Each of these triggering points will provide a different view of the machine – ie, the strobed position of the machine will vary.

Reflected IR

A third method of measuring the RPM of a rotating machine is shown in Fig.3. This is purely a non-contact method and relies on light reflection from the machine.

In some cases, a reflecting strip will have to be attached to the machine in order to get sufficient variation in the light reflection as the machine rotates. However, for rotating parts such as propeller or fan blades, the brightness variation should be sufficient without adding any reflective material.

In this measuring mode, an infrared (IR) light source is shone on to the machine and the resulting reflected light variations detected using an infrared photodiode. Using infrared prevents other light sources such as fluorescent lights from affecting the reading.

Strobe duration

When using a strobe, the duration of the flash determines just how much of the machine's rotation can be seen. Ideally, the flash should be as short as possible to prevent blurring of the strobed image (ie, we don't want the machine to move too much during the flash period).

Traditional strobes use xenon tubes, and these produce short, bright flashes that are ideal for strobing rotating machinery. However, this circuit uses a high-brightness white LED and its output is much lower than that from a xenon tube.

As a result, the flash period needs to be a compromise between brightness and the amount of movement that can be tolerated during the flash. And in case you're wondering, most white LEDs can be driven with very short pulse widths for use in strobe applications. If you are not convinced, read the 'Busting a Myth' panel in Part 2 next month.

For our LED strobe, the flash period can be set anywhere between 32μs and 6.5ms. A longer flash period gives a brighter light, but in practice, the period needs to be set to suit the application. The faster the machine spins, the lower we need to set the flash duration to prevent 'blurring' of the strobed machine.

For example, if the machine is rotating at around 5200 RPM, then we need to set the flash duration to just 32μs to limit the movement during this period to 1°. However, at just 166 RPM, the flash duration can be increased to 1ms for 1° of movement.

As an alternative to a fixed flash period, there is an automatic mode which sets the flash period as a percentage of the measured RPM. This percentage can also be manually adjusted from 1% to 10% in 1% steps.

Note, however, that these percentage settings are not obtainable at very high or very low RPM values, due to the limited flash duration range (32μs to 6.5ms).

Operating modes

In order to carry out the different measurement techniques depicted in Fig.1 to Fig.3, the unit has two different operating modes: (1) generator and (2) triggered. Block diagram Fig.4(a) shows the generator mode of operation, while Fig.4(b) shows the triggered mode.

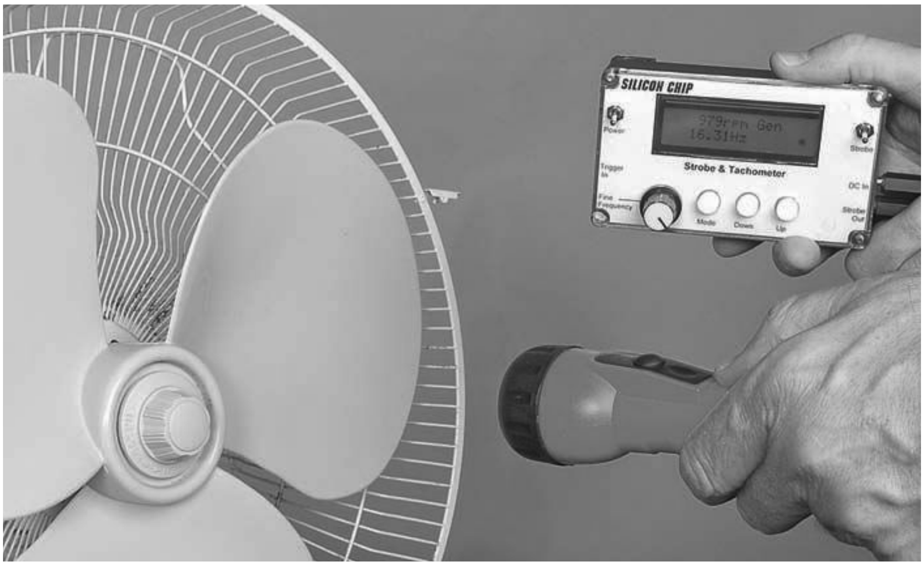
The generator mode is used for basic stroboscopic measurements and when this mode is selected, the unit directly drives the strobe light. In operation, the tachometer is initially adjusted using Up and Down pushbuttons and this sets the strobe rate and adjusts the corresponding RPM reading on the LCD.

Each pushbutton alters the RPM setting in 100 RPM steps, while an adjacent knob provides for fine adjustment to 1 RPM resolution. The resulting LCD readout shows both the RPM (1 RPM resolution) and the frequency in Hz (0.01Hz resolution).

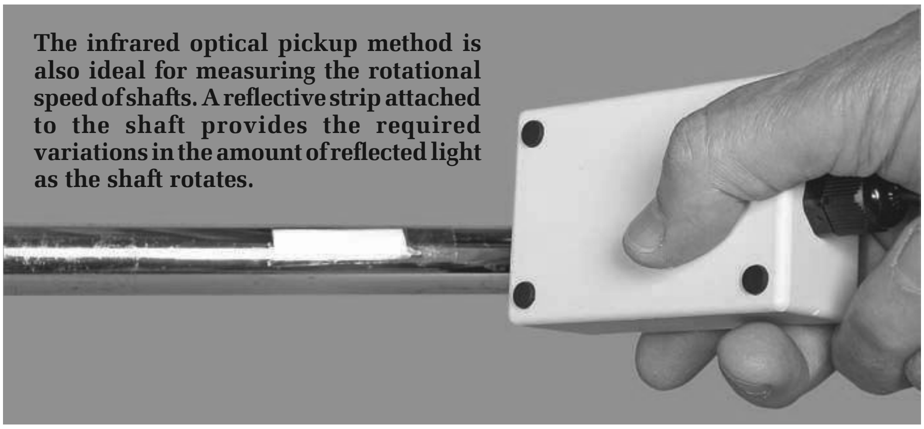
The alternative triggered mode is used to make the measurements depicted in Figs.2 and 3. In this mode, the tachometer is triggered by the pick-up sensor and the LCD shows the RPM and the frequency of the incoming trigger signal. The strobe light is optional and is also triggered by the pick-up sensor.

As discussed earlier, the sensor can be either a slotted disc and photo-interruptor assembly or an optical pick-up relying on reflected IR light. Note that, in this mode, the RPM reading cannot be adjusted manually and the tachometer reads the rotational speed according to the trigger pulses from the sensor.

If there is more than one trigger pulse per revolution, the strobe can be set to fire on any one of these by pressing either the Up or Down switch, to shift to the next trigger edge. In addition, the division ratio must be set to get the correct reading.



The strobe technique is used for measuring the speed of fan blades and for 'freezing' the motion while the machine is running. Alternatively, the infrared optical pickup method can be used for measuring the RPM of fans and model aircraft propellers, since the blades usually give good reflection variations.



The infrared optical pickup method is also ideal for measuring the rotational speed of shafts. A reflective strip attached to the shaft provides the required variations in the amount of reflected light as the shaft rotates.

How the tacho works

The way in which the tachometer works to measure the incoming RPM pulses is rather unconventional.

The traditional method of measuring frequency is to count the number of incoming pulses over a set period, usually one second. This is quite an acceptable method when the frequency is high and a lot of counts are obtained during the 1s period.

However, for RPM readings, the incoming frequency is usually relatively low and in most cases there just aren't enough counts over a 1s period to ensure sufficient accuracy. For example, at 1000 RPM, the incoming frequency would be just 16.66Hz (assuming one pulse per rev) and so we would read either 16Hz or 17Hz on a counter. After multiplying by 60 to convert to RPM, the display would show either 960 RPM or 1020 RPM.

In other words, there would be a 60 RPM uncertainty in the reading.

Of course, we could count the signal over 10s or even 100s to get 6 RPM or 0.6 RPM resolution. However, 10s is a long time to wait for a reading update and a machine can vary its RPM value quite significantly during that time. As for waiting 100s, forget it.

So how do we measure RPM with high resolution and a fast update time? Fig.4 shows how it's done.

For the triggered mode of operation, the tachometer utilises a 5MHz oscillator and a counter. The counter is configured to count the number of pulses from the 5MHz oscillator between each trigger signal.

For example, if the trigger signal has positive going edges that are 60ms apart, the counter will count to 300,000 between each pulse. The value

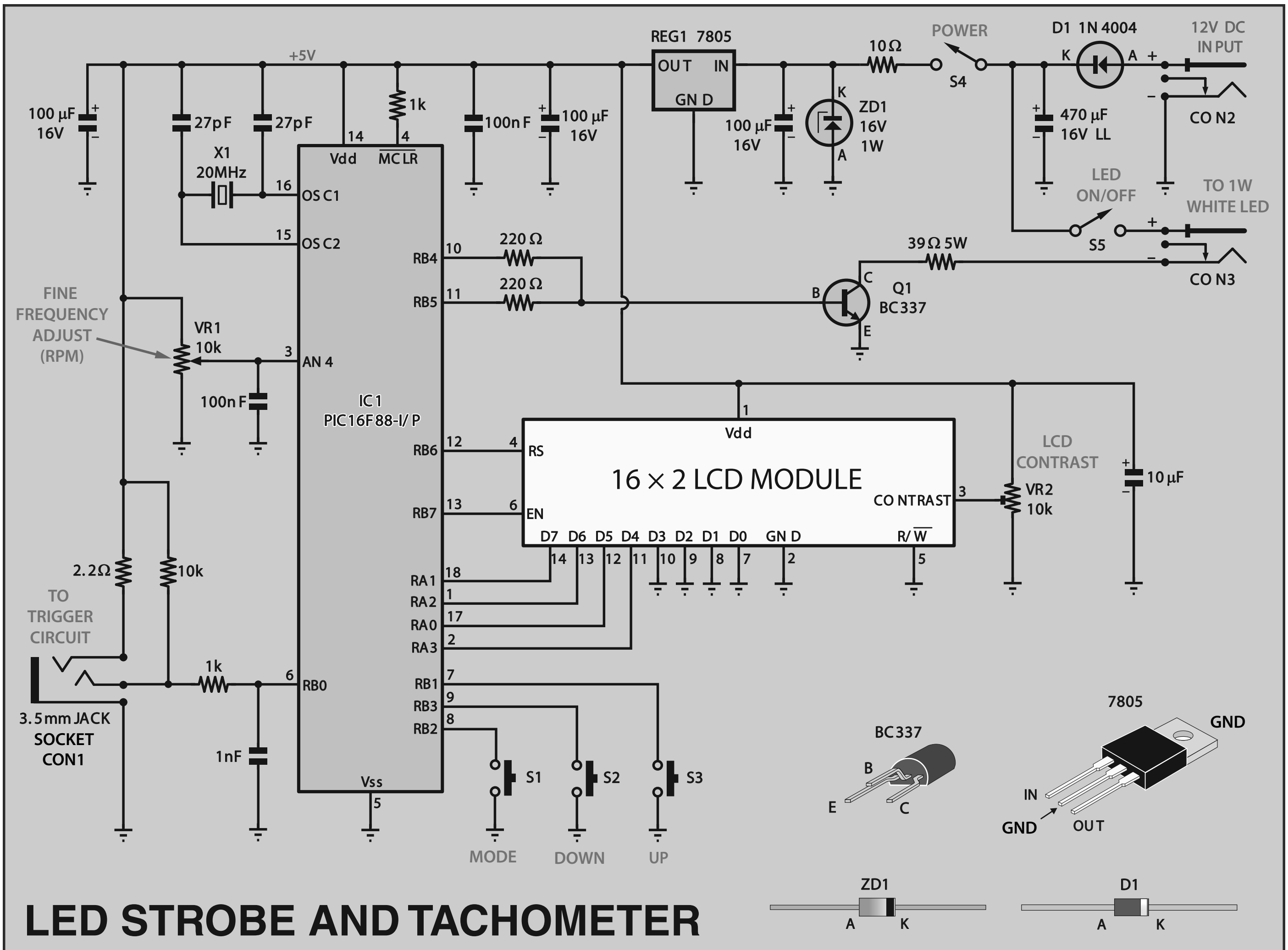


Fig.5: the circuit is based on a PIC16F88-I/P microcontroller (IC1) and a 16 × 2 LCD module. External trigger signals are applied to RB0 of IC1 via CON1, while RB4 and RB5 drive the white-LED strobe via transistor Q1. Power comes from an external 12V DC plugpack, with regulator REG1 providing a +5V supply rail for IC1 and the LCD.

of the count is then stored in a capture register, and the counter cleared so that it is ready for the next count.

A calculation is now made to derive the RPM. This simply involves dividing 300,000,000 (ie, the number of pulses from a 5MHz counter in one minute) by the register value. So, if the register value is 300,000, we get 1000 RPM.

Another calculation is made to derive the trigger frequency (50,000,000 divided by the register value).

This 1000 RPM calculation is made in just 60ms and has a resolution of 1 in 300,000, thus giving a display resolution of 1 RPM. This is significantly better than the method first described, which involved counting the 16.66Hz signal over a 1s period.

For the Generator mode, the operation is slightly different. The counter still counts the 5MHz signal, but in this case, a calculation is made to determine the value that the counter must reach to provide the required RPM value and strobe flash rate.

In this case, the calculation is 300,000,000 divided by the RPM setting. The calculated value is placed in the compare register and when the counter reaches this value, the strobe is fired. The counter is then reset and counts again to fire the strobe at the set RPM rate.

Circuit details

The full circuit details for the LED Strobe and Tachometer is shown in Fig.5. It consists of a PIC16F88-I/P microcontroller (IC1), a 16×2 LCD module and not much else.

So, in spite of the seemingly complex operation, the circuit itself is really very simple.

Most of the 'smarts' are hidden inside the micro, which is really the heart of the circuit. It runs at 20MHz using crystal X1 as its timebase, and this signal is also divided by four to derive the 5MHz oscillator that's used for the RPM calculations.

In operation, IC1 monitors the external trigger signal (if one is present) at its RB0 input (pin 6), while RB1, RB3 and RB2 monitor the Up, Down and Mode switches respectively. In addition, IC1's AN4 analogue port monitors the position of potentiometer VR1, which is used for fine RPM adjustments.

Note that RB1 to RB3 have internal pull-up resistors, so these inputs are normally pulled high to +5V. When a switch is closed, the associated input is pulled to 0V and so IC1 can detect this button press.

IC1 also directly drives the LCD module. RA0 to RA3 are the data outputs, while RB6 and RB7 drive the register select and enable lines respectively. Trimpot VR2 sets the display contrast voltage.

When IC1 is operating in trigger mode, the signal applied to the RB0 input (pin 6) is used as the trigger for RPM measurements. This input is protected from excessive current using a 1kΩ series resistor, while a 1nF capacitor filters out any transient voltages to prevent false counts.

The external trigger circuit is connected via a 3.5mm jack socket and is fed with a +5V rail via the socket's ring terminal and a 2.2Ω resistor. The tip carries the external trigger signal and in the absence of signal, is pulled high via a 10kΩ pull-up resistor to the +5V rail.

Potentiometer VR1 is connected across the 5V supply and the wiper (moving contact) can deliver any voltage from 0V to 5V to the AN4 analogue input of IC1. IC1 converts this input voltage to a digital value to set the fine frequency adjustment over a 100 RPM range (but only when IC1 is operating in the generator mode).

Note that the operational range of VR1 has been deliberately restricted to 0.54V to 4.46V. This has been done because potentiometers often have abrupt resistance changes towards the ends of their travel. Using a 0.54V to 4.46V range ensures that the more linear section of the potentiometer is used.

Driving the strobe

IC1's RB4 and RB5 outputs provide the strobe (white LED) drive. Each output can source about 20mA into the base (B) of transistor Q1, which turns fully on each time a positive going pulse is applied.

Each time Q1 turns on, it also turns on a 1W high-brightness white LED, which is connected via CON3 (provided S5 is closed). Power for this LED is derived from the +12V supply rail, via reverse polarity protection diode D1. A 39Ω 5W series resistor limits the peak LED current to about 220mA. This resistor value was chosen so that even if the supply is 15V, the current will still be below the 350mA maximum for a 1W Luxeon LED.

Switch S5 allows the strobe LED to be manually switched on or off.

Power supply

Power for the circuit is derived from an external 12V DC plugpack and this is fed in via DC input socket CON2 and power switch S4. A 470μF 16V capacitor decouples the +12V supply, which is then fed to regulator REG1 and the strobe, while a 10Ω resistor and a 100μF capacitor provide additional decoupling for the supply to REG1. Zener diode ZD1 clamps the input to REG1 to 16V.

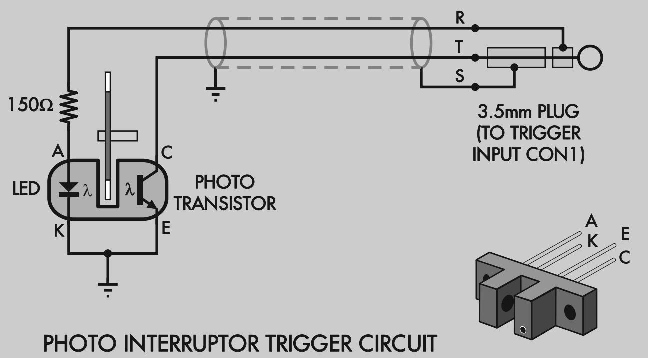
REG1's +5V output is used to supply both IC1 and the LCD. This rail is decoupled using a 100μF capacitor directly at the regulator's output, while an additional 100μF capacitor and a 100nF capacitor bypass the supply close to pin 14 of IC1. A 10μF capacitor provides additional bypassing for the supply at the LCD module.

Photo-interruptor circuit

Fig.6 shows the circuit for the photo-interruptor. It's very simple and is based on a slotted LED and phototransistor package, plus a vane assembly that rotates in the slot.

Power for the circuit comes from the +5V rail of the main circuit and is applied via the ring (R) terminal of a 3.5mm jack. A 150Ω resistor limits the LED current to around 20mA.

Fig.6: the photo-interruptor trigger circuit uses a slotted LED and phototransistor package, plus a rotating vane assembly attached to the machine.



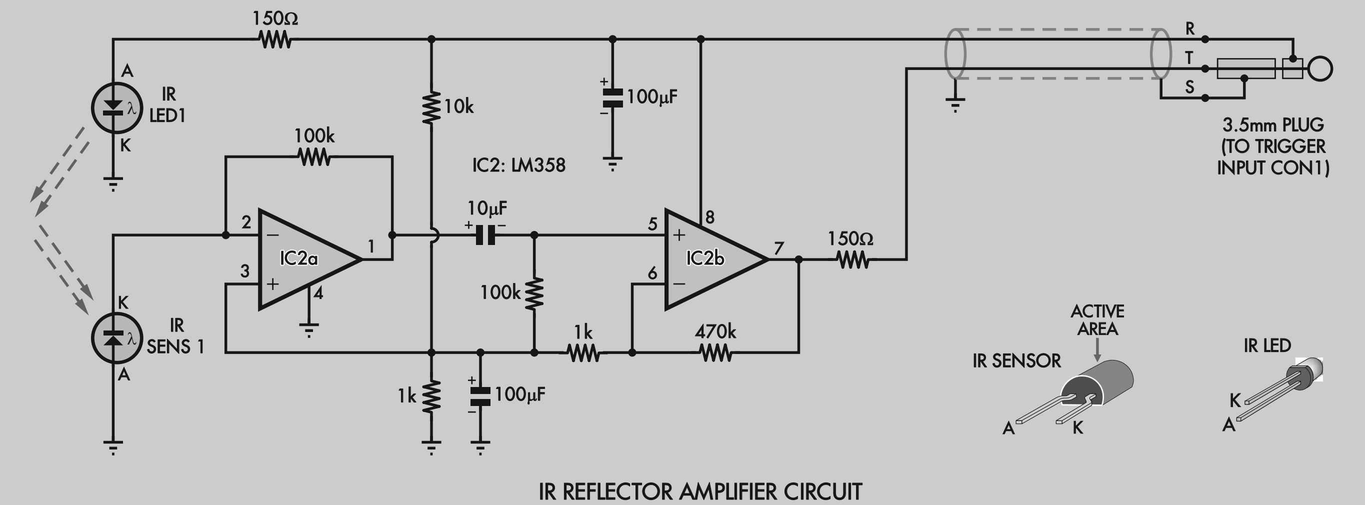


Fig.7: the IR reflector amplifier uses an IR LED and an infrared photodiode (IR SENS1) to pick up the reflected light pulses. The resulting current variations through IR SENS1 are then fed to current-to-voltage converter stage IC2a, which in turn drives amplifier stage IC2b. IC2b's output then drives the trigger input of the main tachometer unit.

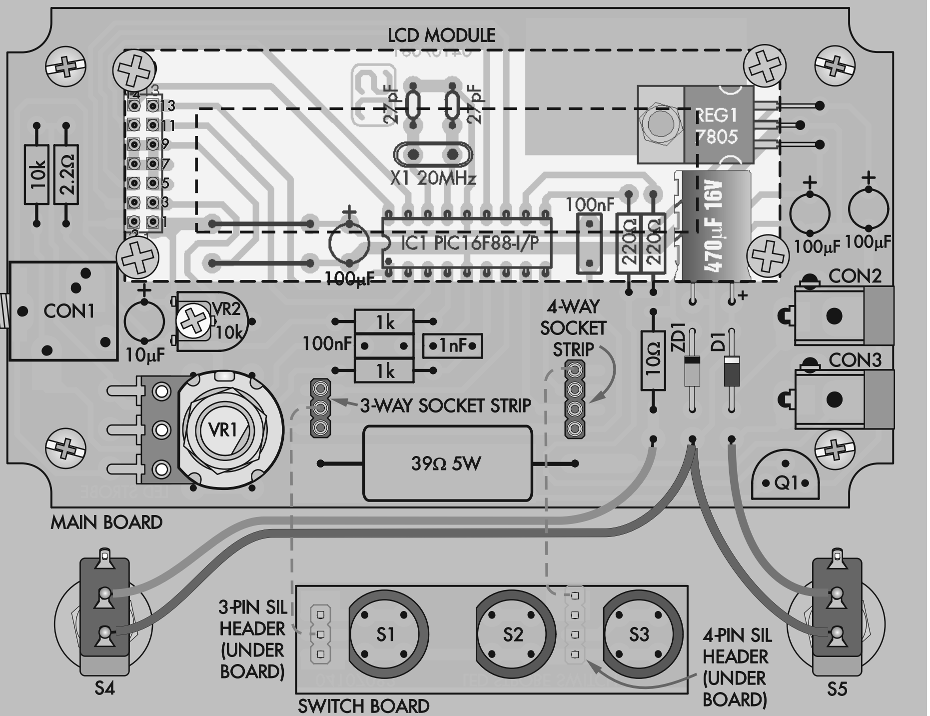
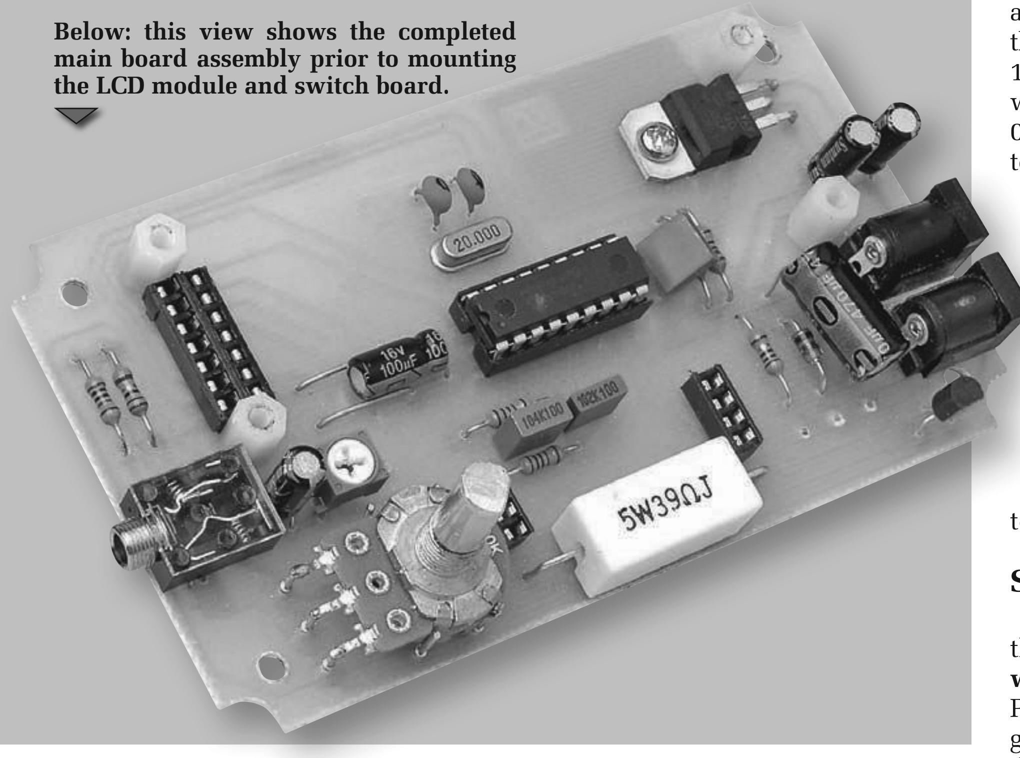


Fig.8: follow this layout diagram to install the parts on the main board and to assemble the small switch board. Take care with the orientation of the switches – they must all be installed with their flat sides to the left (see above).

Below: this view shows the completed main board assembly prior to mounting the LCD module and switch board.



With no vane in the slot, the phototransistor is illuminated by the LED. As a result, the phototransistor turns on and its collector (C) pulls pin 6 of microcontroller IC1 low via the tip connection of the jack socket. Conversely, when a vane passes through the slot, the phototransistor turns off and its collector is pulled to +5V via the 10kΩ pull-up resistor on the main circuit

IR reflector amplifier

The optical pick-up circuit is a bit more complicated – see Fig.7. It's based on an infrared LED (IRLED1), an infrared photodiode (IR SENS1) and an LM358 dual op amp (IC2). The infrared LED is powered via a 150Ω resistor from the +5V 3.5mm jack connector ring terminal and operates continuously whenever power is applied.

As mentioned previously, the photodiode is aimed at the rotating machine and the light is reflected back to the photodiode via a blade or a reflective strip attached to a shaft.

The infrared photodiode is connected to pin 2 of IC2a. This op amp is wired as an inverting amplifier and operates as a current-to-voltage converter. As shown, its non-inverting input (pin 3) is biased to about 0.5V by a voltage divider consisting of series 10kΩ and 1kΩ resistors connected across the 5V supply.

In operation, the current through the photodiode varies with the reflected light, and these current variations are converted to voltage variations at IC2a's pin 1 output. This signal is then AC-coupled to pin 5 of IC2b via a 10μF capacitor.

IC2b is connected as a non-inverting amplifier with a gain of 471, as set by the 470kΩ feedback resistor and the 1kΩ resistor at the inverting input. As with IC2a, IC2b is also biased to about 0.5V by the series 10kΩ and 1kΩ resistors across the 5V supply. The 100kΩ resistor between pin 5 and this 0.5V supply ensures that, in the absence of a signal from IC2a, IC2b's output normally sits at 0.5V.

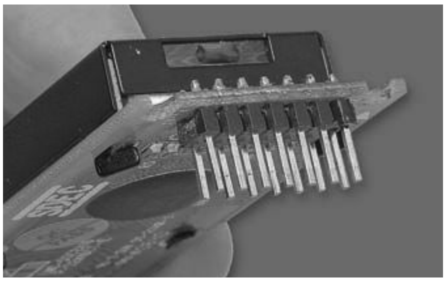
Each time sufficient light is reflected onto the infrared photodiode, IC2b amplifies the signal from IC2a and its output swings to about 4.5V. This signal is then fed to the tip of a 3.5mm jack plug via a 150Ω isolating resistor and applied to pin 6 (RB0) of IC1.

Software

The software files are available via the *EPE* Library site, accessed via **www.epemag.com**. Pre-programmed PICs will also be available from Magenta Electronics – see their advert in this issue for contact details.

Construction

The main LED Strobe and Tachometer circuit is built on two PC boards: a main PC board coded 775 (size, 115mm × 65mm) and a switch PC board coded 776 (size, 52mm × 15mm).



The 14-way DIL header is installed from the underside of the LCD module and soldered to the pads on the top of the module's PC board.

This switch board plugs into the main board and the assembly is housed in a bulkhead style case with a clear lid.

Another two boards are used for the photo-interrupter and IR reflector amplifier circuits. The photo-interrupter board is coded 777 and measures 50mm × 25mm, while the IR reflector amplifier board is coded 778 and measures 53mm × 32mm.

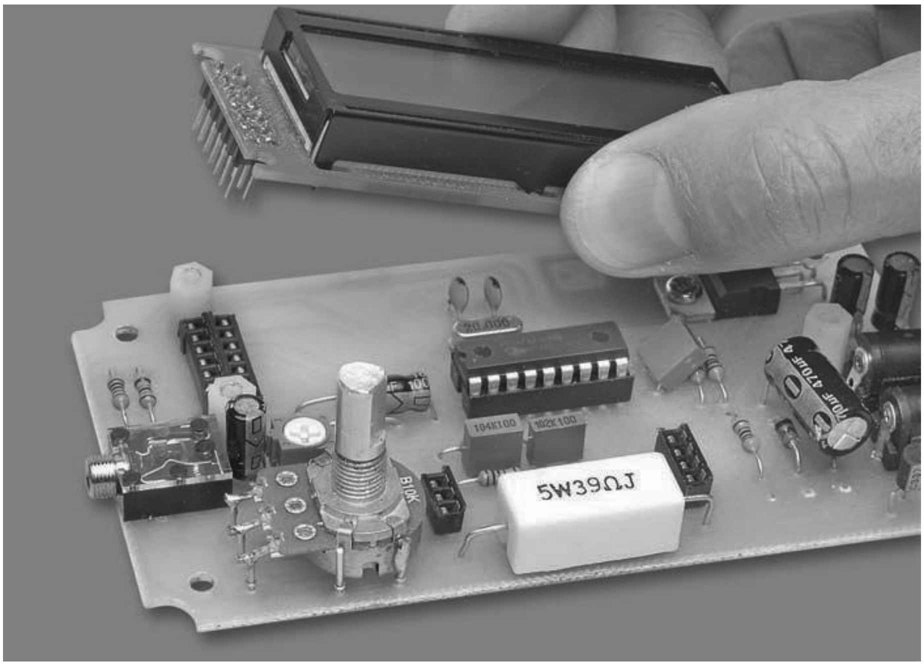
All these printed circuit boards will be available from the *EPE PCB Service*.

Main board assembly

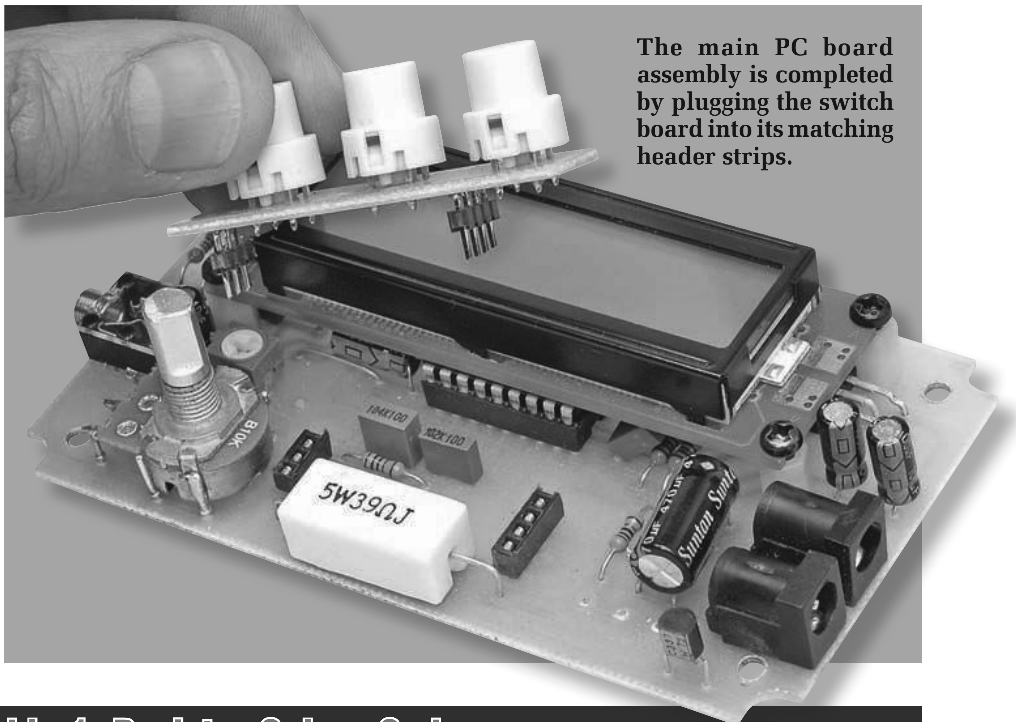
Fig.8 shows the main board assembly details. Begin construction by checking the board for any defects. Check also that the hole sizes for the connectors and potentiometer VR2 are correct by test fitting these parts. Enlarge these holes so that the parts do fit, if necessary.

In addition, the holes for the four corner mounting screws, the LCD mounts and for REG1 must be 3mm in diameter. Check also that the PC board is cut and shaped (note the corner cutouts) so that it fits into the box.

Once these checks have been completed, install the two wire links then solder the resistors in position. Table 1 shows the resistor colour codes, but you should also check each value



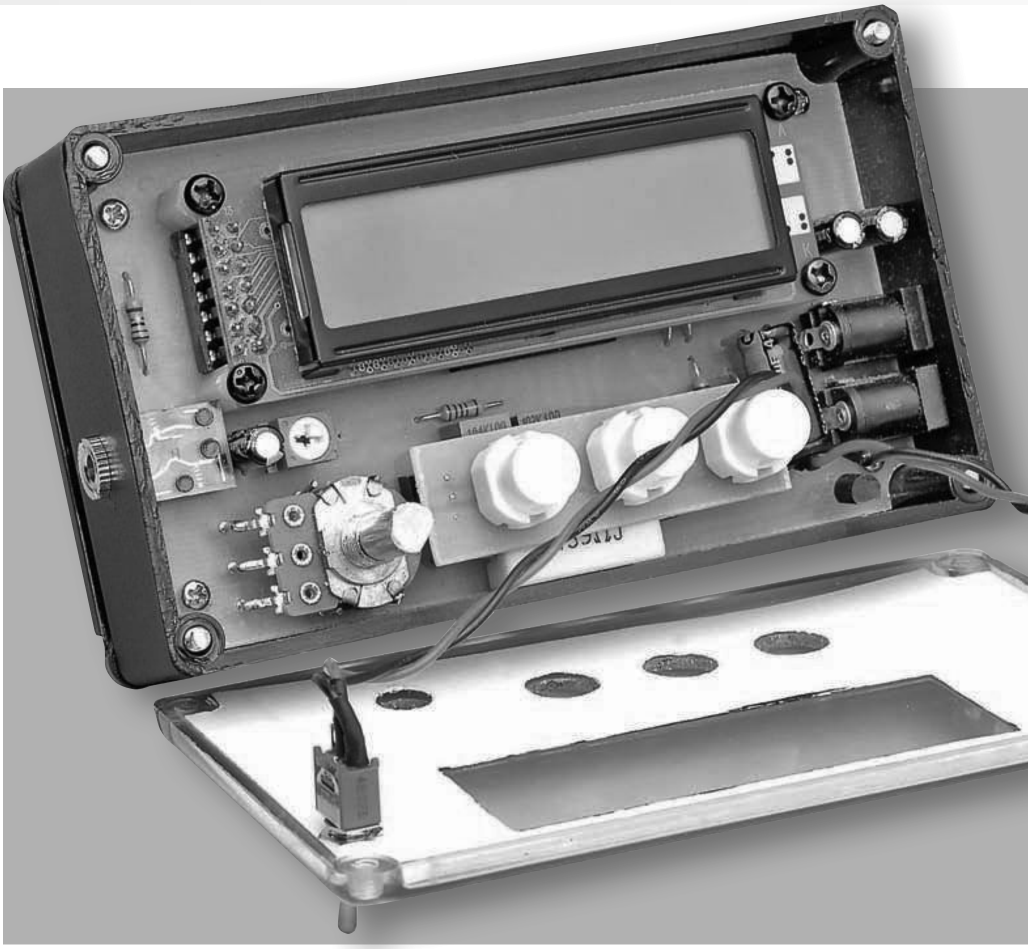
Once the header has been attached, the LCD module is plugged into matching socket strips on the main board and secured to four M3 × 9mm nylon spacers.



The main PC board assembly is completed by plugging the switch board into its matching header strips.

Table 1: Resistor Colour Codes

❏	No.	Value	4-Band Code (1%)	5-Band Code (1%)
❏	1	470kΩ	yellow violet yellow brown	yellow violet black orange brown
❏	2	100kΩ	brown black yellow brown	brown black black orange brown
❏	2	10kΩ	brown black orange brown	brown black black red brown
❏	4	1kΩ	brown black red brown	brown black black brown brown
❏	2	220Ω	red red brown brown	red red black black brown
❏	2	150Ω	brown green brown brown	brown green black black brown
❏	1	10Ω	brown black black brown	brown black black gold brown
❏	1	2.2Ω	red red gold brown	red red black silver brown



The main PC board assembly is secured to integral pillars inside the case using four self-tapping screws. Be sure to fit heatshrink tubing over the lead connections to the switches and the PC stakes, to prevent the leads from breaking after they have been soldered.

using a digital multimeter (DMM) before soldering it to the board.

Follow these parts with the 10 PC stakes. Seven PC stakes are used for potentiometer VR1, three for its terminals and four more to support its body. The remaining three PC stakes are used to terminate the wiring from switches S4 and S5.

Next, install diode D1, Zener diode ZD1 and a socket for IC1, taking care with their orientation. (Do not install IC1 in its socket at this stage). That done, install the 3-way and 4-way single in-line (SIL) socket strips that are used to mount the switch board. These socket strips are made by cutting down an 8-pin IC socket using a hobby knife. Clean up the edges of these socket strips with a small file before soldering them in position.

Similarly, the LCD module is connected via a 14-pin DIL socket strip. This is made by cutting a 14-pin IC socket to produce two 7-way strips, which can then be installed adjacent to each other on the board.

The capacitors can go in next. Note that the electrolytic types are polarised and must be oriented as shown. Note also that the 470μF capacitor goes under the LCD module and must be mounted horizontally (ie, with its body flat against the PC board). The 100μF capacitor to the left of IC1 must also lie horizontally – see photos.

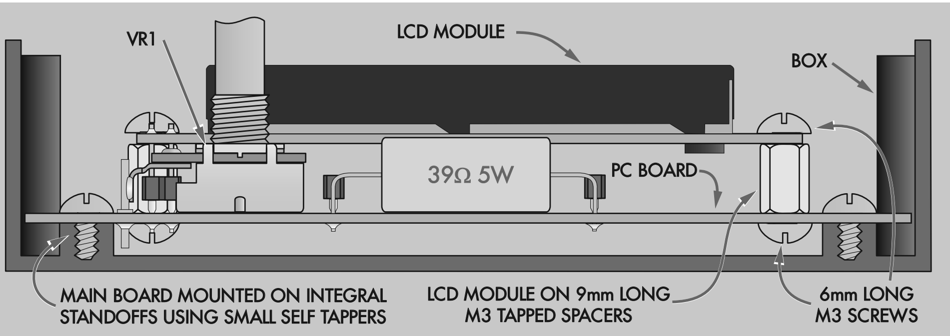


Fig.9: this diagram shows how the main board assembly is secured to the case pillars and how the LCD module is secured to the M3 × 9mm nylon spacers.

Next on the list is regulator REG1. As shown, this device also mounts horizontally on the PC board, with its leads bent down by 90° to go through the relevant holes.

To do this, first bend the two outer leads down about 9mm away from its body and the middle lead down about 6mm away. The device is then fastened into position using an M3 × 6mm screw, nut and washer, and its leads soldered.

Do not solder REG1's leads before bolting its tab down; you could crack the PC tracks or lift the solder pads as the nut is tightened down if you do.

The DC sockets, the 3.5mm PC-mount jack socket and trimpot VR2 can now be installed, followed by potentiometer VR1. Before mounting VR1 though, it will be necessary to cut its shaft to a length of about 14mm (from the end of its threaded boss), to suit the knob used.

As shown in the photos, the pot is mounted upright on the PC board, with its body soldered to four PC stakes. Note that you will have to scrape away some of the coating on the pot body at each solder point, in order to get the solder to 'take'. Once it's in position, solder its three terminals to their adjacent PC stakes.

Parts List – LED Strobe and Tachometer

Main Unit
1 PC board, code 775 (Main), size 115mm × 65mm
1 PC board, code 776 (Switch), size 52mm × 15mm
1 bulkhead case with clear front, 120mm × 70mm × 30mm (Jaycar HB-6082 or equivalent)
1 12V DC 350mA plugpack
1 1W Luxeon white LED or Cree XR-C white LED with collimator lens
1 small torch to house LED and optics
1 2.5mm DC line plug
1 2-line 16-character LCD module, with backlight (Jaycar QP-5516 or equivalent)
1 16mm 10kΩ linear potentiometer (VR1)
1 10kΩ horizontal trimpot (VR2)
1 knob to suit potentiometer
1 20MHz parallel resonant crystal (X1)
2 PC-mount 2.5mm DC sockets
1 PC-mount stereo 3.5mm jack socket
3 click-action PC-mount switches (S1 to S3)
2 sub-miniature SPDT toggle switches (S4,S5)
1 14-pin DIL header (2.54mm pin spacing)
1 4-way SIL header (2.54mm pin spacing)
1 3-way SIL header (2.54mm pin spacing)
1 14-pin DIL IC socket (cut to suit the 14-pin DIL header)
1 8-pin DIL IC socket (cut to make a 4-way SIL socket and a 3-way SIL socket)
1 18-pin DIL IC socket
4 9mm M3 tapped nylon spacers
8 M3 × 6mm screws
1 M3 × 10mm screw
1 M3 nut
4 No.4 × 6mm self-tapping screws
1 80mm length of 0.7mm tinned copper wire
1 500mm length of medium-duty hookup wire
1 30mm length of 1.5mm heatshrink tubing
10 PC stakes

Semiconductors
1 PIC16F88-I/P preprogrammed microcontroller (IC1)
1 7805 5V voltage regulator (REG1)
1 BC337 *NPN* transistor (Q1)
1 1N4004 1A diode (D1)
1 16V 1W Zener diode (ZD1)

Capacitors
1 470µF 16V low-ESR electrolytic
3 100µF 16V PC electrolytic
1 10µF 16V PC electrolytic
2 100nF MKT polyester
1 1nF MKT polyester
2 27pF ceramic

Resistors (0.25W, 1%)

1 10kΩ	1 39Ω 5W
2 1kΩ	1 10Ω
2 220Ω	1 2.2Ω

Photo-Interrupter Detector
1 PC board, code 777(Inter.), size 50mm × 25mm (Next month)
1 photo-interruptor (Jaycar ZD-1901 or equivalent)
1 150Ω 0.25W resistor
1 3.5mm stereo jack plug
2 M3 x 6mm screws
2 M3 nuts
3 PC stakes
1 1m length of 2-core shielded cable

IR Reflector Amplifier
1 PC board, code 778 (IR Reflect Amp), size 53mm × 32mm (Next month)
1 plastic utility box, 82mm × 53mm × 31mm
4 M3 tapped 6mm nylon spacers
4 M3 × 12mm countersunk screws
4 M3 nuts
1 LM358 dual op amp (IC2)
1 infrared photodiode (IR SENS1)
1 infrared LED (IR LED1)
2 100µF 16V PC electrolytic capacitors
1 10µF 16V PC electrolytic capacitor
1 1m length of twin-core shielded cable
1 cable gland to suit 3mm cable
1 3.5mm stereo PC-mount jack socket
3 PC stakes

Resistors (0.25W, 1%)

1 470kΩ	2 1kΩ
2 100kΩ	2 150Ω
1 10kΩ	

All printed circuit boards will be available from the *EPE PCB Service*

The LCD module is connected via a 14-way pin header strip at one end and is supported on four M3 × 9mm nylon spacers at its corner positions. We'll describe how the header strip is fitted to the LCD module shortly. For the time being, just fit the four nylon spacers to the PC board and secure them using M3 × 6mm machine screws.

Switch board

There are just three switches and two header strips on the switch board – see Fig.8. Install the three switches first, taking care to ensure that the flat side of each switch is oriented correctly. The 3-pin and 4-pin header strips can then be installed.

Both headers are mounted on the copper side of the board. In each case, the longer pins of the header are first pushed into their mounting holes so that they sit about 1mm above the top of the board. That done, solder the pins to the board pads, then slide the plastic spacer along the pins towards the PC board, so that it rests against the soldered joints – see photo.

Once the assembly is finished, the assembled switch board can be plugged into the main board.

Fitting the LCD header

The next step in the assembly is to fit a 14-pin DIL header to the left-hand end of the LCD module. As before, this header is installed from the underside of the module.

Before soldering the header pins, you first have to adjust the plastic

Specifications

RPM range: 1 RPM (0.0166Hz) to 65,535 RPM (1029Hz) recommended maximum

Accuracy: within 1 RPM at 17,000 RPM, 1.33 RPM at 20,000 RPM

Adjustment: 100 RPM coarse steps with seperate 1 RPM fine adjustment over 100 RPM range

Display: both RPM and Hz

Display resolution: 1 RPM and 0.01Hz

Flash period: adjustable from 32μs to 6.50ms in 25.4μs steps, or adjustable from 1-10% of period

Display update period: 200ms but can be slower for measurements below 300 RPM (5Hz) and with averaging.

Division ratios: 0.5, 1, 2, 3, 4, 5, 6, 7 and 8

Flash position: can be shifted to any pulse edge or edge number when the division ratio is 2 or more

Averaging: from 1-10 measurements for measurements over 300 RPM, reducing in number at lower RPM

Trigger edge: rising or falling (user selectable)

Flash period: setting can be either fixed or automatic

Flash delay from triggered edge to flash: 8.75μs

Reflective trigger range: 65mm for off-white plastic, 95mm for white paper

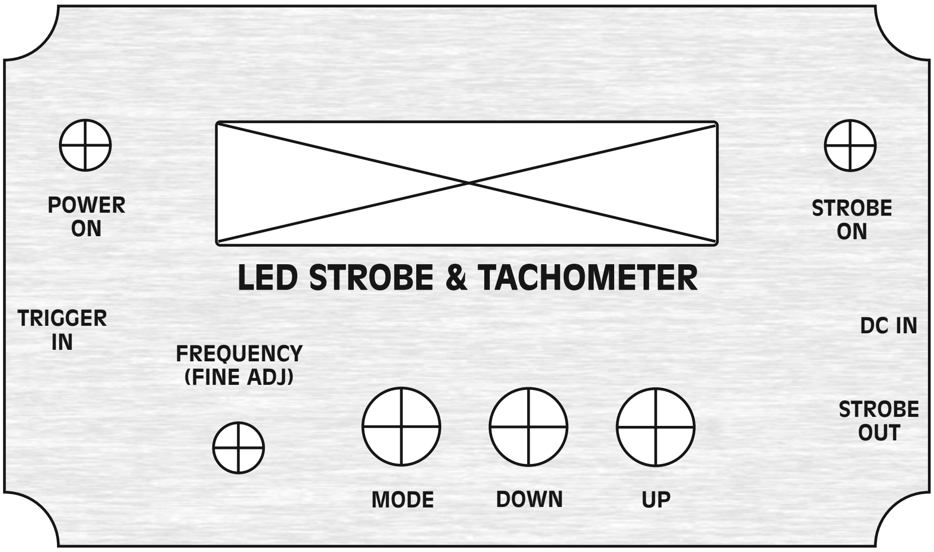


Fig.10: this full-size artwork can be used as a drilling template for the front panel.

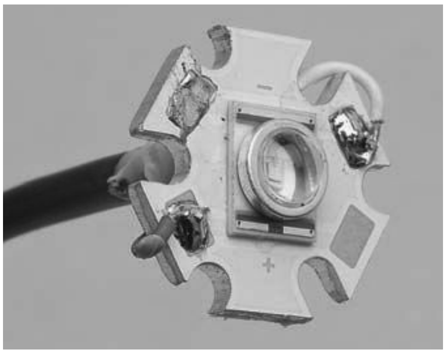
spacer so that the pins will protrude exactly 8mm below the module's PC board. This is done by simply placing the pins on a flat surface and then sliding the spacer along them in one direction or the other so that the pin length below the spacer is about 5.5mm (the spacer thickness is 2.5mm).

Once this adjustment has been made, the header can be installed from the underside and the pins soldered to the pads on the top of the module. Don't plug the LCD module in at this stage though.

Voltage checks

Before applying power, check that IC1 is out of its socket and that the LCD module is also unplugged. That done, temporarily wire in power switch S4, apply power and check for 5V between pins 14 and 5 of IC1's socket. If this is correct, switch off, remove the switch and install both IC1 and the LCD module.

Note that there is a tab beneath the LCD module (bottom, centre) that needs to be bent flat against the module's PC board, so that it clears IC1.



A larger-than-life size view of the 1W white LED. It is wired using a 1.5m length of shielded 2-core cable. Solder the red wire to the positive terminal and the white wire to the negative terminal and cut the shield wire off short.

Secure the LCD module in place using four M3 × 6mm screws.

Preparing the case

If you are buying a complete kit, the case will probably be supplied pre-drilled and with screen-printed lettering. If not, then you will have to drill the holes yourself.

The first step is to drill two 6mm holes in the side of the case to provide access to DC sockets CON2 and CON3. These holes should be located 9mm down from the top of the base and 17mm and 27mm in from the outside front edge.

Next, drill another 6mm hole in the other end of the case for CON1. This hole must be positioned 13mm down from the top and 29mm in from the outside top-front edge of the case. The PC board can then be fitted in place and secured on the integral standoffs using No.4 self-tapping screws.

Now for the lid, Fig.10 shows the full-size artwork for the lid, and this can be photocopied and attached to the inside of the lid and used as a drilling template. You can also photocopy the magazine artwork for the case front panel.

All holes in the lid should initially be drilled using a small pilot drill, then carefully enlarged to size using a tapered reamer. Switches S1 to S3 require 10mm holes, S4 and S5 require 5mm holes and VR1's shaft requires a 7mm hole.

Once the holes have been drilled, fit switches S4 and S5 and wire them to the PC board. It's a good idea to fit heatshrink tubing over these connections, to prevent the wires from breaking (hint: push the heatshrink

The connecting cable is secured to the back of the 1W white LED assembly using silicone sealant.

Silicone sealant is also used to secure the collimator lens inside the front assembly of the torch.

The 1W white LED is then clipped into the collimator lens and secured using additional silicone sealant.

tubing over the switch wires before soldering the connections, then slide the tubing into place and shrink it down).

Testing

The first step here is to apply power and adjust VR2 for best contrast on the LCD. The display should show a reading of between 1000 RPM and 1100 RPM on the top line and 16.66Hz on the bottom line. The Mode should be GEN.

If this checks out, attach the lid and mounting brackets to the case using the four screws supplied.

Now check that the RPM value can be adjusted over a 100 RPM range using potentiometer VR1. Similarly, the UP and DOWN switches should change the reading in 100 RPM steps.

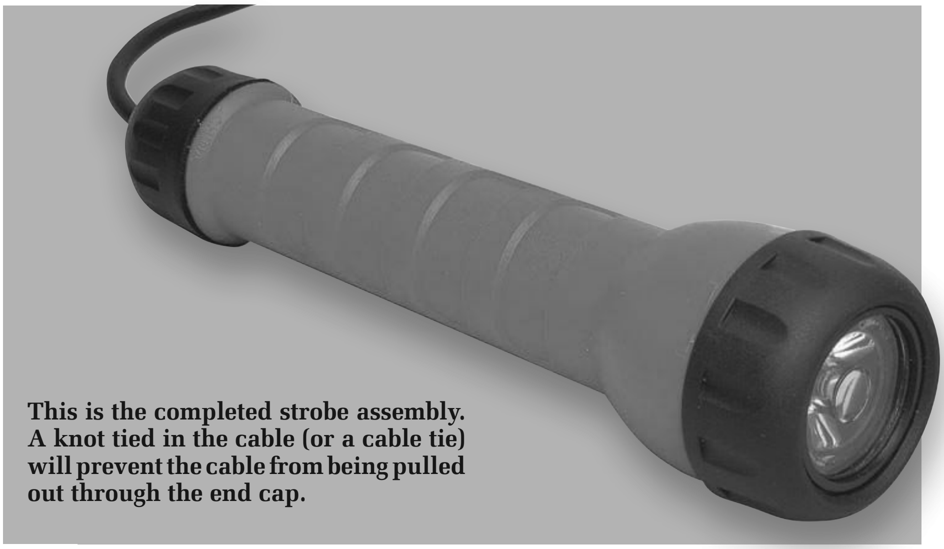
The default flash period is set to automatic at 5% in generator mode. In the triggered mode, the defaults are: edge is rising, division is 1, flash period is automatic at 5% and averaging takes place over two measurements.

The assembly of the main unit is now complete. Now let's build the strobe unit.

Strobe construction

As shown in the photo above, the 1W white LED for the strobe is housed in a small plastic torch housing. The original reflector inside the torch was removed and the LED and its associated collimator lens placed just behind the front torch lens.

Depending on the torch, the reflector may be easy to remove or it may be integrated with the screw thread that secures the front assembly to the torch body. In the latter case, the reflector can be removed by cutting around its perimeter using a hobby knife.



This is the completed strobe assembly. A knot tied in the cable (or a cable tie) will prevent the cable from being pulled out through the end cap.

The 1W white LED is wired using a 1.5m-length of shielded 2-core cable. Connect the red wire to the positive LED terminal, the white wire to the negative terminal and cut the shield wire off short. Once it's wired, secure this lead to the back of the LED assembly using silicone sealant.

Silicone sealant is also used to secure the collimator lens to the front lens assembly of the torch. Once it's in place, leave it to cure for several hours, then clip the LED assembly to the back of the collimator lens and secure it using additional silicone sealant. Leave this assembly to cure overnight.

Once the silicone has cured, feed the lead from the LED through a hole drilled in the rear end-cap of the torch. Use a cable tie or tie a knot in the wire to prevent the wire being pulled out of the end of the torch when the end-cap is refitted.

The far end of the cable is fitted with a 2.5mm DC plug. Connect the red (positive) lead to the centre pin of the plug and the white (negative) lead to the earth terminal.

That's all we have space for this month. Next month, we'll show you how to build the IR Reflector Amplifier and Photo-Interrupter boards and describe how the unit is used. ***EPE***