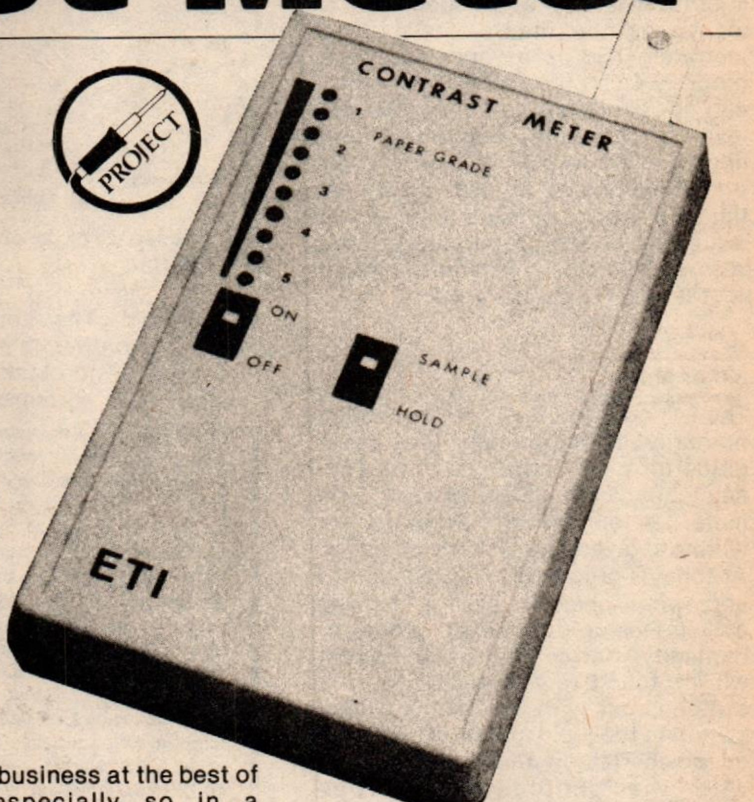
Contrast Meter

What's black and white and read all over? Answer — a photographic negative, providing you've built this simple and useful device. Design and development by Rory Holmes.



CONTRAST RATIO is a very important quality of photographic negatives that must be assessed during the printing process, in order to select the correct grade of photographic paper. The contrast of negatives depends on the type of film used, the lighting conditions and the developing process; consequently five grades of printing paper are available to enable the full range of tones from black to white to be reproduced from any negative. Grade 1 is termed the softest and it is used with the highest contrast negatives. At the other end of the scale, grade 5 is the hardest paper, which will enhance the tonal variations of poor contrast negatives.

During the design stage of this project we experimented initially with two separate photodetectors which measured the instantaneous light difference between two points. There are a number of problems with this approach, as the photodiodes and their associated amplifiers must be carefully matched in light sensitivity.

Secondly, the lightest and darkest points of the image must be known exactly, and the two photodetectors need to be simultaneously positioned on these points while the reading is taken. This is an awkward business at the best of times, but especially so in a darkroom!

We considered that a different approach was required and developed the circuit of Fig. 1 to overcome some of these difficulties. Only one photodetector is used and the peak positive and negative voltages obtained from different light levels are followed and stored independently by sample and hold circuits.

Now, as long as the photodiode is scanned at some time through the lightest and darkest points of the image, the peak detectors will memorize the maximum and minimum voltages, and thus provide a contrast measurement.

The photodetector input stage of our meter is rather unusual in its configuration. Photodiodes are usually used in the 'photovoltaic mode' where the photocurrent developed and measured is linearly proportional to the light intensity. Our input amplifier has an extremely high input

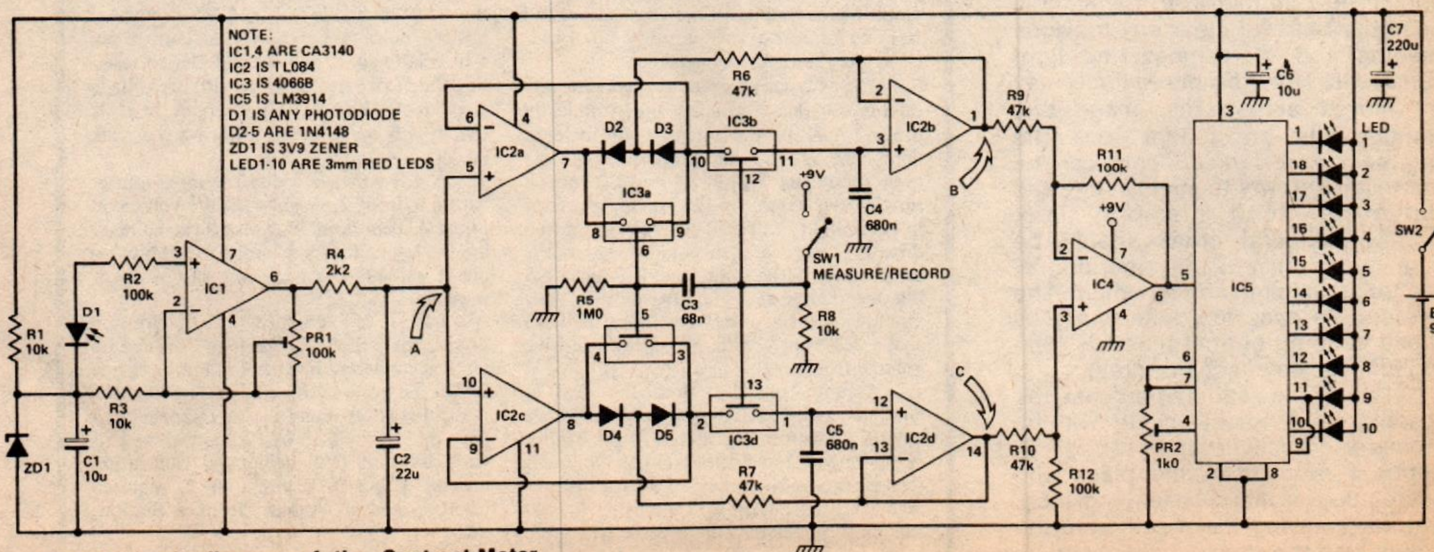


Fig. 1 Circuit diagram of the Contrast Meter.

impedance and thus measures the open circuit voltage generated by the photodiode. This voltage is logarithmically proportional to irradiance as the graph of Fig. 2 illustrates. This is a very convenient property since the sampling circuitry can now work on the log of the light level to provide maximum and minimum values. By simply subtracting these two values with a differential amplifier we obtain a voltage that is logarithmically proportional to the ratio of the maximum and minimum light levels, i.e. the contrast.

Meter Made

The ETI contrast meter was intended primarily to determine the paper grade for a well balanced print; consequently a 10 LED bargraph type meter is sufficiently accurate for calibrating the five grades of paper. At today's prices this also works out somewhat cheaper than a moving coil meter and is less prone to damage. After calibration, the meter will be found very easy to use. It is switched on with the 'sample/hold' switch in the 'hold' position and placed down flat on the enlarger base with the photodetector probe anywhere in the image area. (The photodiode has been mounted in a separate probe with its amplifier in order to keep it as close to the focused image plane as possible. If it were much higher than this the detecting element would pass through an unfocused image, giving a false contrast reading).

Any red safety lights should be switched off before the reading is taken to avoid error since the photodiode is responsive at this wavelength. The sample/hold switch should now be moved to the sample position; this will clear any previous reading and start measuring light variations. Now the photodiode may be moved across the image and through the areas that look the brightest and darkest. This can be done quite slowly thanks to the peak detectors' long memory time; however, several areas should be scanned to ensure the recording of the true maximum and minimum. The eye can be deceived quite easily by those cunning optical illusions lurking among the shades of grey!

During the scanning process the reading on the LED scale will increase and finally level-off at the true contrast ratio when the black and white peaks have been covered. Before removing the meter from the image area the sample/hold shoud be set to 'hold'. The meter will now be immune to further light variations and will continue to display the contrast reading for a considerable time, thanks to the even longer memory of the sample/hold circuitry!

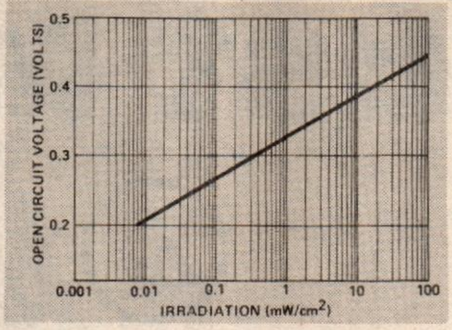


Fig. 2 Response of the photodiode used in this project.

A true ratio is provided by the meter and thus the contrast reading for a given negative will be independent of the light source intensity and enlargement size (photographic aberrations known as "circles of confusion" may produce sources of error under certain conditions). Negatives may thus be compared or matched for contrast.

Construction

The meter is built into a slim style plastic enclosure. This houses the battery and main PCB on which all

HOW IT WORKS

The general circuit arrangement consists of a photo-amplifier which feeds a voltage derived from varying light levels in an enlarger, to a pair of peak detectors. One follows the peak positive voltage and the other the peak negative voltage. The capacitors used for storing the voltage peaks in the followers also form part of sample and hold circuits which are then switched to 'hold' after measurement. Their outputs represent the maximum and minimum values of light intensity. A differential amplifier then computes the ratio of these values and the result is displayed on an LED bargraph meter.

IC1, a CA3140 CMOS op-amp, is used as the photodetector amplifier. It is configured as a non-inverting DC amplifier with a gain variable from unity to about 10, set by PR1. Although IC1 can have input and output voltages all the way to ground, this facility is not used owing to the driving requirement of the TL084 quad op-amp. This requires inputs at least 1V above ground, and thus IC1's output is offset by a reference voltage of 3V9 provided by R1, ZD1 and C1. The anode of the photodiode is connected via R2 to the non-inverting terminal of IC1 which has an effectively infinite input impedance. Thus the open circuit voltage generated by the photodiode is amplified according to the gain set around IC1 and appears at the output on pin 6 added to the reference voltage.

The voltage at point A (ignoring the reference offset) will be logarithmically proportional to the intensity of incident light, owing to the properties of the photodiode (see Fig. 2) R4 and C2 form a simple filter to remove 120 Hz ripple caused by AC light bulbs. This voltage is fed directly to the peak detectors. These circuits are essentially the same, the difference being the polarity of the rectifier diodes. They operate in exactly the same way, and we shall deal only with the peak positive voltage follower.

Assume initially that the CMOS analogue switch IC3c is open and IC3d is closed. C5 will be connected to the output of op-amp IC2c via the rectifiers D4 and 5 (we can ignore the action of R7 for the moment). C5 will charge up via the rectifiers to the most positive voltage peak when the voltage at point A on the non-inverting terminal is greater than the capacitor voltage applied to the inverting terminal. The voltage held on C5 will droop over a period of time due to leakage current through the rectifiers D4 and 5 and the input bias current of IC2c. IC2c was chosen as a FET op-amp with a low input bias current and R7 is included to reduce the diode leakage current.

forward high impedance voltage follower to buffer the stored voltage. When the input voltage to IC2c at point A drops below the peak value, IC2c's output will go negative, reverse biasing D4. However, IC2d applies the capacitor voltage via R7 to the anode of D5, effectively removing leakage current through D5.

The peak positive value of the signal at A thus appears at point C, and likewise the peak negative value at point B. When the analogue switch IC3d is now opened, C5 is disconnected from the peak detector and acts in conjunction with IC2d as a sample and hold circuit thus isolating the measured values from further light variations.

When SW1 is open, R8 and R5 hold the control pins 13 and 5 of IC3 low, opening both analogue switches. This is the 'hold' mode. When SW1 is now closed, the control pin 13 is taken high, switching to the 'sample' mode. C3 and R5 produce a positive pulse (about 50 mS) on control pin 5 to briefly short out D4 and D5, so resetting the peak detector to the current voltage at point A. When C3 has charged the IC3c switch will open again, allowing the peak detector to function.

IC4 is wired as a differential amplifier with a gain of 2, to subtract the voltage at point C from point B. Since these voltages are the log of the light levels, the output on pin 6 will represent the contrast ratio of these light values.

IC5 is a standard LED bargraph driver, the LM3914. The input voltage on pin 5 is converted linearly to illuminate one LED on a scale of 10. Full scale deflection (LED 10) is set internally at 1V2; the zero scale deflection is set by PR2 anywhere between 0V and 1V2 during the calibration process. C6, a 10 uF tantalum, is required for IC5 to ensure stability from oscillation.

the parts are mounted. Since the light sensing element must be as close to the enlarger base plane as possible, we have mounted it externally on a separate small PCB with its associated amplifier. A probe to house the external sensor is made from a short length of aluminium channel extrusion. Figure 3 shows the dimensions for the probe; if the

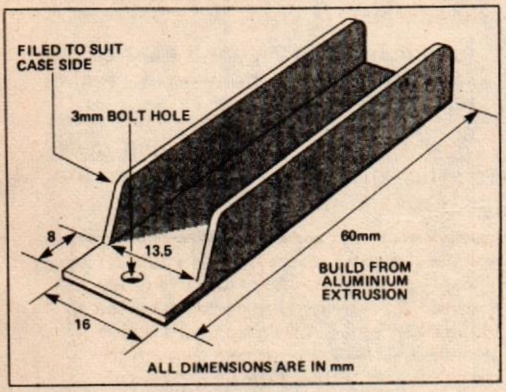


Fig. 3 Details for the aluminium extrusion that houses the photoprobe.

PARTS LIST

Resistors (all ¼ W, 5%)

R1,3,8	10k
R2,11,12	100k
R4	2k2
R5	1M0
R6,7,9,10	47R

Presets

PR1	100k subminiature horizontal preset
PR2	1k0 miniature horizontal preset

Capacitors

C1	10u 35V tantalum
C2	22u 25V tantalum
C3	220u 16V electrolytic
C4,6	82n polycarbonate
C5	68n ceramic

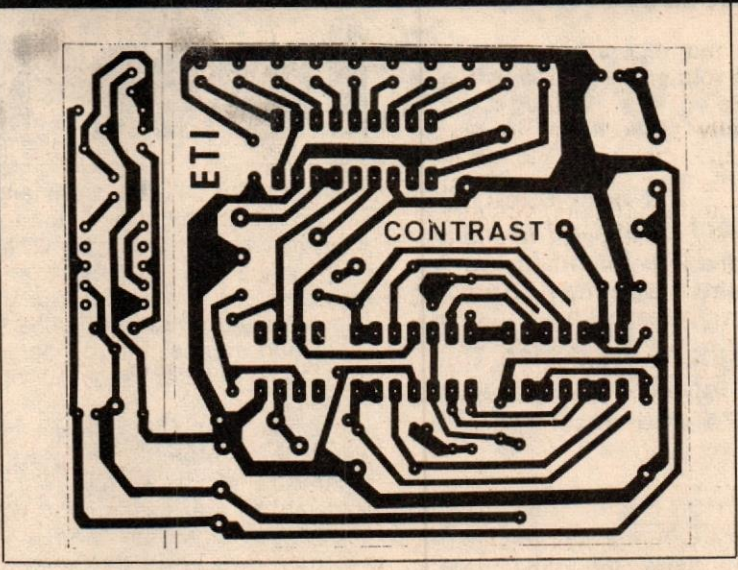
Semiconductors

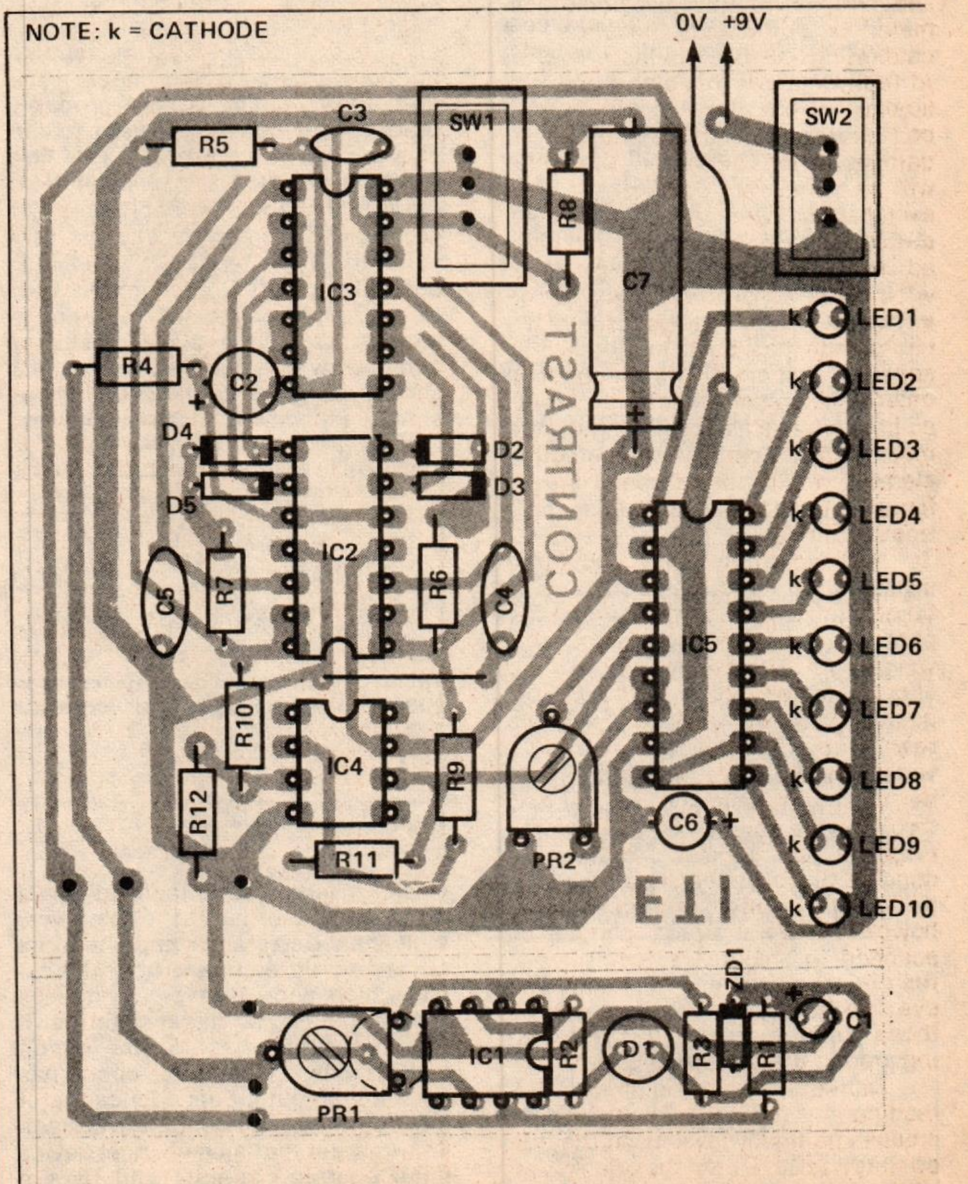
IC1,4	CA3140
IC2	TL084
IC3	4066B
IC5	LM3914
D1	Any photodiode, e.g. TIL413
D2,3,4,5	1N4148
LED1-10	3mm red LED

Miscellaneous

SW1,2	miniature slide switches

Case; PCB; B1 9V battery (preferably alkaline type).





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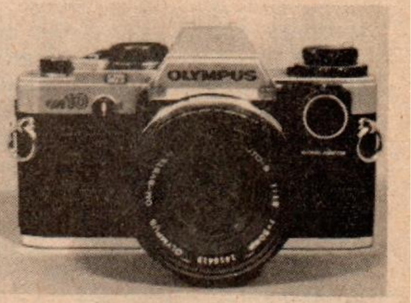
ELECTRONICS IN PHOTOGRAPHY



Latest developments exposed by Phil Gerring.

SINCE JOSEPH NIEPCE produced the first photographic image in 1826 the science of photography has advanced beyond all recognition. Indeed Niepce, confronted with a modern SLR compact, would be at a loss to know what it is — let alone how to use it. Niepce's first photograph took eight hours to expose; today the same scene can be captured in 1/1000 of a second (at a far better quality).

The camera manufacturers are continually bringing out new models incorporating the latest technology. This article follows and explains the development of electronics as applied to photography, and looks into the future.

Exposure Meter

As far back as 1873 a guy by the name of Willerby Smith noticed that the conductivity of a piece of selenium varied with the amount of light falling on it. Despite this early instance of photo-conductivity, it wasn't until the 1930s that the first commercial electric light meter was developed. Since then there have been many advances and developments. In the late 40s germanium and silicon were applied to photo-voltaic and photo-conductive uses. In the 50s light meters became a permanent fixture on cameras and in the 60s 'Through the Lens' metering was instituted on both semi-automatic and fully automatic cameras.

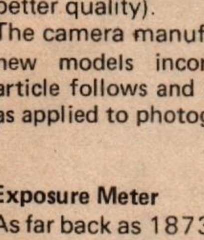


Fig. 1. Structure of the selenium cell. This was used in the first commercial exposure meter and is still popular today.

There are four different types of photocell used in exposure meters. The first of these are selenium cells or barrier layer cells (Fig. 1). They generate their own electricity (photovoltaic) and use a sensitive galvanometer attached to a mechanical claculating dial. Their sensitivity is limited and dependent on the area of cell exposed to the light. The light meter uses a baffle to limit the acceptance angle to that of the camera lens employed. Its advantages are that it requires no power supply and is relatively inexpensive. It is, however, too large to be incorporated inside the camera and does not perform very well in low light levels.

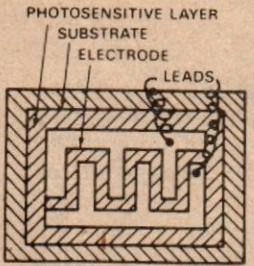


Fig. 2. The cadmium sulphide cell, with leads for the external power supply. Its sensitivity allows its use in TTL metering.

The cadmium sulphide cell (CdS) is a photosensitive cell and an increase in light reduces its resistance to a flow of electricity, thus increasing the flow of current from a battery across the cell (Fig. 2). A sensitive galvanometer is used to calculate the exposure setting (see Fig. 4). It is usually employed as a 'Through The Lens' light meter (TTL) as it is very compact. It is more sensitive than the selenium cell and responds well in low light levels. Its disadvantages are that it tends to retain or memorize a light level (it is slow to respond to a new one) and it is also very sensitive to red light which results in under-exposure of red subjects.

Silicon cells (Si) are solid state photodiodes (Fig. 3) that generate a minute current (photovoltaic). This is then amplified to obtain a useful output and an op-amp is used as a current-to-voltage converter with a suitable

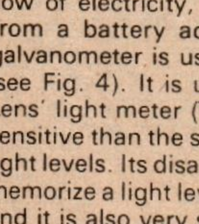


Fig. 3. Silicon cells are extremely fast reacting and very small.

feedback resistor to give high output voltage in proportion to the incident light on the cell. This then gives a significant response even at low light levels and also a linear response over a wide range with an almost instantaneous response to changing levels. As these cells are small and reliable, they are used in common camera bodies. Being very sensitive to red light, they are often fitted with blue filters and called Silicon Blue Cells (SBC) which give a better acceptance of the spectrum. However, the cell becomes unreliable in temperature extremes.

The fourth type is the gallium arsenide phosphide cell (GaAsP). This is a fast-reacting compact photocell and provides reliable readings in blue and red light. It also responds well in low light levels and is not over sensitive to temperature extremes. It is similar to the Silicon cell in that it responds about 1000 times faster than the CdS cell. It is, however, a fairly recent innovation and is not at the moment in common use.

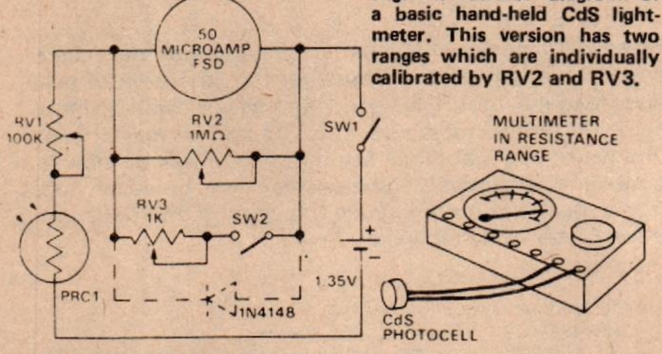


Fig. 4. Circuit diagram of a basic hand-held CdS light-meter. This version has two ranges which are individually calibrated by RV2 and RV3.

Semi Automatic Cameras

A practical semi-automatic system first became possible with the development of a compact photosensitive resistor which could be installed in or on the camera. The next development was to directly link the light meter circuitry to the shutter, aperture and film speed controls. This was achieved using a series of variable resistors. By the mid-70s the cameras used a moving coil meter with a needle as an indicator.

There are two basic metering systems. One uses a two needle system. A "match" needle is linked to the ASA film speed which is directly linked to the metering coil. The aperture and shutter are linked to the other needle, which may have a ring attachment at its end. The photographer adjusts the ring until it is aligned with the needle by altering the shutter speed and aperture controls.

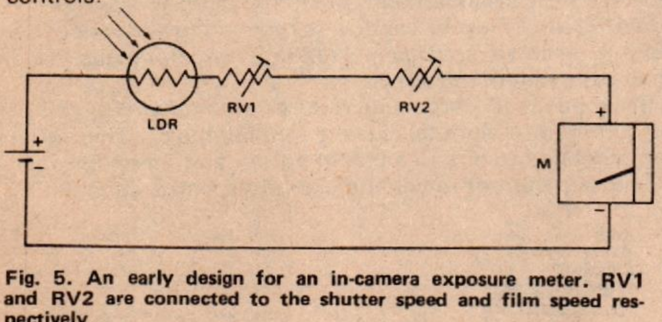


Fig. 5. An early design for an in-camera exposure meter. RV1 and RV2 are connected to the shutter speed and film speed respectively.

The other major system uses the needle centre method (Fig. 5). All the exposure controls as well as the light-dependent resistor are connected to a single needle which is situated at the side of the viewfinder and is free to swing between two markings. If the needle swings towards the +ve end of the scale this indicates that the picture will be over-exposed and conversely, if it swings the other way it will be under-exposed. The photographer can then adjust his aperture and/or shutter speed accordingly.

A typical handheld light meter. This particular unit costs approx $20.00 and is self powered.

The drive circuits for the integral systems, as described above, in modern 35mm cameras can be very basic arrangements. For example, the single-ended circuit operates a meter by measuring the amount of light falling on the LDR through the lens of the camera. As the ASA of the film and the shutter speed are preset, the meter can be centred by adjusting the aperture ring. (Note: The aperture is not connected to the circuit.)

This circuit arrangement has disadvantages and can be unreliable because it is dependent on a constant voltage supply from the battery. So if the battery voltage fluctuates above or below its normal it is going to result in a faulty meter reading and consequently affect the exposure.

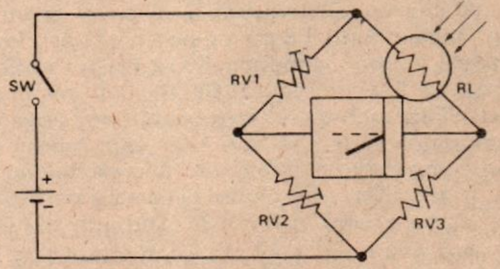
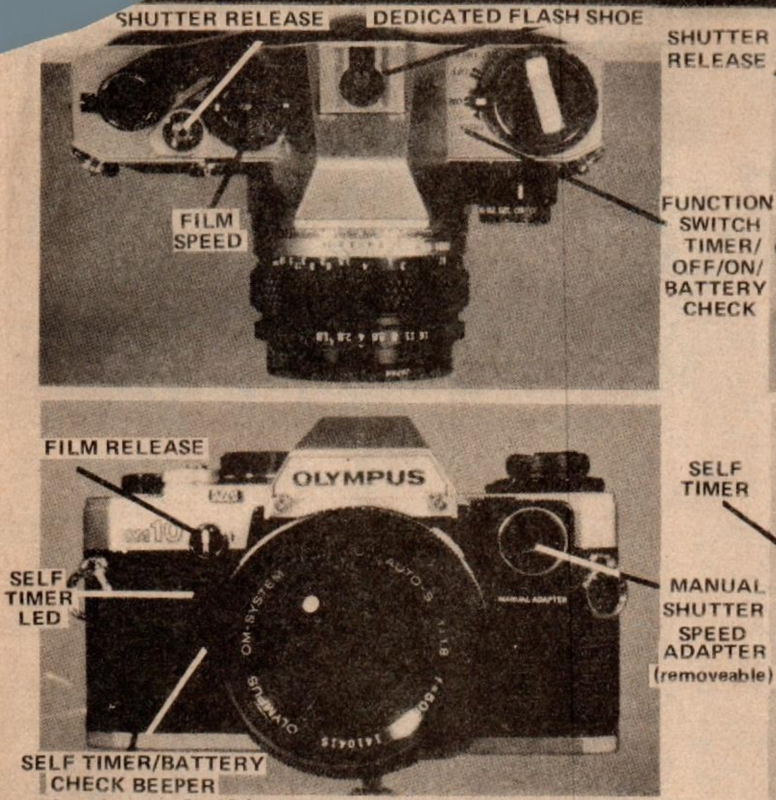


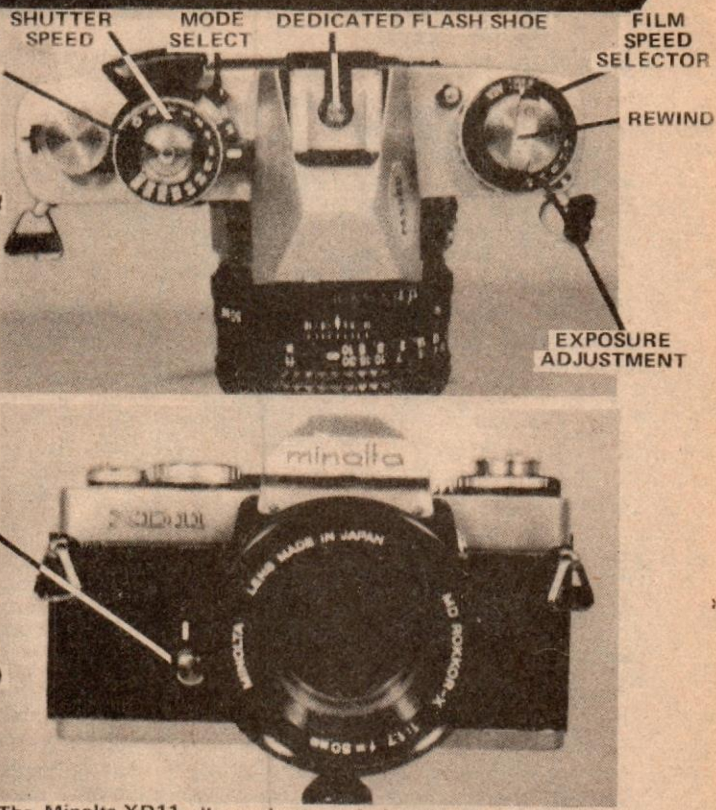
Fig. 6. Wheatstone bridge arrangement.

A more reliable circuit is achieved by using a Wheatstone bridge arrangement (Fig. 6), which operates independently of any fluctuations in the battery voltage.

The sensitivity of the microammeter in the metering system of semi-automatic cameras is so crucial that should it get damaged the whole metering system would have to be replaced and this can be very expensive. So when LEDs first appeared on the market, camera manufacturers were quick to see the obvious advantages of these solid state devices, and they began developing them for application in photography. Linked to a drive 'chip', these devices have many advantages over the old moving coil metering system. The most common display arrangement used is a vertical column of three LEDs. The top and bottom LEDs glow red to indicate either over- or under-exposure. When the exposure is correct the middle LED glows green.



The Olympus OM10 is an aperature – priority automatic camera. Features include a electronic self timer with flashing light and beeper, audible battery check and touch on light meter. The shutter speed selector is removeable.



The Minolta XD11 allows shutter priority, aperature priority and manual exposure operation. Exposure compensation of up to 2 f-stops either way is possible.

Automatic Cameras

In the 50s crude forms of automatic exposure meters were being built into cameras but these were mainly mechanical systems designed for the amateur market.

They were not always reliable and had a fixed shutter speed. The aperture was adjusted electro-mechanically. A photo-voltaic cell would measure the incident light and power a servo motor which then adjusted the aperture, using a series of geared wheels.

Another popular system in early 'automatic' cameras used the needle trap method. A meter is used to read the output from a photocell and then the meter needle is clamped into position (which doesn't do a microammeter much good). Then on depressing the shutter button a lever travels to the position at which the needle was trapped and adjusts the aperture as it moves. This sytem is accurate but easily damaged. It can, however, incorporate a range of resistors which allows for a variety of shutter speeds.

By the early 60s microcircuitry was beginning to come into its own and in 1968 Konica brought out the first fully-automatic electronic 35mm SLR. All the other major manufacturers soon followed with their own versions.

Most of these early auto cameras have an 'aperture priority' control whereby the photographer sets the film speed on the dial which is in turn linked to the exposure calculator circuitry. Then, by moving the aperture control only, the camera works out the correct shutter speed to go with the chosen aperture. This is done using a comparator chip which can accept the output from the photoelectric cell and the variable resistances from the aperture and film speed settings.

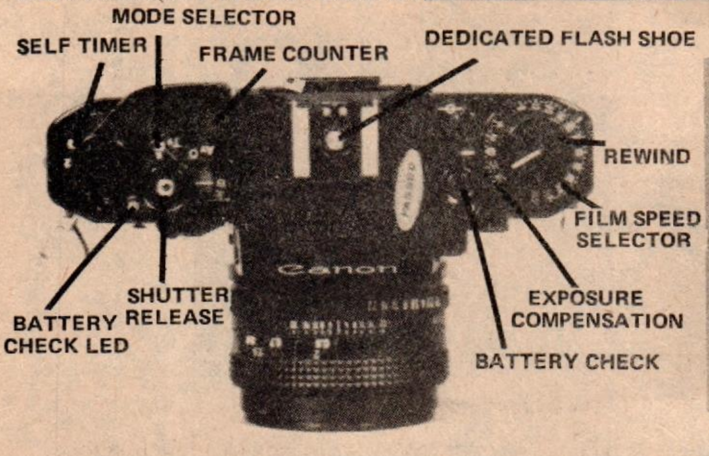
Most of the recent auto-exposure cameras use electro-magnetic aperture control with a direct electronic link made to the timing circuitry giving faster and more accurate exposures. The early versions had automatic aperture controlled by levers and servos.

Micro-electronic developments, such as more 'intelligent' and compact chips as well as flexible circuit boards and greatly increased reliability, have made it possible for cameras to have more than one auto-exposure mode. As well as manual operation they are capable of aperture priority or, with the flick of a switch, shutter speed priority. This dual mode feature coupled with an increased reliability is particularly attractive to professional photographers.

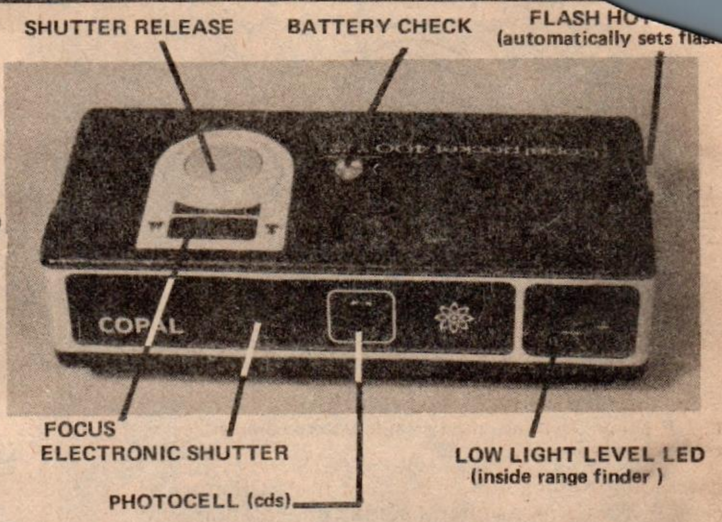
Some modern cameras are pre-programmed by the manufacturer so that if there is either too much or too little light for the exposure even after the shutter or aperture has gone to its limits, the camera will take over the setting. These alterations are usually displayed in the viewfinder so that a check can be made in case the settings are not close enough to get the desired effect.

Some cameras make use of stepped programmes. These are mainly incorporated in compact 35mm cameras in the higher price range. The exposure rating is staggered between the aperture and exposure settings, thus giving the photographer a balanced setting between depth of field (aperture) and fast exposure (shutter speed).

Using electronic shutters and apertures enables cameras to operate with continuous exposure values to give more accurate and more consistent exposures. There are some recent fully automatic cameras where the light reading is taken partly off the actual surface of the film emulsion. So with fast-reacting electronics a shutter speed or aperture can be corrected in mid-exposure. In compact cameras a stepless exposure works only above 1/100th of a second so that camera shake problems are minimised.



The Canon A-1, easily the most automated 35mm camera on the market today. Its internal microprocessor allows virtually every possible permutation of exposure programmability. In addition, Canon dedicated flashes will set the camera's aperature and shutter speed.



Automation comes to pocket cameras. The Copal Pocket 400 is a typical example of electronic pocket cameras. Such cameras are invariably aperature preferred (f-8 to optimize optics and depth of field). This camera will accept either magicubes or an electronic flash.

Electronic Shutters

Polaroid produced the first commercially-available electronic shutter to operate efficiently in the small body of a camera. The other major manufacturers soon followed but with more professional systems. The development of mechanical shutters had attained a high standard by the time electronic shutters appeared on the scene and initially there were no real advantages in using an electronic shutter except where weather conditions were extreme.

The electronic systems gained the advantage though when they were linked to the automatic exposure systems . . . In 1971 Asahi Pentax introduced the Pentax ES (electronic shutter) and this set the route by which the electronic shutter was going to develop.

There are two basic types of shutter used in cameras, they are the 'between-the-lens shutter' (ie between the elements of a compound lens) and the 'focal plane shutter.

Between-the-lens arrangements have appeared in many different forms from a single blade type as found in the simpler cameras such as Instamatic cameras, and the lower-priced Rangefinder Compacts. More expensive cameras use a between-the-lens arrangement with more than one blade. This system has fewer operating problems than the focal plane shutter because it allows an even one step illumination over the whole film area. The first form of electronic shutter which appeared in the 60s was the electronically operated spring-loaded diaphragm shutter. This shutter uses an electromagnet to attract a lever which moves a collar attached to the shutter leaves. The electromagnet is connected to a switch and a power supply, normally a small battery.

When the exposure button is depressed, this energizes the coil which attracts the lever and a capacitor-resistance network starts timing. When the exposure is completed, the electromagnet is de-energized and the shutter is closed by the force of a spring acting on the lever. Another arrangement of shutter control is by the use of permanent magnets in place of the spring. The use of magnets reduces mechanical moving parts and also closes the shutter more efficiently than a spring. Automatic exposure systems can be linked to this shutter by exchanging the resistor network with a silicon cell device which can judge the exposure while light is landing on the film surface.

Mechanical timing arrangements were used at first to control these shutters, but microcircuitry has made it possible to incorporate an electronic timer. When the electro-magnet in the shutter is activated it also trips a switch which allows a capacitor to charge at a predetermined rate, controlled by a variable resistor or by a resistor series network. This is linked to the shutter speed setting on the camera and when the voltage in the capacitor attains a critical level a transistor switching circuit will take over and cut off the current to the solenoid allowing the shutter to close.

The focal plane shutter is not situated in the lens but directly in front of the film plane. One blade shuts out the light. When the shutter is released it slides across. When the film has been exposed for the correct length of time a second blade follows across to complete the exposure.

The most common type of electric shutter is a spring loaded system which is attached to and cocked by the film wind-on lever. The electronics are similar to those in the between-the-lens shutter, using a capacitor charged via a variable resistor (Fig. 7). By pressing the shutter release trigger, switch (SW2) is closed and this allows current to pass through an op amp which in turn charges a solenoid. The charged solenoid pulls a spring tensioned lever up to the electromagnet and at the same instant releases a catch allowing the first shutter blade to shoot along its track close to the focal plane. At the same instant, the resistor and capacitor circuit starts timing the shutter. After the set time the op amp switches off and discharges the solenoid. The lever is then released and the spring returns to its starting point at the same time releasing the second blade and covering the film again.

There are several types of electronic timing used in conjunction with electronic shutters, the most popular being the Schmitt trigger and the SCR. In the Schmitt circuit (Fig. 8), the capacitor is charged up to a level predetermined by the resistor R. When the trigger voltage is reached, the 'off' and 'on' transistors are switched over. The SCR circuit (Fig. 9) can operate using very low power levels. The SCR starts out as an open circuit. When the power is connected, the first shutter blade is released and the capacitor charges up to a low

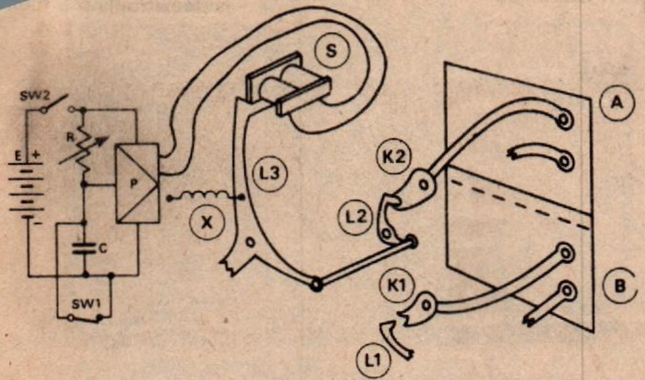


Fig. 7. Many electronic shutters still require complex lever arrangements to function.

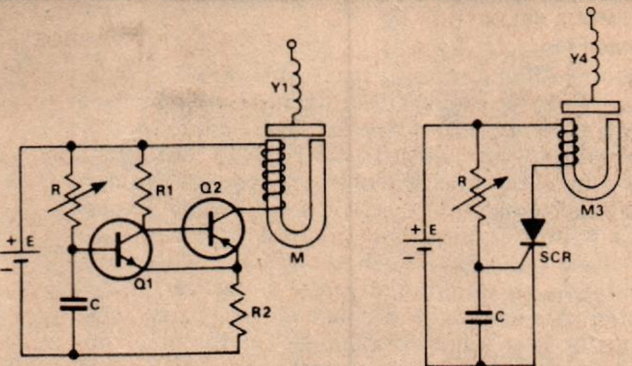


Fig. 8. 9. The Schmitt trigger and SCR timers.

gate voltage which then triggers the SCR (to a closed circuit). This puts a voltage across the solenoid which in turn attracts the lever releasing the second blade of the shutter.

Autofocus

Cameras have developed rapidly in recent years with the aid of high technology electronics. Cameras can decide and set their own shutter speed, aperture and even film speed controls to give you fully automatic operation. The next stage was the development of autofocusing, so that a camera could calculate the distance of the subject from the lens to bring it into focus.

The first autofocus camera was developed by Canon in 1963 but autofocusing cameras did not actually come onto the market until 1978 with an autofocus camera designed by Konica. There are now three systems used. The first, and at the moment most predominant, system is based on the Honeywell Visitronic Autofocus Module. This uses a system of comparing the contrast of light on a subject as viewed by two banks of light sensitive cells.

The second is a system used by Polaroid. This sends out an ultrasonic wave (sonar type) at the subject for automatic focusing. The third and newest system is one used by Canon which bounces an infra red light beam off the subject.

In the Honeywell system light from the subject passes through two windows on the front of the camera and is reflected by a series of mirrors into the autofocusing module. Here the two light sensitive panels (silicon photocells) compare the lighting contrast from the two views of the subject. The contrast is a maximum at the point of exact focus and falls away on each side of it.

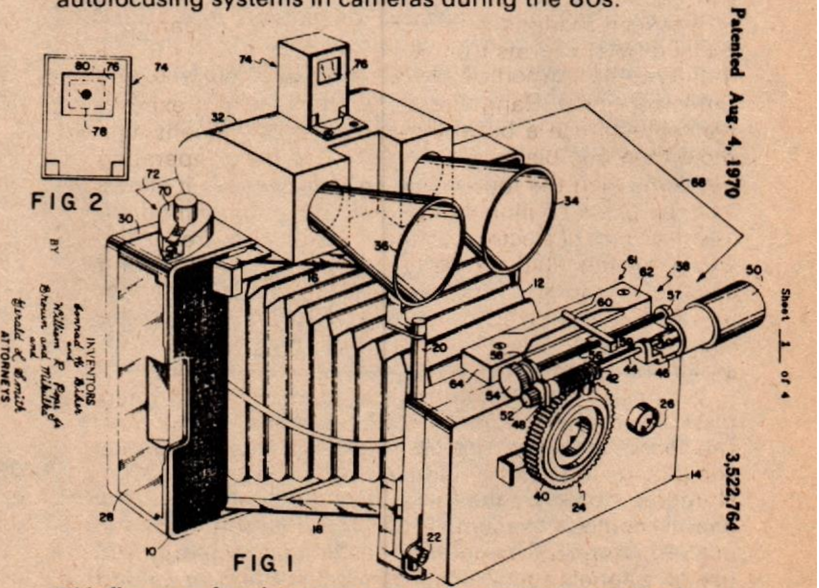
The sonar system employed in Polaroid cameras works on the same principle as that used by submarines. A transducer sends out and later receives the sound waves and converts them into electrical energy. The transducer sends out a chirp lasting about 1/100 sec towards the subject. The chirp contains four ultrasonic frequencies between 50 and 60 kHz. A crystal oscillator clock times how long it takes for the chirp to rebound onto the camera and a chip calculates the focal setting from this information, a servo motor adjusting the lens accordingly.

The Canon autofocus system uses an infra red light beam to assess the correct focus. It works using an IRLED (infra red light emitting diode) which sends out a beam of invisible light of about 900 nm (nanometres) wavelength. The camera has two rangefinder-style windows. The infra red leaves one window and scans the subject scene from left to right through an angle of about 10°. When the receiving sensor is receiving the maximum signal, the IC electronics informs the lens of the correct setting, and all this takes about 120 milliseconds.

Each system has its advantages and disadvantages. The Honeywell is compact and for the first time afforded quick, easy, sure, sharp automatic focusing for all photographers. It does, however, have a slight 'memory' whereby it retains previous focal settings and does not function very dependably in dim light or low contrasting light (and is therefore inadequate for flash). It can also have trouble focusing on small repetitive patterns.

The advantage of the ultrasonic or sonar system is that it does not depend on bright lighting of the subject and so can focus in absolute darkness. The only drawback is if a solid object such as a window lies between the subject and the camera, as the sonar cannot then judge the distance to the subject.

The infra red system works in almost any situation in which the Honeywell system does not and it can focus even in total darkness. It can also focus through glass. The only drawback to the system is that it may not work well on subjects with low reflectance characteristics. It is the infra red system which will probably predominate autofocusing systems in cameras during the 80s.



This first sonar-focusing camera was — as an experimental model — completed in 1967. Following the introduction of SX-70 photography, a sonar-focusing SX-70 camera was readied by 1976 and refined for introduction in 1978. This particular model never got past the prototype stage.

Electronic Flash

1851 saw the first electronic flash when Fox-Talbot, an early photographic pioneer, borrowed equipment from Faraday and demonstrated the use of an electric spark as an artificial light. But it wasn't until the 20th century that electronic flash became available as a convenient light source. Flash guns require a DC power supply, capacitors, flash tube, triggering circuit and a reflector. Modern flash guns have flash tubes filled with xenon surrounded by a toughened glass envelope. This is connected to a capacitor which has been specifically designed for flash guns and similar instruments, and these are called either energy storage or auto flash types.

There are three types of flash guns which make use of varying sizes of capacitor depending on the application. Low power amateur flash guns make use of capacitors charged from 180-500 volts. Portable studio guns use 500-1500 volts and industrial giants can use 1500-15000 volts. As thousands of volts are discharging through the flash circuit, there will be several hundred amps moving along the flash tube for 1/250th to 1/1000th of a second. Therefore the power produced can be as high as a 100kW at the peak of the flash.

In modern portable flashguns the capacitor requires a power pack running from a few 1.5 pencil batteries. The small 1.5 volt cells can charge the capacitor up to sufficiently high voltage by using a transistor 'invertor' circuit (Fig. 10). This circuit oscillates at an audio frequency (this accounts for the whining noise heard as the flashgun charges up). The oscillator produces an AC voltage which is stepped up by a transformer and the high-voltage AC is then converted back to DC by a rectifying diode, and goes to charge the storage capacitor via a current limiting resistor. The flash gun then has to be fired to release the stored charge.

It is critical that the flash synchronizes precisely with the shutter. A synchronizing switch is built into the camera. This switch cannot directly handle the flash current, so it is used to trigger a thyristor in the flash unit.

Charge control circuits are built into flashguns to ensure constantly bright flashes regardless of the state of the batteries. This circuit fully charges the capacitor before switching off to conserve the battery power. But if the voltage drops below a certain % level the circuit will automatically switch itself back on again to keep the flash at a consistent level. A small neon light is included in the circuit and lights up to indicate when the flash gun is fully charged.

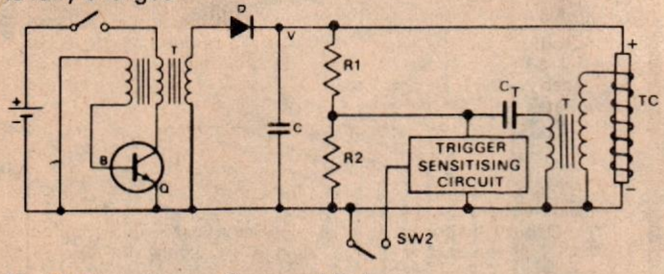
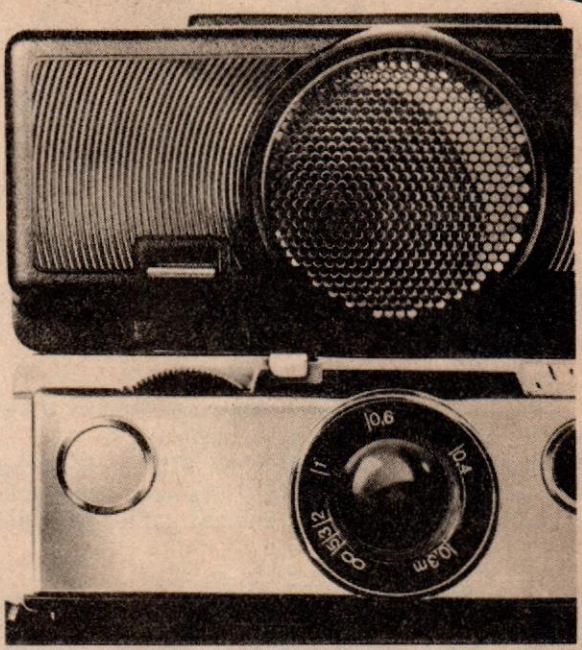


Fig. 10. Basic diagram of a manual flashgun.



The transducer on Polaroid's sonar auto-focus cameras acts as both loudspeaker and microphone — transmitting and receiving millisecond-long ultrasonic waves to travel to the subject and echo back to the camera, advanced electronics set the camera lens at the precise focus position. The transducer, 3.5cm in diameter, is composed of a concentrically-grooved backplate (the capacitor) over which a 3-mil foil of gold-coated Kapton is stretched. The foil is the moving element transforming electrical energy to sound waves and the returning echo into electrical energy.

In recent years automatic flashguns have become keenly competitive with ordinary flashguns (as described above). The automatic flashguns use a fast acting photocell such as a silicon photodiode. These cells operate so quickly that they are able to calculate the correct exposure setting while taking the light reading off the subject. In the flashgun the cell is used to read the amount of light reflected from the object and transfer the information to an integrated circuit which works out when enough light has been reflected to register on the film. It then shuts off the flash by cutting the power supply.

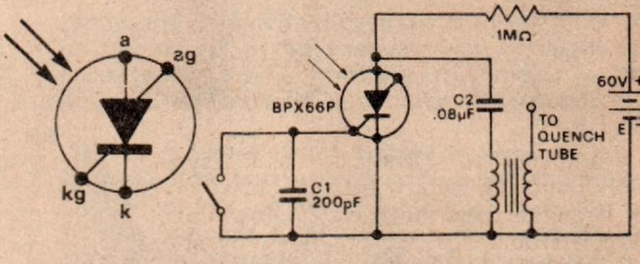
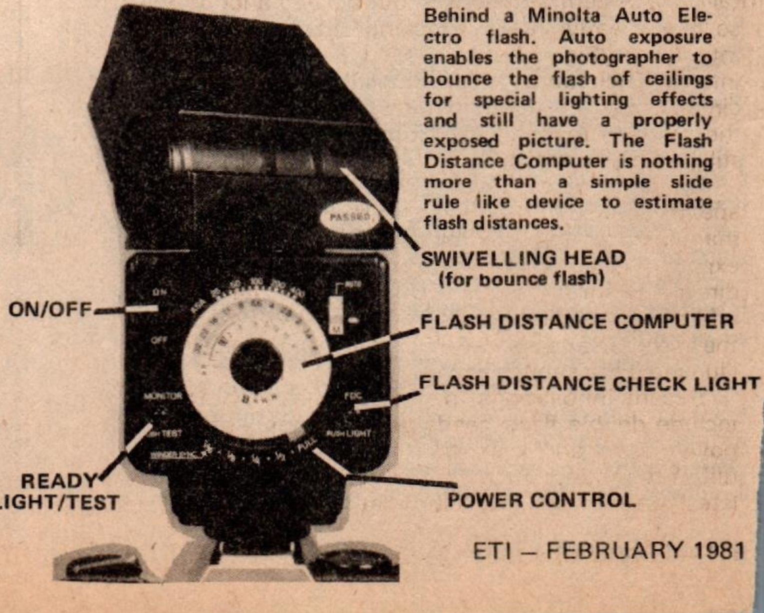
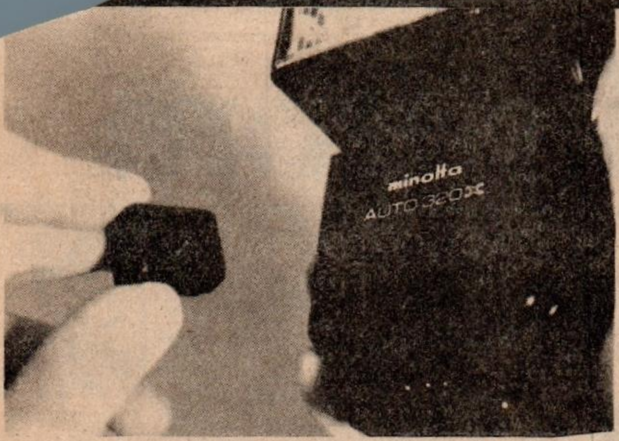


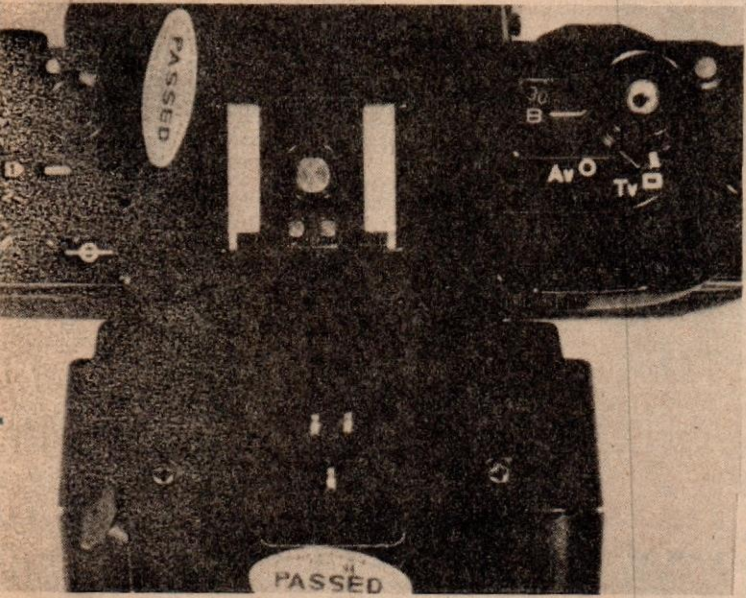
Fig. 11. The extra circuitry required for an automatic flashgun.



Behind a Minolta Auto Electro flash. Auto exposure enables the photographer to bounce the flash of ceilings for special lighting effects and still have a properly exposed picture. The Flash Distance Computer is nothing more than a simple slide rule like device to estimate flash distances.



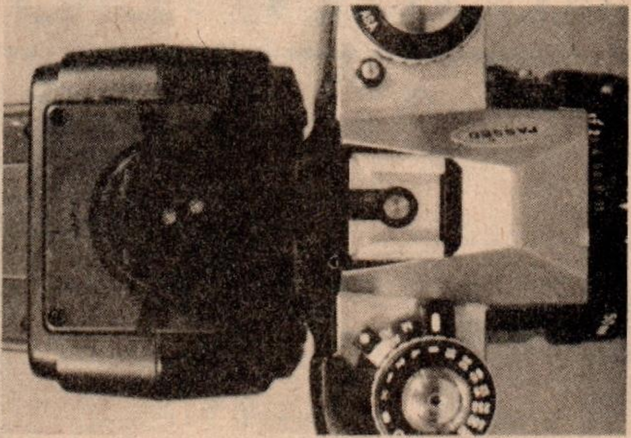
The 'eye' of an automatic flash. A phototransistor measures incoming light and shuts the flash down when the right amount of light comes back. Removeable sensors allow remote operation of the flash.



The auto flashes of the 60s used a system called 'Dump Quenching' which meant that when the integrated circuit decided that there had been enough light emitted it would cut out the flash by shorting the remainder of the power in the capacitor to the negative rail. The system worked well but wasted a lot of power, so in the early 70s a 'Blocking Quench' system was introduced (Fig. 11). This used a silicon sensor and integrated circuit as before but instead of shorting the circuit it used a faster thyristor which cut the power from the capacitor to the flash gun thus leaving the capacitor still partially charged.

On some recent auto exposure cameras there is a special connection for flash guns made by the same manufacturer (for the really dedicated) whereby the exposure calculation circuitry controls the flash power directly and also has an LED readout in the viewfinder informing the photographer of the state of readiness of the flash gun and also whether there was enough light to illuminate the subject correctly.

Recent innovations in portable flash photography include double flash heads on one body — one a low power flash and the other high power, for bounce diffused lighting. Rollei have recently introduced their latest flash which has an illumination range of 80 feet for an average speed film. The development in their flash is that it has an LED readout — and when the ASA film speed and aperture used are fed in it works out the distance the flash can cover.

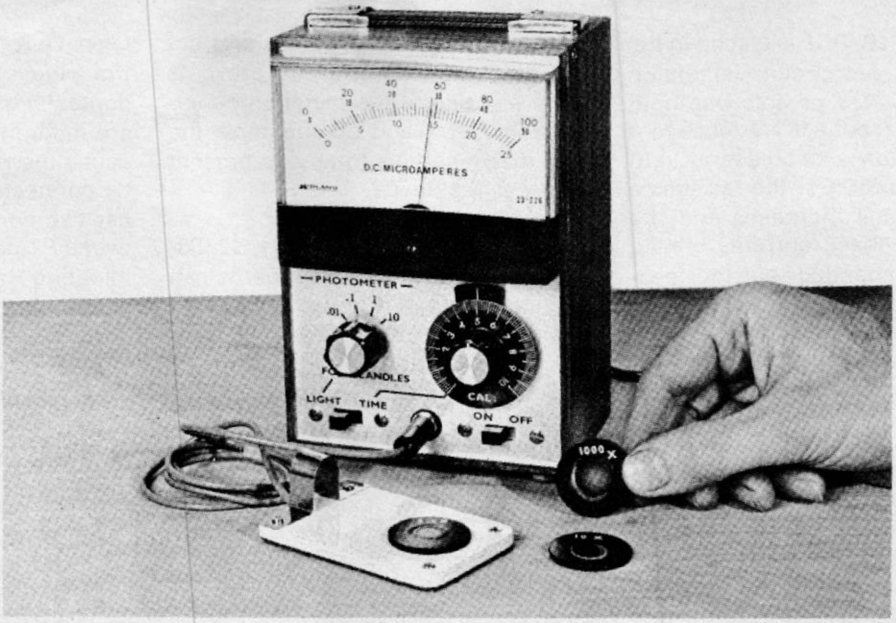


Hot shoe contacts of two dedicated flashes. On the right, the Minolta Auto Flash has an extra contact that automatically puts the camera in flash synchronization whenever the flash is ready. The Canon shoe (on the left) has two contacts, One for setting shutter speed, the other for setting the aperature.

This gives some idea of the way in which electronic flash photography is rapidly developing. The flashguns these days can even switch the cameras electronic shutters to the speeds required to take flash pictures. ●

All the figures illustrating this article are reproduced from "Electronics And The Photographer" by T.D.Towers, and appear by permission of the publishers, Focal Press. We recommend this book to anyone wanting to read further on this subject. You'll have to send for it though, write to Focal Press, 31 Fitzroy Square, London W1, U.K.

In addition, special thanks to Black's Cameras (and their Thornecliffe Park Branch in particular) for the loan of the Minolta XD11, Canon A1 and flash used in the pictures in this articles.



BUILD A

Wide-Range Photometer/Enlarger and/Exposure Met

BY A. A. MANGIERI

Valuable darkroom accessory covers broad spectrum of light intensities and exposure time ranges

IF YOU do any type of photographic enlarging, contact printing, light-intensity measuring, etc., you need a photometer/exposure-time meter. Here is a high-resolution instrument with 0.01-, 0.1-, 1.0 and 10-foot-candle (ft-c) ranges that are usable down to 0.0005 ft-c. Neutral-density filters can be used to extend the upper range to 10,000 ft-c.

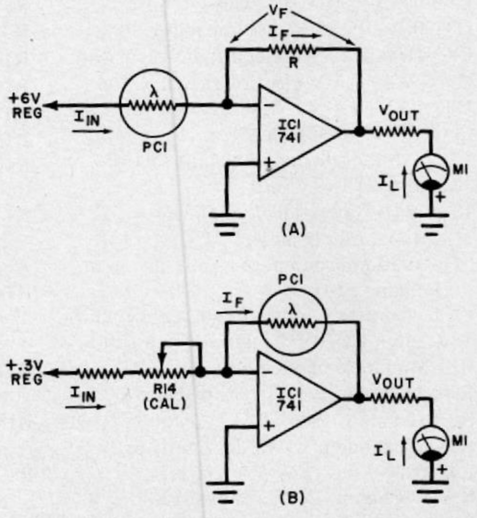
Exposure-time ranges include 0 to 25, 50, and 100 seconds at any multiple or intermediate range desired. A calibration control accounts for differences in paper speed and other factors. And a number of contrast ranges assist in paper grade selection.

The assembled instrument features an illuminated meter scale, and a high-stability operational amplifier IC that has instant-on, zero drift, and immunity from line-voltage variations. A high-speed linear cadmium-sulfide photocell is used to sense the measured light.

About the Circuit. In the simplified light-measuring circuit shown in Fig. 1A, as the light intensity on *PC1* increases, the photocell's resistance decreases. This causes an increase in the input current, I_{in}. The feedback current in light-range resistor *R* produces a voltage, V_F, across this resistor which is the same as V_{out}. Consequently, *M1* indicates in direct proportion to the intensity of the light.

In the basic time-measuring circuit

Fig. 1. Simplified op amp circuit for measuring light level (A) and exposure time (B).



shown in Fig. 1B, *PC1* is placed in the op amp's feedback circuit. Calibration potentiometer *R14* presets the input current—and feedback current—to a fixed level. With a decrease in light intensity striking *PC1*, the resistance of the photocell increases and the input and feedback currents remain equal and unchanged, but the feedback and output voltages increase. Thus, the meter indications are inversely proportional to the intensity of the light falling on *PC1*. An appropriate setting of *R14* provides a direct reading in seconds on *M1*.

The complete schematic diagram of the photometer/timer is shown in Fig. 2. Switch *S2* provides either light-level or time modes, while *S1* is used to select the light range. A split zener-diode power supply (*D1* and *D2*) provides the regulated voltages for *IC1*. Potentiometer *R16* sets the op amp's input bias, while *R15* is the offset-voltage null adjustment.

Meter movement protection is provided by the limiting (saturating) action of the op amp, while *C5* prevents rapid pegging of the meter's pointer. Capacitors *C1* and *C3* minimize the amplifier response to any ac present on the signal leads.

Construction. Except for *S1, S2, S3, R14, M1*, and *T1*, all components can be mounted on perforated board with push-in solder clips. Use a socket for *IC1*. Install *C1* and *C2* close to the IC socket. (A completely wired board assembly is shown in Fig. 3.)

Select an enclosure that is large enough to accommodate the meter and other front-panel controls, with enough depth to permit mounting the board assembly and *T1*. Start assembling the system by machining the enclosure's front panel to accept the controls and meter movement, and mount the parts in their respective holes. Do not forget to install phone jack *J1* on the front panel. Note that a two-circuit phone jack and plug are used. Only the tip and ring contacts of the plug (and their respective jack contacts) are used for the *PC1* lead connections. This is necessary because the photocell's leads must not be connected to ground. If you wish, use two-conductor shielded cable between *P1* and *PC1*, leaving the shield "floating" at the *PC1* end and connecting to the barrel contact on *P1*.

The meter scales (0-25 and 0-100) must be properly labeled to provide the appropriate meter readings. This can be accomplished with the aid of a dry-transfer lettering set. Carefully remove the snap-on cover from the meter movement and label the scales as shown in the lead photo. While the cover is off the movement, you can install the optional illumination lamps (*I1* and *I2*). Uniform scale illumination can be obtained by installing a bright reflective metal strip above the meter scales.

Use a well-subdivided scale for calibration potentiometer *R14*. Either

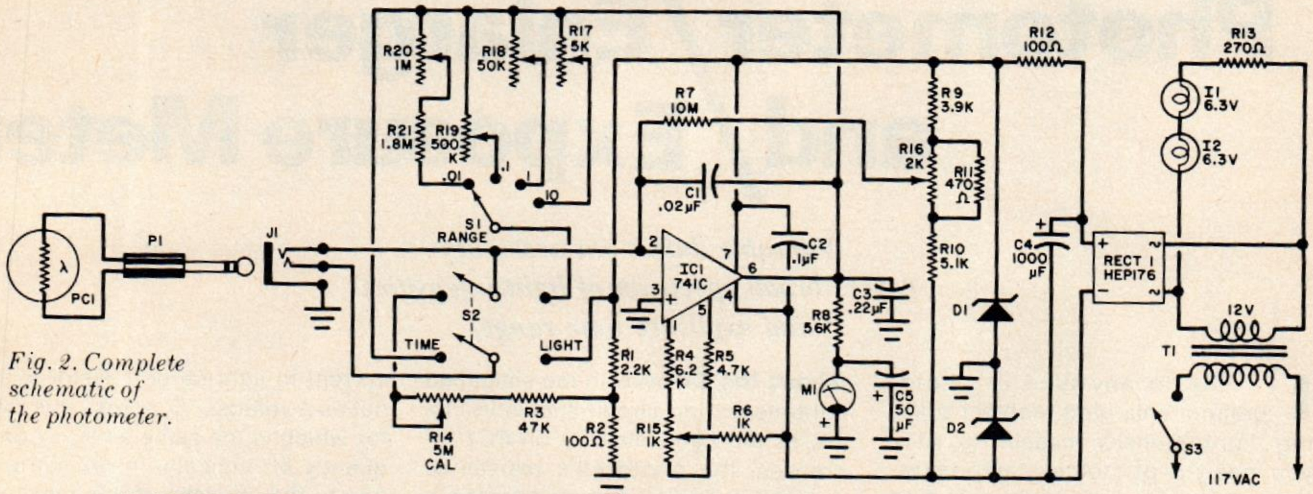


Fig. 2. Complete schematic of the photometer.

PARTS LIST

C1—0.02-μF, 25-V disc capacitor
C2—0.1-μF, 25-V disc capacitor
C3—0.22-μF, 25-V disc capacitor
C4—1000-μF, 35-V electrolytic capacitor
C5—50-μF, 15-V electrolytic capacitor
D1, D2—6.2-V, 1-W zener diode (HEP103 or similar)
I1, I2—Meter illumination lamp kit (Midland F71)*
IC1—741C operational amplifier
J1—Miniature phone jack
M1—0-50-microampere, 4-in. dc meter (Midland F64)*
PC1—Linear high-speed photocell (Clairex CL705HL) (Do not substitute)
P1—Miniature phone plug
R1—2200-ohm, ½-W, 10% resistor
R2—100-ohm, ½-W, 10% resistor
R3—47,000-ohm, ½-W, 10% resistor
R4—6200-ohm, ½-W 5% resistor
R5—4700-ohm, ½-W, 5% resistor
R6—1000-ohm, ½-W, 10% resistor
R7—10-megohm, ½-W, 10% resistor
R8—56,000-ohm, ½-W, 5% resistor
R9—3900-ohm, ½-W, 5% resistor
R10—5100-ohm, ½-W, 5% resistor
R11—470-ohm, ½-W, 10% resistor
R12—100-ohm, 1-W resistor (see text)
R13—270-ohm, 2-W resistor (see text)
R14—5-megohm, audio-taper potentiometer (Mallory U65 or similar)
R15—1000-ohm wirewound pc-type potentiometer (Centralab V-1000 or similar)
R16—2000-ohm wirewound pc-type potentiometer (Centralab V-2000 or similar)
R17—5000-ohm carbon pc-type potentiometer
R18—50,000-ohm carbon pc-type potentiometer
R19—500,000-ohm carbon pc-type potentiometer
R20—1-megohm carbon pc-type potentiometer
R21—1.8-megohm, ½-W resistor
RECT1—1-A, 200-V PIV bridge rectifier (HEP176 or similar)
S1—Single-pole, four-position, shorting-type rotary switch
S2—Dpdt slide switch
S3—Spst slide switch
T1—12-V, 0.3-A filament transformer (Radio Shack 273-1385 or similar)
Misc.—Perforated board; flea clips; case 3" x 4½" x 6½" (Vector W30-66-46); miniature shielded cable; line cord; dial plate; knobs; IC socket; 1/16" phenolic sheet; 22-megohm carbon resistors (2); 15,000-ohm carbon resistor; etc.

* The following are available from Electronics Distributors, Inc., 4900 N. Elston Ave., Chicago, IL 60630; meter (F64 less lamps), meter scale illumination kit (F71).

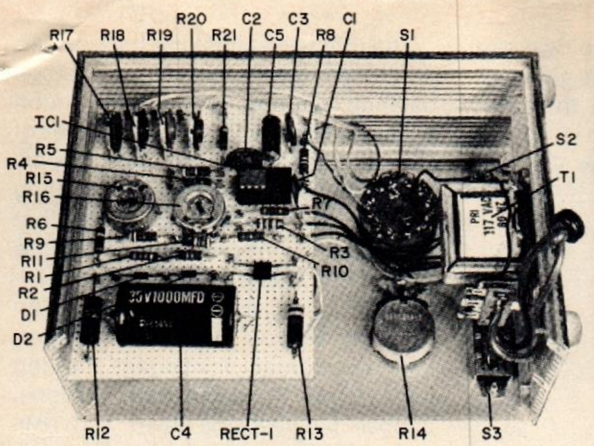


Fig. 3. Interior view of prototype showing placement of all parts.

a panel-mounted dial plate or a rotating dial flange can be used. Identify the front-panel controls with dry-transfer lettering.

Mount *PC1* between two pieces of thin phenolic board, allowing the sensitive surface of the cell to protrude through a hole in the upper board. The protrusion should be about $^1/_{16}$ in. (1.59 mm) above the board's surface. After properly mating the boards, remove *PC1* and spray the outer surfaces a flat (matte) white paint.

Connect and solder the two inner conductors of a thin two-conductor shield cable to the leads of *PC1*. (Do *not* connect the shield to the photocell.) Insulate the solder joints with electrical tape. Place *PC1* in position and secure the two pieces of board together, with the cable sandwiched between them. A metal finger loop can be mounted on one end of the assembly for ease in positioning the sensor.

Connect the free end of the microphone cable to *P1*. The shield goes to the barrel contact, while the inner conductors go to the ring and tip contacts.

Power transformer *T1* can be mounted to the bottom or one wall of the enclosure with machine hardware. Connect its primary leads to a two-lug, *non*-grounding type terminal strip. Route the line cord through a rubber-grommet-lined hole drilled through the rear wall of the enclosure. Connect it to *S3* and *T1* as shown in Fig. 2.

Adjustment and Calibration. Using clip leads, connect a milliammeter in series with *R12*. If necessary, adjust the value of *R12* for an indicated current of approximately 70 mA. Install *R13* and measure the voltage drop at the meter lamp terminals; it should be 6.3 volts across both lamps. If not, adjust the value of *R13*. Check that there are about 20 volts dc across *C4*, and about 6 volts across *D1* and across *D2*.

To adjust the bias current of *IC1*, set *S2* to TIME, *R14* to maximum resistance, and remove *R1* from the circuit. Connect about 44 megohms of resistance (two 22-megohm carbon resistors in series) to a phone plug and insert it into *J1*. Then, adjust *R16* until *M1* indicates zero. If this cannot be accomplished, replace *R10* with a resistance between 3900 and 7500 ohms. Alternatively, you can increase (or omit) *R11* for a broader range.

The next adjustment compensates *IC1*'s input offset voltage. With 44 megohms plugged into *J1* and all other conditions as above, connect a 15,000-ohm, 10-percent resistor across pin 2 (input) and pin 3 (ground) of *IC1*. Adjust *R15* for a zero indication on *M1*. If this is not possible, slightly increase the value of *R5* and decrease *R4*, or vice versa. Maintain the sum of *R4* plus *R5*, at 8000 ohms or more.

Upon removing the 15,000-ohm resistor, *M1* should remain at zero. If not, repeat the input bias and offset adjustments. Install *R1* and check to see that there is a 0.3-volt dc drop across *R2*. Adjust *R1* or *R2* if necessary.

The final adjustments are made to calibrate the foot-candle ranges. The nominal resistance of *PC1* is 28,000 ohms at 2 ft-c and 56,000 ohms at 1 ft-c. Set range potentiometers *R17* through *R20* about halfway through their travels and set *S2* to LIGHT. Connect a 5600-ohm resistor to a phone plug and insert it in *J1*. This simulates the ideal resistance of *PC1* at 10 ft-c.

Set *S1* to the 10-ft-c range and adjust *R17* until *M1* indicates full-scale. Similarly, use a 56,000-ohm, a 560,000-ohm, and a 5.6-megohm resistor, respectively, to calibrate the 1-, 0.1-, and 0.01-ft-c ranges while adjusting the corresponding potentiometers. The simulating resistors used should have 5-percent or better tolerances. If an accurate photometer is available, you can use it to calibrate the light ranges.

Although neutral-density filters can be used to extend the light ranges, filters using film negatives are satisfactory for non-critical use. Using the enlarger as a light source, focus it and remove the film from the carrier. Place *PC1* on the enlarger easel and set *S1* to the 1-ft-c range. Stop down the lens until *M1* indicates 1 ft-c. For the X10 multiplier, select a portion of unwanted negative that, when placed over the sensor, causes the meter to indicate 0.1 ft-c. Affix the film to a thin blackened washer or disc that fits over the top of the photocell. Place the glossy side up to protect the emulsion from scratches. Selected film bits should be uniform and without detail.

Application. Measure light with *S2* set to LIGHT and *S1* set to the desired range. Measure time with *S2* set to TIME and *R14* set to a previously determined calibration setting for the particular application. The calibrating procedure for *R14* accounts for paper speeds, mode of operation, time scale in use, and processing factors. This is performed once for each set of conditions and recorded for future use. When calibrating or using the instrument, all darkroom lights must be off. Avoid directly illuminating *PC1* by the meter's lights.

Select an average negative and make the best possible print in the conventional manner using test strips. As an example, let us assume the best print required 15 seconds of exposure time at f/8 aperture. For the integrated light method, you will need a 2½-in. (6.35-cm) square piece of ground glass as a light scatterer. With the enlarger undisturbed, place *PC1* at the center of the projected image and set *S2* to TIME. Hold the light scatterer up to the enlarger's lens. Then adjust and record the settings of *R14* that result in 15 seconds indication on the 25-, 50-, and 100-second scales where possible. Also, record the data on the projection paper in use.

To use the exposure meter at a later date, set *R14* to the recorded setting for the particular paper and time scale. At almost any lens aperture and print magnification, use the light scatterer and observe the required exposure time. You can select the exposure time desired by varying lens aperture (or vice versa). A blackened paper tube from a 35-mm film carton positioned over the sensor checks or eliminates the effect of stray light. During exposure, S3 can be switched off.

Calibrate R14 with the lens aperture set to one or two stops larger than the exposing aperture of the test print when using the instrument with small lamp enlargers. In the example, open the lens one full stop to f/5.6. Calibrate R14 for 15 seconds indication on each time scale where possible. Using this mode of measurement, observe exposure time at any selected aperture and close down one stop before exposing. Alternatively, you can halve the indicated exposure and expose at the measuring aperture.

The spot method determines exposure time at print shadows without the use of a light scatterer. To calibrate, place PC1 at important print shadows (bright portion of the projected image) and adjust R14 until the meter indicates 15 seconds on each time scale. To use this mode, set R14 as recorded for the paper and time scale, place PC1 at the print shadows, and observe the required exposure time.

Contrast measurements use the light scales to determine the ratio of [illegible] bright and dark portions o[illegible]. The table gives various contras[illegible]nges with the setup

S1 Range (initial)	M1(%) (preset)	S1 Range (final)	Contrast Range
0.01	100	0.1	10
0.01	100	1	100
0.01	100	10	1000
0.1	40	0.1	2.5
0.1	40	1	25
0.1	40	10	250
0.1	20	0.1	5
0.1	20	1	50
0.1	20	10	500

requirements. Because it is used most frequently, set up the 0-to-25 range with S2 on LIGHT and S1 on the 0.1-ft-c range. Place PC1 at the darkest area of the image and adjust the lens aperture until M1 indicates 40 percent of full-scale. Advance S1 one decade to the 1-ft-c range. Note that M1 now indicates 1 on the 0-to-25 scale.

Move PC1 to the brightest area of the image and read image contrast directly on M1. Middle contrasts of 8 to 15 indicate the use of normal-contrast paper. By keeping notes, relate contrast measurements with the required paper grade.

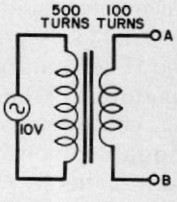
The integrated light method, preferably used with negatives of average balance, requires either a correction or recalibration of R14 for negatives of predominantly light or dark scenes. The spot method, capable of handling almost any negative, assumes that projected print shadow areas are larger than the photocell's diameter.

By installing a photocell in the tip of a probe, you can take measurements on contact print boxes, viewing screens, etc. For camera applications, choose between the LIGHT and TIME scales. The TIME scales can be interpreted in any convenient manner, such as 0 to 2.5, 5, and 10 seconds or 0 to 250, 500, and 1000 milliseconds, and easily converted to fractional shutter speed if desired.

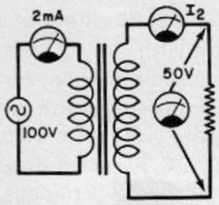
Bear in mind that CdS cells exhibit a memory effect related to previous light history. Therefore, avoid exposing PC1 to sunlight or bright room lights prior to use. Also, response time increases with decreasing light levels. So, allow time for the meter indication to settle at very low light levels. Long-term meter drift proved to be nonexistent in use, but you can check meter zero by setting S2 to LIGHT and removing P1. ◆

WHAT DO YOU KNOW ABOUT TRANSFORMERS?

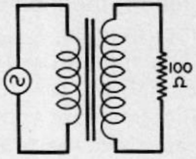
BY ROBERT P. BALIN



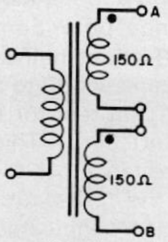
1. *Assuming no losses, the output voltage between A and B is ____ volts.*



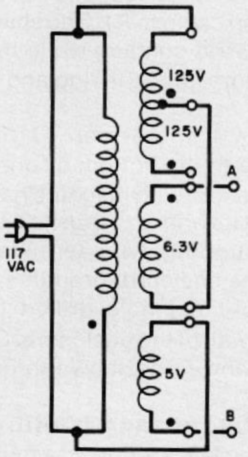
2. *Assuming no losses, secondary current I_2 is ____ mA.*



3. *The 100-ohm secondary load will look like ____ ohms to the primary voltage supply.*



4. *If the two 150-ohm windings are connected as shown, the output impedance between A and B will be ____ ohms.*



5. *Taking into account the way the windings are connected and their polarity markings, the output voltage between A and B will be ____ volts.*

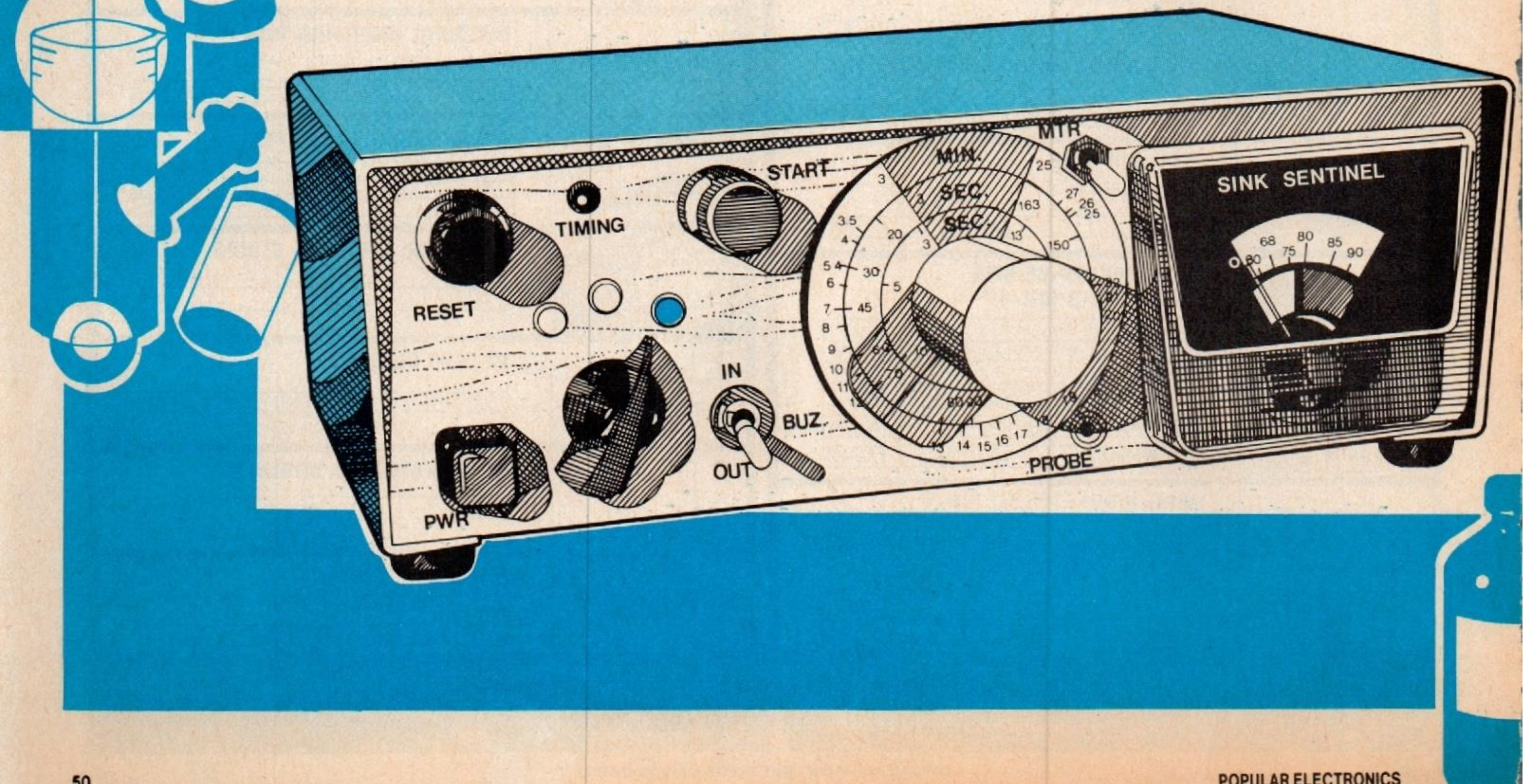
Answers: 1. 2 volts; 2. 4 mA; 3. 25 ohms; 4. 600 ohms; 5. 9.3 volts.

THERE are many reliable timers, thermometers, and quality-control devices to aid the photographer. Unfortunately, most of these commercial devices are expensive. You can, however, build the "Sink Sentinel," which serves as a photo-lab timer, thermometer, and conductivity tester, at a fraction of the cost you would expect to pay for a similar commercial device. The Sink Sentinel accurately monitors the temperature of film-processing chemicals, times film processing, and tells you when your film or paper can come out of the hypo.

About the Circuit. The timer portion of the Sink Sentinel is shown in Fig. 1. It is based on a conventional 555 timing circuit (*IC1*). TIME SET potentiometer *R2* and RANGE switch *S3*, the latter selecting the appropriate range capacitor (*C1* and *C2* shown, but more capacitors can be added, as desired), determine the timing range.

Timing is initiated by pressing START switch *S4*, which places pin 2 of *IC1* at ground potential. Pin 2 is normally held high by *R3*. The timing interval in seconds is approximately equal to 1.5 times the value of *R2* in megohms times the value of the capacitor (selected by *S3*) in microfarads. The timing values for the R

BUILD A PHOTO SINK



and C values shown in Fig. 1 were set in three ranges. The first and most commonly used for photographic printing and enlarging is from about 3 to 23 seconds; the second from 20 seconds to nearly 3 minutes; and the last from 3 to almost 30 minutes. If desired, the R and C values can be changed to produce any desired timing interval.

During the timing interval, the output of *IC1* at pin 3 is high and lamp *I1 and* alarm *A1* (if the latter is switched in via *S5*) will not operate, but *LED1* will be on. At the end of the timing cycle, the output of *IC1* goes low to allow *A1* and *I1* to operate. At this point, *LED1* extinguishes. If at any time you wish to terminate the timing cycle, you simply press RESET switch *S2*.

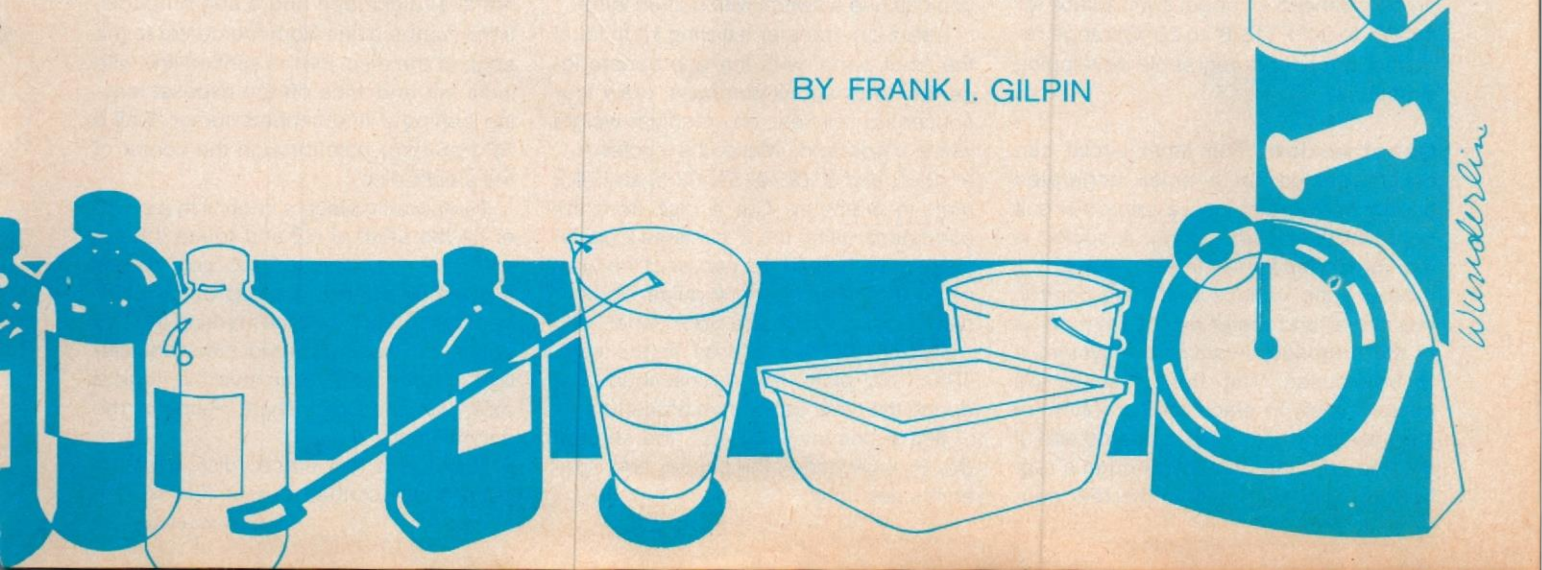
An optional enlarger/safelight powering arrangement is provided by sockets *SO1* and *SO2* and relay *K1*, as shown in Fig. 1. If you prefer not to have this option, you can eliminate *K1* and *SO1* and *SO2*. Assuming you decide to keep this option, when *K1* is not energized at the end of a timing cycle, *SO2* is powered and can be used to power your safelight. During the timing cycle, *K1* is energized, connecting *SO1* to the power line for powering an enlarger.

The temperature/conductivity section

DARKROOM SENTINEL

Moderately priced system monitors temperatures and film process time of photographic chemicals, and alerts user when film or paper processing is completed

BY FRANK I. GILPIN



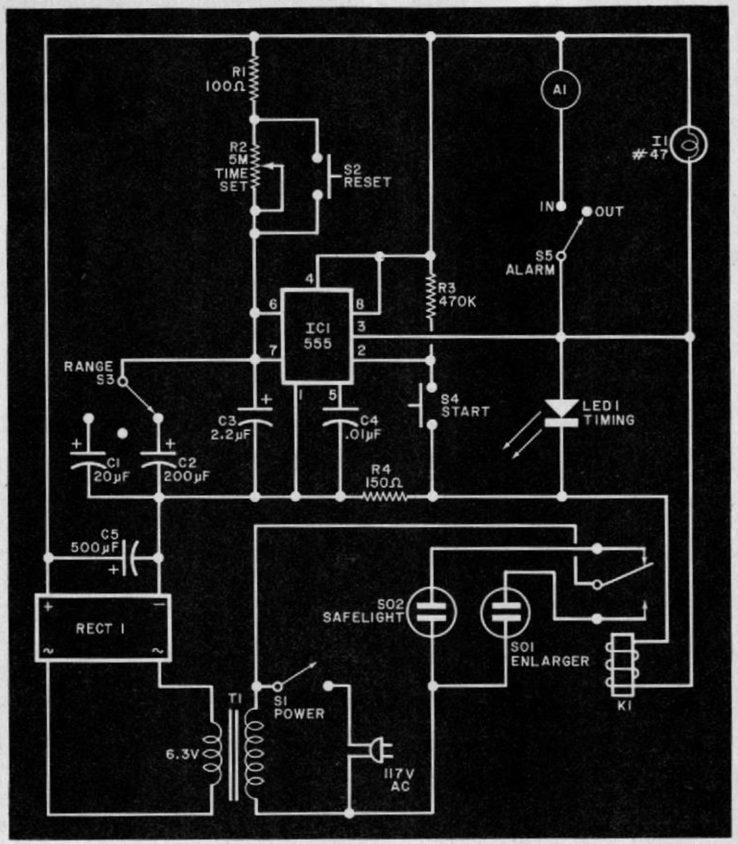


Fig. 1. Basic 555 timer can be adjusted for almost any desired timing ranges. The relay circuit allows timing an enlarger then turning on safelight.

PARTS LIST

A1—6-volt dc alarm or buzzer (Mallory Sonalert No. SC628, Radio Shack No. 273-049, or similar)
B1—9-volt battery
C1—20-µF, 20-volt electrolytic
C2—200-µF, 20-volt electrolytic
C3—2.2-µF, 20-volt electrolytic
C4—0.01-µF disc
C5—500-µF, 20-volt electrolytic
I1—6-volt lamp (No. 47 or similar)
J1—Subminiature phone jack
K1—6-volt, low-current relay (Radio Shack No. 275-004 or similar)
LED1—Red discrete light-emitting diode
M1—0-to-50-µA dc meter movement (Radio Shack No. 22-051 or similar)
P1, P2—Subminiature phone plug
Q1—Pnp germanium transistor in TO1 or TO4 metal case (see text)
The following resistors are ½ - watt, 10%:
R1—100 ohms
R3—470,000 ohms
R4—150 ohms
R5,R6—3000 ohms
R8—3600 ohms
R2—5-megohm linear-taper potentiometer
R7—100,000-ohm miniature potentiometer
RECT1—Rectifier (Radio Shack No. 276-1626)
S1—Spst switch
S2,S4—Normally open spst pushbutton switch
S3—Single-pole, three-position nonshorting rotary switch
S5,S6—Spdt switch
SO1,SO2—Chassis-mounting ac receptacle
T1—6.3-volt, 300-mA transformer
Misc—9″ × 6″ × 3½″ (22.9 × 15.2 × 8.9 cm) aluminum cabinet; holder for B1; ac line cord with plug; pointer knob; plain pressfit control knob; 2″ × 2″ (10.8 × 10.8 cm) perforated board; 36″ (about 1 m) stranded two-conductor speaker cable; 1/16″ clear plastic sheet; quick-set epoxy; plastic cement; silicone-rubber cement; 4″ (21.6 cm) chrome or stainless-steel wire (see text); dry-transfer lettering kit; rubber grommets (2); hookup wire; machine hardware; etc.

of the Sink Sentinel is shown in Fig. 2. It is based on the Wheatstone bridge principle. The circuit measures the relative resistance of either a plug-in temperature or conductivity probe.

The temperature probe is made up of an ordinary pnp germanium transistor with a metal TO1 or TO4 case. Sensing is performed in the emitter-collector junctions. Although such a temperature probe is limited in range, it will suffice for the 60° to 90° F (15.6° to 20° C) range required in most photographic developing situations.

Construction. The timer circuit can be assembled on a small perforated board, or you can use a printed-circuit board of your own design. A socket is recommended for *IC1* in either case.

Mount the various switches, control, indicators, and meter on the front panel of the enclosure in which the system is to be housed. This done, secure the power supply in place on the bottom of the enclosure. Pass the prepared end of the line cord into the box through a rubber-grommet-lined hole in the rear panel. Then, before connecting and soldering the line cord to the appropriate points in the circuit, tie a knot about 4″ (10.2 cm) from the prepared end on the inside of the box to prevent the cord from being torn loose.

Light-emitting diode *LED1 mounts* on the front panel via a rubber-grommet-lined hole. Note that a separate lamp and switch can be used for *I1* and *S1*, or you can use a switch with built-in lamp.

Use a dry-transfer lettering kit to label the front panel with the appropriate legends. With an ink compass, draw four concentric circles on medium-weight white cardboard. Make the circles ⅝″, 2″, 2½″, and 3″ (15.9, 51, 63.5, and 76.2 mm) in diameter. Cut a disc from the cardboard, using the 3″ circle as a guide. Next, cut a hole in the center of the disc, using the ⅝″ circle as a guide. Rubber cement the disc to the front panel, with the shaft of *R2* centered in the hole. (This "dial plate" will be inscribed later during the timer calibration procedure.)

Slip a pointer knob onto the shaft of *S3*. Properly index the pointer and tighten the setscrew.

Next, cut a 3″ disc from 1/16″ (1.6-mm) thick sheet of clear plastic. Using a metal straightedge and a sharp needle, firmly scribe a line from the center to the edge of the disc. Fill the scribed line with india ink and wipe off the excess, leaving behind a fine scribed cursor. Drill a ⅜″ (9.5-mm) hole through the center of the plastic disc.

Temporarily place a knob with a pointer on the shaft of *R2* and rotate it to locate the two stops on the pot. Locate this angular gap at the top of the cardboard disc (lightly pencil marking the two points on the cardboard disc) equidistant to both sides of an invisible vertical axis with the pot's shaft. Remove the pointer knob.

Now place the plastic disc over the pot's shaft, scribed cursor line toward

(Continued on page 56)

SINK SENTINEL

(Continued from page 52)

the cardboard disc. Center the plastic disc over the cardboard disc and line up the cursor line with the *right* pencilled stop mark on the cardboard disc. Temporarily tape the plastic disc in place. Rotate the pot's shaft fully counterclockwise. Apply a thin bead of plastic cement to the back of a plain plastic friction-fit control knob. Slide the knob onto *R2*'s shaft and gently press it against the plastic disc. Allow the cement to set for at least 8 hours before removing tape.

Meanwhile, fabricate the conductivity probe as follows. The probe itself (see Fig. 2) consists of a pair of closely-spaced conductors, with a limiting resistor, that can be plugged into *J1*. The probe elements can be made from two 2″ (5.1-cm) lengths of chrome or stainless-steel 12-gauge rod. A bicycle spoke or a length of stainless-steel antenna rod will do.

Solder *R8* to one end of one of the rods. Then trim away 1″ (25.4 mm) of one of the conductors at one end of a 36″ (about 1-meter) length of speaker cable. Strip away the insulation from both conductors of this end of the cable, twist together the wires and tin them lightly with solder. Connect and solder the shorter conductor to the free end of *R8* and the other conductor to one end of the remaining rod.

Now, cut two 1″ × ⅜″ (25.4 × 9.5 mm) strips from a sheet of 1/16″ thick sheet of plastic. Drill two ⅛″ (3.2-mm) holes ⅛″ apart in the center of both strips of plastic. Slip the free ends of the rods through one hole in each strip of plastic and apply a drop of fast-setting epoxy cement at each hole to secure the strips to the rods.

While the cement is setting, drill a ½″ hole through the center of the bottom of a plastic film or pill container. Drill eight or more ⅛″ holes around this hole and 25 or more ¼″ holes through the body of the container. Assuming the epoxy cement has set, slightly bend the tops of the rods apart to obviate any possibility of the two touching each other.

Pass the free end of the speaker cord through the ½″ hole from the *inside* of the container and pull it through until the tips of the rods are just slightly recessed from the open end of the container. Then liberally apply silicone-rubber cement over the resistor and the three soldered connections. Just fill the space around and between the tops of the rods to fill the ½″ hole. This will provide a mechanically secure mount for the conductivity probe's elements and a seal against the caustic solutions into which it will be immersed. Allow the cement to set for at least 24 hours.

To one end of a 36″ length of speaker twin-lead cord, connect and solder a subminiature phone plug. Separate the cord at the other end for a distance of about 4″ (10.2 cm). Strip away about ⅜″ of insulation, twist together the wires, and lightly tin the conductors with solder. Plug in and turn on the Sink Sentinel. Then, making sure to prevent the tinned conductors from contacting each other, insert the phone plug into *J1*.

Temporarily connect the collector and emitter leads of a pnp germanium transistor to the tinned conductors. Make sure that the emitter connects to the *R5* junction and the collector connects to the *R7/M1* junction. Note that the meter's pointer swings upscale. In a typical 68° F (20° C) ambient room, adjust *R7* for about a one-quarter-scale pointer swing.

Bring the transistor close to a turned-on light bulb; the meter's pointer should swing to full-scale. If this does not occur, repeat the procedure with a different germanium transistor until you locate one that is relatively heat sensitive. Put a kink or other identifying mark on the transistor lead connected to the speaker cable conductor with ribbed insulation. Then disconnect the cable from the circuit and turn off the power.

Once you have your heat sensitive transistor, clip away its base lead close to the metal case that houses it. Connect and solder the emitter and collector leads of the transistor to the cable's conductors, making sure that the identified transistor lead goes to the cable conductor with ribbed insulation. This done, pack silicone rubber cement over the exposed metal connections and down to the case of the transistor. Do *NOT* coat the sides or top of the transistor's case with the cement. Put this cable assembly aside to allow the cement to set for at least 24 hours.

Calibration. The timer section can be calibrated with the aid of a stopwatch, digital watch with seconds display, or an ordinary analog watch with a sweep second hand. Plug the Sink Sentinel into the power line and turn on the power. Lamp *I1* should come on and the alarm will sound if ALARM switch *S5* is on.

Set the RANGE switch to the maximum time (*C2* in Fig. 1) and the pointer knob for minimum resistance (fully counterclockwise). Carefully mark with an awl or the point of a pin, on the plastic disc over the potentiometer dial, the points where the cursor line crosses the circles on the cardboard disc. Remove the cursor knob and drill a 1/16″ hole at the two points marked. Then slip the knob back on the pot's shaft.

With the knob fully counterclockwise, push the point of a pin through both holes in the cursor disc to lightly detent the cardboard disc. Turn the knob fully clockwise and repeat the procedure. Return the pot fully counterclockwise.

Now calibrate the minutes range on the inner circle of the dial plate as follows. Simultaneously start your stopwatch (or wait for your watch to reach the zero seconds mark) and press START switch *S4*. The LED should come on, *I1* should extinguish, and the alarm should cease to sound (assuming it is switched in). When the countdown is completed by the timer, *I1* will come on, the LED will extinguish, and the alarm will sound. Note how long this took on a sheet of paper under the heading "MIN." Adjust *R2*'s cursor slightly clockwise and repeat this procedure. At the end of the countdown, note the time elapsed and slightly detent the inner circle on the cardboard with a pin. Repeat this procedure until the pot is at its fully clockwise stop. Then repeat this procedure for the

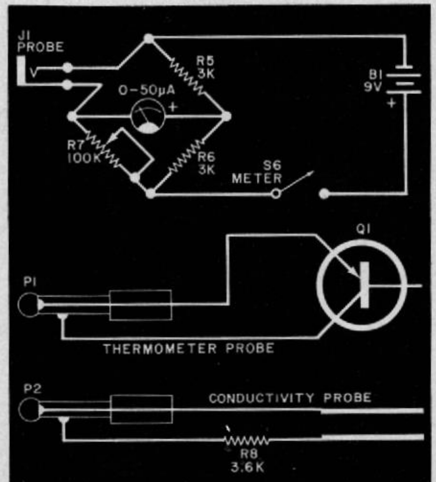


Fig. 2. Temperature/conductivity is measured on conventional Wheatstone bridge. Both probes are also shown. Temperature probe uses standard germanium transistor, while resistivity probe has stainless steel rods.

other two positions of the RANGE switch and the two SEC circles on the cardboard disc. (If you prefer, you can adjust the pot's setting to coincide with exact seconds and minutes to obtain a neater dial plate. This is time-consuming but well worth the effort.)

When you have completed calibration, turn off the Sink Sentinel and remove the cursor knob from the shaft of the pot. Mark three or four points on the perimeter of the cardboard disc and on the front panel exactly in line with them. Then lift off the cardboard disc. Using a dry-transfer lettering kit (or working with a pen), place tick marks at each detented point on the circles on the disc and label each with the appropriate time in your calibration listing. Then rubber cement the disc back in place, using the marks on it and the front panel as a guide. Slip back onto the shaft of the pot the cursor knob. (A typical finished dial is shown in the lead photo.)

The temperature probe can be calibrated with the aid of an accurate mercury-column thermometer. Since the most used range will be between 60° and 90° F, leave the probe in ambient room air (about 68° F) until the meter's pointer deflection stabilizes. Then adjust *R7* for a pointer deflection of about one-quarter scale. Carefully place a pencil mark on the scale at this point. Place both the mercury thermometer and temperature probe in water and adjust the temperature for an indicated reading of 95° F on the mercury thermometer. Again, place a pencil mark on the meter's scale at this point. Reduce the temperature of the bath by 2.5° F and again make a pencil mark on the scale. Repeat reducing the bath's temperature by 2.5° F and indicating each point on the scale until you reach 60° F. Turn off the power and remove the line cord from the ac power line.

Carefully remove the dial-scale card from the meter and relabel it with a dry-transfer lettering kit for each of the pencil marks. Start with 60° F and label only in 5° F increments, placing a small but easily legible tick at the 2.5° locations on the scale. Then replace the scale card. Plug in and turn on the Sink Sentinel and replace the temperature probe with the conductivity probe.

Calibration of the meter scale for conductivity is simple. Allow a cold water tap to run for awhile. Then fill a clean container with water. Place the conductivity probe in the water and mark the meter pointer's deflection on the scale with a pencil. Add some hypo to the water and wait a few seconds; the meter's pointer should swing upscale, the amount of deflection determined by the concentration of the hypo in the water. No further marks need be made on the meter's scale. Run cold water in the container while observing the pointer deflection. As the concentration of hypo diminishes and finally is all gone, the meter's pointer will swing down-scale and ultimately come to rest at the mark you made on the scale.

Turn off the power and, using a black felt marker, place an easily legible dot at the point pencilled in just below the arc of the scale. Then replace the protective cover on the meter and assemble the project's case.

Use. When you start your film-washing cycle, set the timer for a period of slightly less than the time recommended by the chemical manufacturer. Insert the conductivity probe into the wash water. Then when the timer's alarm sounds (or *I1* lights), note the position of the meter's pointer with respect to the mark made below the scale arc. If it is at the mark, it is safe to stop the wash cycle. However, if the pointer is above the mark, continue to wash until it gets there.

To operate the complete system, turn on the METER switch (*S6*), plug in the temperature probe, and place the probe in the chemical bath. When the proper temperature is reached, set RANGE switch *S3* to the appropriate range and TIME SET control *R2* to the desired interval. Start the developing cycle and press START switch *S4*. (If you desire visual signals only, switch off the alarm with *S5*.)

When the programmed-in developing time is completed, the timer will signal with both *I1* and the alarm (if the latter is switched in). Set the time for the correct fixing period and press START switch *S6* to start the timing cycle.

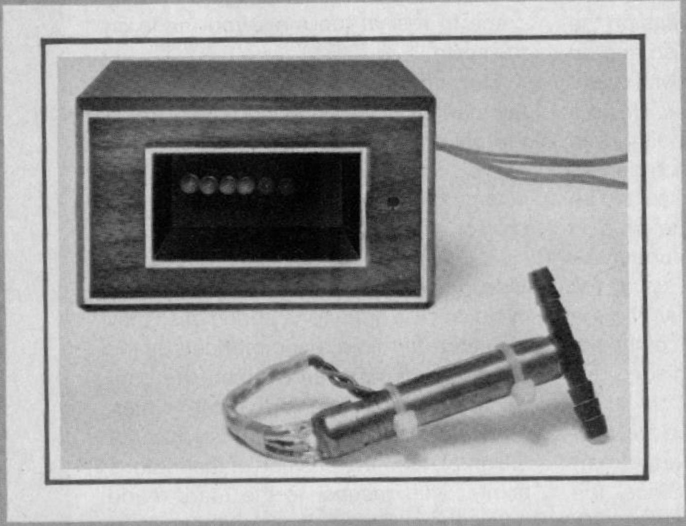
During the fixing cycle, you replace the temperature probe with the conductivity probe. When the timer's alarm sounds, end the fixing and start the washing cycle. Set the timer just short of the recommended period and, when the timer signals again, immerse the conductivity probe into the wash water. Continue washing until the meter's pointer drops to the mark on the scale.

You will find that, once you become familiar with its operation, the Sink Sentinel will take the guesswork out of your photographic lab processing. It will insure accuracy and let you turn out more professional negatives and prints. ◇

CURB “FUELISHNESS

with the

Automotive Econometer



Solid-state vacuum gauge monitors gas consumption and driving habits

BY BILL GREEN

POOR DRIVING habits can reduce fuel economy by up to 50% regardless of how well-tuned and maintained the vehicle. In the era of high-cost energy and shortages, you want to get as much as possible from every drop of fuel your car burns. One good way to do this is by using a device such as the Econometer described here. It constantly and accurately monitors the relative fuel consumption of your car so that you can adjust your driving technique accordingly.

The Econometer is an electronic device that keeps tabs on intake-manifold vacuum. It has a display consisting of a row of eight LEDs. At idle, four or five LEDs normally glow. With your vehicle in motion, more or fewer LEDs glow, the maximum number (high vacuum) corresponding to high engine rpm and a small throttle opening and the minimum indicating low rpm and open throttle. High vacuum conditions give maximum fuel economy.

You will not be able to maintain high vacuum under all driving conditions. Naturally, accelerating from a standing start, driving up a steep grade, or hauling a heavy load all take more fuel than cruising on a level surface with a light load. But by observing the Econometer, you will be able to avoid using more throttle than necessary for any conditions, thereby saving fuel.

About the Circuit. The simple circuit of the Econometer is shown schematically in Fig. 1. The vacuum transducer, a proprietary device manufactured by Alpha Electronics, receives power from 5-volt regulator *IC2* through current-limiting resistor *R1*. The output signal from the transducer is developed across *R2*, which is also connected to the stable 5-volt source.

The transducer mounts in the vacuum line from the carburetor. Its electrical output across *R2* varies from 0.3 to 1 volt, depending on instantaneous manifold pressure. This voltage is applied to 10-step analog detector *IC1*.

The new integrated circuit used for *IC1* contains 10 comparators and a reference-voltage network that detects the level of the analog signal at the input. Each comparator drives an open-collector transistor that is capable of sinking 40 mA at 32 volts. Since the comparators are arranged in a "totem pole," as input signal level increases, the LEDs light in succession. Potentiometer *R3* provides a means for setting the operating thresholds.

Construction. Because of the simplicity and noncritical demands of the circuit, any convenient board-type method of assembly—Wire Wrap, point-to-point on perforated board, or printed-circuit board—can be used. An actual-size etching-and-drilling guide for a pc board is shown in Fig. 2.

Mount the LEDs with their tops flush and their bottoms about 1/4" (6.2 mm) above the surface of the board, carefully observing polarity during installation. Then install the single jumper and two ICs, again taking care to properly orient them. Use of a socket for *IC1* is optional, but if you do use a socket, try to [illegible] a means of securing the IC (a daub of silicone rubber cement will do) so it will not vibrate loose.

Before mounting it in an enclosure, test the circuit board assembly. To do this, temporarily connect a jumper wire between the SNS (sense) point and GND (ground) in the circuit, apply 12 volts dc to the circuit, and check for a 5-volt dc reading between the junction formed by *R1* and *R2* and the ground bus. With *R3* fully clockwise, all LEDs should light; turning the pot fully counterclockwise should extinguish all LEDs. Disconnect the dc power and remove the temporary jumper from the circuit.

Temporarily mount the circuit-board assembly in the enclosure in which it is to be housed. Carefully determine and mark the locations of the display and adjustment slot of *R3* on the enclosure. Remove and temporarily set aside the circuit assembly. Then cut the display-window slot and drill a screwdriver access hole for *R3*. Drill another hole through the side or rear of the enclosure to provide entry for the wires that will interconnect the circuit with its transducer and the vehicle's electrical system. Deburr all holes and glue a red plastic filter over the display window. Line the wire-entry hole with a rubber grommet if you are using a metal enclosure.

Installation. Five well-insulated color-coded wires, preferably 18-gauge stranded, are required to interconnect the Econometer with its transducer and the vehicle's electrical system. Lengths of the wires are determined by the mounting location of the Econometer where it will be easily visible at a glance and the location of the engine's vacuum hose. Starting from where the Econometer will be positioned and leaving several extra inches, route a black-insulated wire to a metal chassis connection or screw that is at chassis ground. Repeat this procedure with a red-insulated wire, this time terminating it at a source of fused +12 volts that is "live" only when the ignition is on. Connect and solder the free ends of the black and red wires to the GND and POS pads, respectively, on the circuit-board assembly. Identify on your schematic diagram the colors used for each function for future reference.

Locate a source of intake-manifold vacuum (usually a rubber hose near or on the carburetor) so that the transducer and its leads will not be near a moving part or engine heat. Using this as your reference point, route three wires with different color insulation (not red or black) back along the chassis, through the firewall, and into the passenger compartment under the dashboard. Continue routing to the Econometer's case location, leaving several inches of slack at both ends of the wires before cutting to final length.

Now, working with only one wire at a time, strip away 1/4" of insulation from the first selected, slip on a 3/4" (19-mm) length of insulated tubing, and solder the wire to the terminal closest to the black dot on the transducer. Solder the other end of this same wire to the SNS pad on the circuit board.

Remove 3/4" of insulation from the second selected wire and connect and solder it to *both* center lugs on the transducer. Solder the other end of this wire to the GND pad on the board. Then, prepare the last wire in the same manner as for the first, including the insulated tubing, and solder it at one end to the remaining lug on the transducer (push the tubing down over both connections) and to the SRCE pad on the circuit board at the other end. Indicate your wire colors on your schematic.

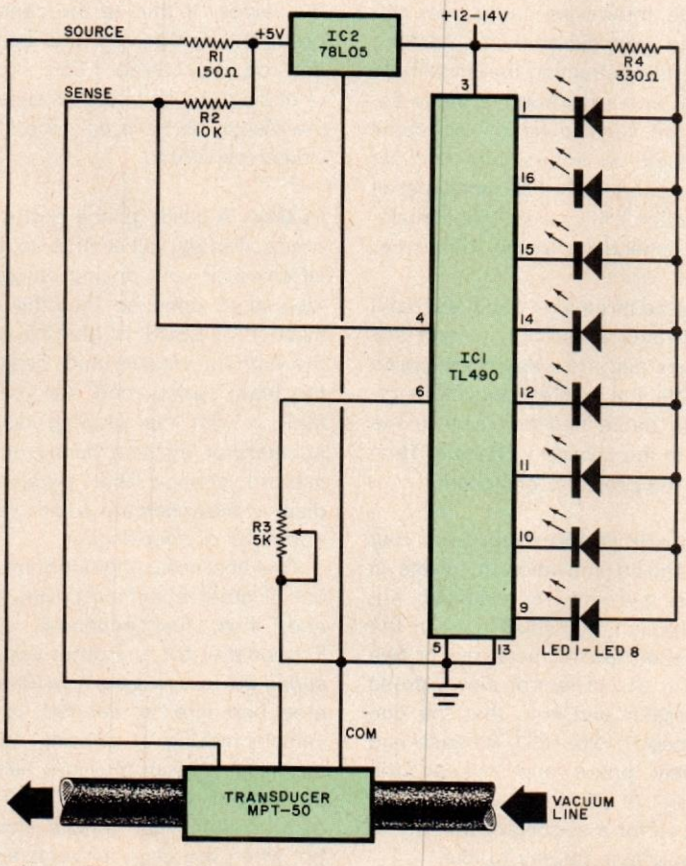


Fig. 1. The transducer converts vacuum level to a dc voltage. This is measured by level detector IC1 and displayed on a series of LEDs. More LEDs glow as the vacuum increases.

PARTS LIST

IC1—TL490 10-step adjustable analog level detector (Texas Instruments)
IC2—78L05 5-volt regulator
LED1 thru LED8—Red light-emitting diode
R1—150-ohm, 1/4-watt resistor
R2—10,000-ohm, 1/4-watt resistor
R3—5000-ohm pc-type potentiometer
R4—330-ohm, 1/4-watt resistor
Transducer—MPT-50 (see Note below)
Misc.—Enclosure (Radio Shack No. 270-303 or similar); red plastic filter; color-coded stranded insulated wire (see text); insulated tubing; machine hardware; solder; etc.

Note: The following items are available from Alpha Electronics, P.O. Box 1005, Merritt Island, FL 32952 (Tel: 305-453-3534): Complete kit of parts, less case and wire, for $18 plus $2 in US, $4 in Canada, $8 all other countries for postage and handling. Included in kit, but also available separately: No. PC179 etched and drilled printed-circuit board for $5.50 in US (add $2 for Canada, $4 for all other countries); No. MPT-50 transducer for $11 in US (add $2 for Canada, $4 for all other countries); TL-490 for $4.50 in US (add $2 for Canada, $4 for all other countries). Florida residents, please add 4% sales tax.

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J1124 (5¼ Triax II-75 Watts)	78 50
J1069 (6x9 Coax-45 Watts)	39 50
J1037 (6x9 Coax II-90 Watts)	58 50
J1077 (5¼ Coax-45 Watts)	39 50
J1041 (5¼ Coax II-75 Watts)	48 50

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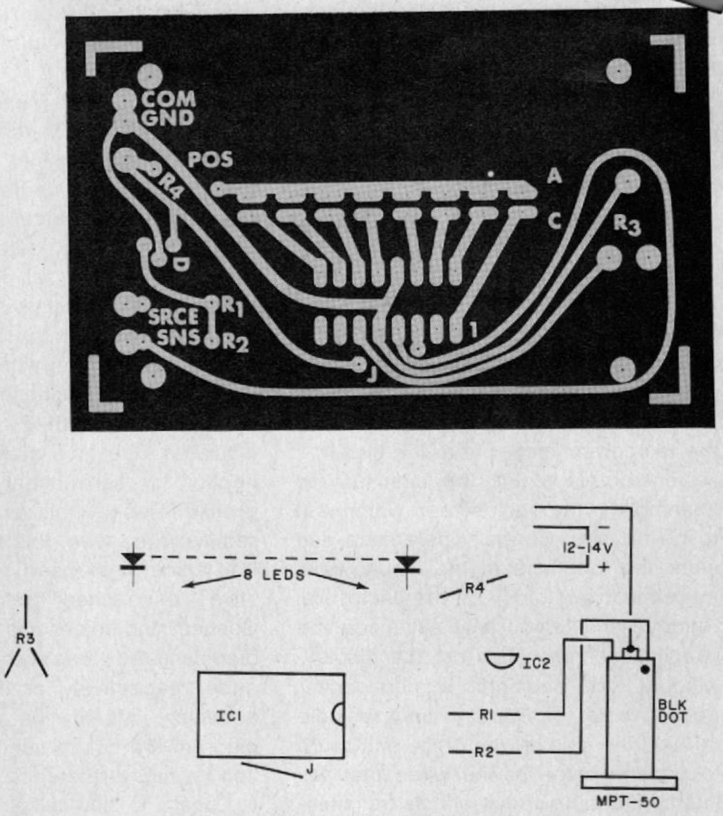


Fig. 2. Same-size etching and drilling guide for pc board is at top. Component placement directly above.

Bend the three-wire cable over the side of the transducer's case, taking care to avoid obstructing the small hole in the case, and secure with a cable tie. Now, cut the vacuum hose and install the transducer in series with the cut ends. (You can install the transducer in either direction.) After installation, make sure the connections to the transducer are airtight.

Position the three-wire cable so that it and the transducer do not contact any moving parts and are away from engine heat. Bundle the cable conductors together with cable ties and secure the assembly to the vehicle's chassis. Then assemble the project's enclosure.

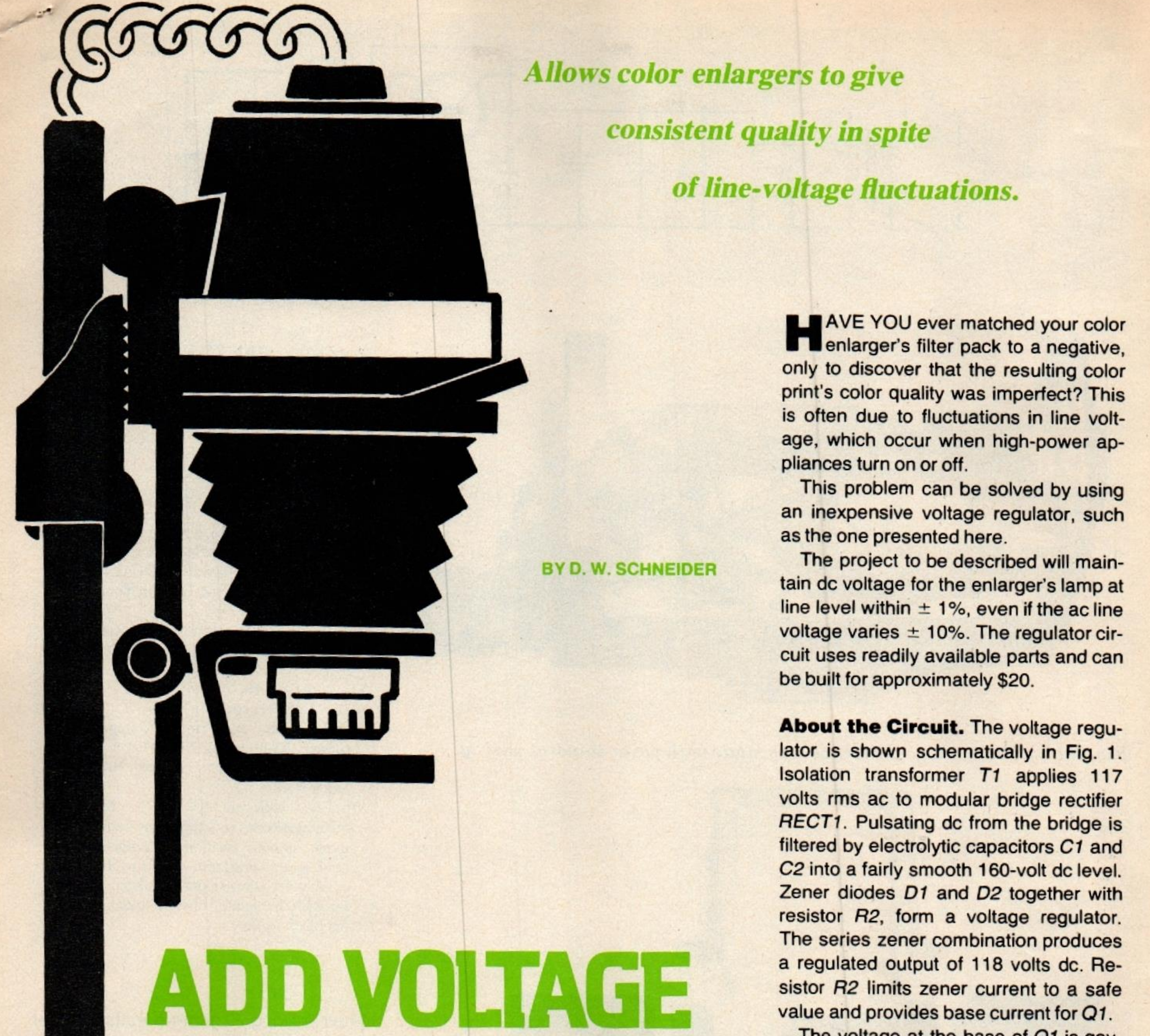
Checkout and Calibration. Start your vehicle's engine and allow it to idle in neutral. Using a small screwdriver, adjust *R3*, through the small hole in the front of the enclosure, until four or five LEDs are on. Still in neutral, slowly press the accelerator and note that the display changes by one LED. Release and then quickly press and release the accelerator. At first, only one LED should be on for a second or so, four or five as the engine returns to idle.

In some vehicles, the vacuum connection is located above the throttle butterfly valves. If this is the case, slightly press the accelerator and adjust *R3* to turn on only three LEDs. Completely releasing the accelerator should cause the display to have only one of the LED indicators lighted.

In Use. A quick glance at the Econometer's display will suffice to keep you informed of your driving efficiency. The idea is to drive so that the maximum number of LEDS is glowing, indicating the highest vacuum and, consequently, the least fuel/burned. As you become familiar with the glowing display and accelerator position during driving, any marked change that persists in the display may indicate a problem in the operation of your engine.

One final note: "right foot awareness" has a great effect on driving efficiency and, thus, fuel economy. Using the Econometer (or any other vacuum-measuring device) reveals how little accelerator pressure is needed to keep a vehicle moving at cruising speed with maximum vacuum. You may be surprised at how far you can back off the gas pedal before your vehicle slows down. So, when you get your vehicle up to the desired speed use a feather touch instead of a lead foot. ◇

Allows color enlargers to give consistent quality in spite of line-voltage fluctuations.



ADD VOLTAGE REGULATION TO A COLOR PHOTO ENLARGER

BY D. W. SCHNEIDER

HAVE YOU ever matched your color enlarger's filter pack to a negative, only to discover that the resulting color print's color quality was imperfect? This is often due to fluctuations in line voltage, which occur when high-power appliances turn on or off.

This problem can be solved by using an inexpensive voltage regulator, such as the one presented here.

The project to be described will maintain dc voltage for the enlarger's lamp at line level within ± 1%, even if the ac line voltage varies ± 10%. The regulator circuit uses readily available parts and can be built for approximately $20.

About the Circuit. The voltage regulator is shown schematically in Fig. 1. Isolation transformer *T1* applies 117 volts rms ac to modular bridge rectifier *RECT1*. Pulsating dc from the bridge is filtered by electrolytic capacitors *C1* and *C2* into a fairly smooth 160-volt dc level. Zener diodes *D1* and *D2* together with resistor *R2*, form a voltage regulator. The series zener combination produces a regulated output of 118 volts dc. Resistor *R2* limits zener current to a safe value and provides base current for *Q1*.

The voltage at the base of *Q1* is governed by the zener action of *D1* and *D2*, and is thus substantially independent of variations in line voltage. Even if the line voltage drops 10 volts, the filtered output of the rectifier is greater than the combined zener voltages. This is so because the filter output is approximately equal to the peak value of the ac line's waveform, not its rms value. Unless the line voltage decreases greatly, there will always be enough current in the zener diodes to keep them operating in the avalanche region. The zener voltages will therefore remain constant within ± 1% or so.

Most enlargers use incandescent

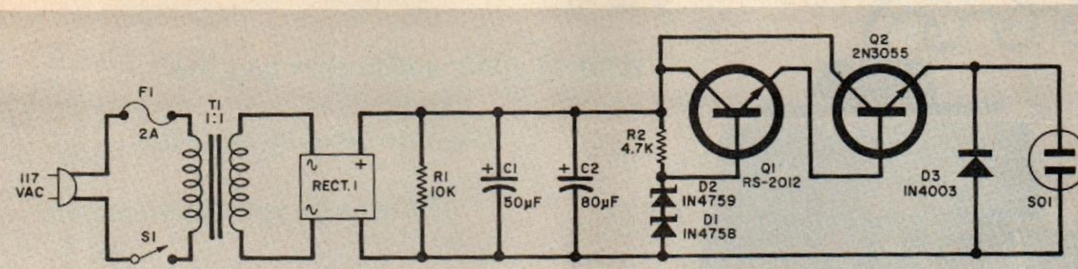


Fig. 1. Circuit has zener diode regulation and amplifier pair.

PARTS LIST

- C1, C2—Dual (80- and 50-µF, 250-volt) electrolytic capacitors or equivalent.
- D1—1N4758 56-volt, 1-watt zener diode
- D2—1N4759 62-volt, 1-watt zener diode
- D3—1N4003 silicon diode
- F1—2-ampere fuse
- Q1—RS-2012 (Radio Shack) npn silicon transistor
- Q2—2N3055 npn silicon power transistor (Radio Shack 276-1634. See text.)
- R1—10,000-ohm, 10-watt wirewound resistor
- R2—4700-ohm, ½-watt carbon composition resistor
- RECT1—400-PIV modular silicon bridge rectifier (Radio Shack 276-1173 or equivalent)
- S1—SPST switch
- SO1—Ac power socket
- T1—25.2-volt, center-tapped, 2-ampere transformer (Radio Shack 273-1512) or 117-volt isolation transformer (Stancor No. 6410). See text.
- Misc.—Suitable enclosure, TO-3 heat sink, mica washers, and transistor socket, zinc oxide silicone heat sink compound, line cord, strain relief, terminal strips, fuse holder, magnet wire, solder, insulated sleeving, machine hardware, fiber shoulder washers, flat black paint, etc.

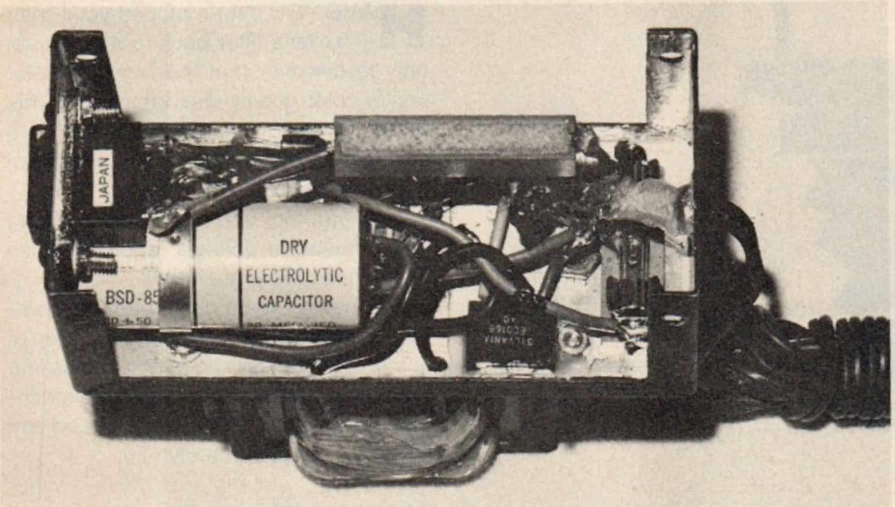


Fig. 2. Photo shows how prototype was made with point-to-point wiring.

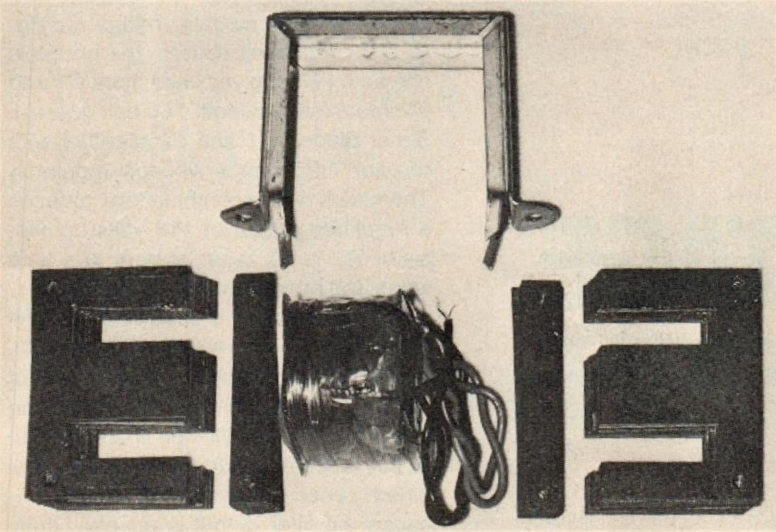


Fig. 3. Transformer T1 can be made by modifying a readily available model. This shows the parts of the transformer disassembled and ready for re-winding.

Fig. 4. Photo of assembled prototype shows transformer mounted on heat sink.

lamps drawing 75 or more watts. If zener diodes alone were used as voltage regulators, they would have to have very large power dissipation ratings. The cost of such diodes is prohibitive. However, the Darlington amplifier composed of *Q1* and *Q2* allows the use of small (1-watt) zener diodes. The diodes present a regulated voltage which drives the Darlington pair. Two diode voltage drops (approximately 1.2 volts) cause the output voltage at the emitter of *Q2* to be slightly less than the combined zener voltages.

The voltage regulator as shown has been successfully used with enlargers containing 75-watt incandescent bulbs. If your enlarger has a lamp that requires more than 100 watts, output transistor *Q2* should be a premium 2N3055 rather than the hobby-grade component specified in the Parts List.

Construction. The regulator can be

assembled using point-to-point wiring and terminal strips. The project should be housed in a 5" x 2¼" x 2¼" (12.7 x 6.4 x 6.4 cm) aluminum utility box. When you have procured all necessary parts, lay them out in the box as in Fig. 2. Drill mounting holes for those parts which are directly attached to the box (fuseholder, terminal strips, power switch, retaining band for the electrolytic capacitor, etc.) Holes must also be drilled for *Q2*'s heatsink and isolation transformer *T1*. Make a cutout in the box to allow clearance for the socket used with *Q2*.

Mount all components in the utility box except for *T1* and the transistor/heat sink assembly. Wire the components according to the schematic diagram. (Use insulated sleeving liberally.) Be sure to observe polarities of *C1, C2, D1* through *D3*, and *Q1*. Next, mount *Q2* on the heat sink in the following manner. Spread a layer of zinc-oxide silicon heat sink compound on the bottom of *Q2*'s case, on each side of the two TO-3 mica washers, and on top of the heat sink where *Q2* will sit. Pass the two washers over the pins of *Q2*, and position the transistor on the heat sink.

Holding the transistor in place, turn the heat sink over and lay two fiber shoulder washers on the holes drilled in the heat sink for the transistor's retaining screws. Then mount a TO-3 socket by pushing it down over the protruding transistor pin leads. Secure the assembly with 6-32 machine screws. (It might be necessary to enlarge the threads in the transistor socket with a 6-32 tap to accommodate the machine screws.) Be sure that the shoulder washers isolate the machine screws from the heat sink.

Mount the transistor/heat sink assembly on the utility box with machine hardware. Wire the transistor socket according to the schematic. To maximize the project's ability to dissipate heat, all exterior surfaces of the utility box and heat sink should be coated with a layer of flat black enamel spray paint.

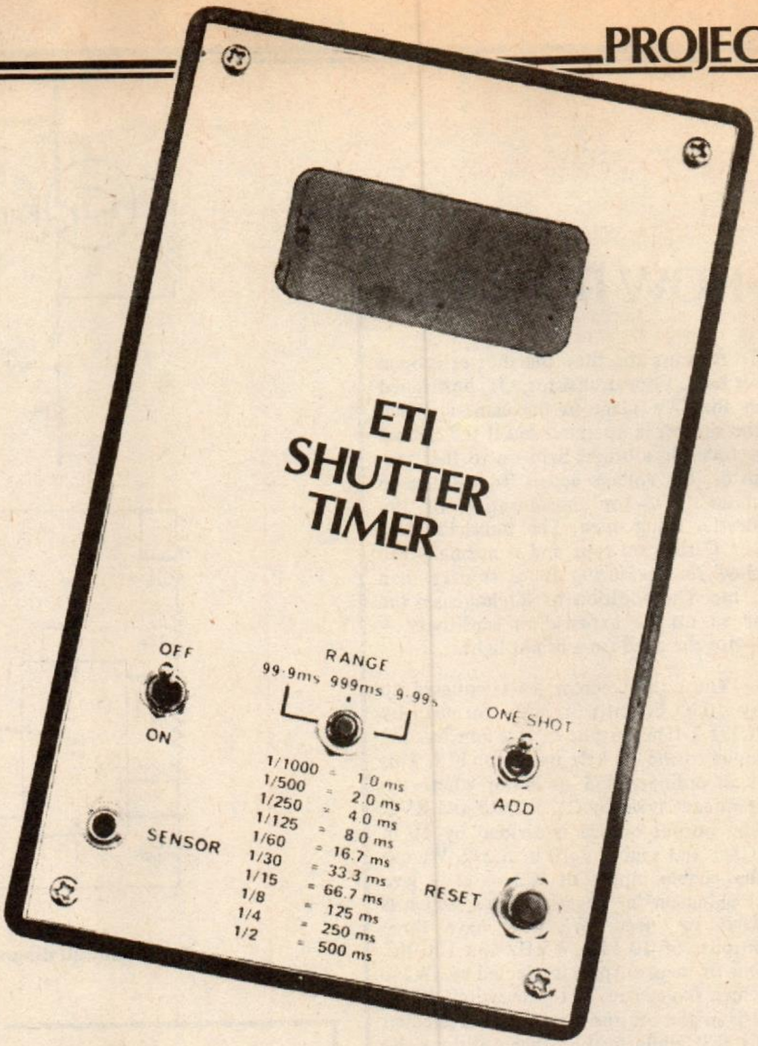
Transformer *T1* can be made by modifying a Radio Shack 25.5-volt, center-tapped power transformer. Separate the transformer mounting bracket from the laminated iron core by bending the two metal tabs on the bottom of the bracket outward. This will allow the core to slip out. The "E" and "I" shaped laminations can then be removed one at a time from the plastic bobbin on which the transformer windings are wound. Tapping the laminations with a small hammer will loosen the varnish between them, allowing the end laminations to be slid out. A photo of the disassembled transformer is shown in Fig. 3.

When the wound plastic bobbin is free, remove the outer, larger diameter (approximately No. 20) copper secondary winding. Do not disturb the inner primary winding or its insulated leads. Wind approximately 670 turns of No. 26 or 28 enamelled magnet wire in place of the secondary just removed. Scrape some enamel from the new secondary wires and solder insulated leads to them. If desired, seal the windings with coil dope. Wrap a few turns of vinyl electrical tape (Scotch No. 33 or equivalent) over the windings. Then paint the transformer bracket with flat black enamel and reassemble the transformer.

In the prototype, the transformer was mounted on the heat sink over *Q2*, as shown in Fig. 4. If preferred, a more expensive and slightly larger isolation transformer such as the Stancor No. 6410 can be used in place of the modified 25.2-volt transformer.

Use. Plug the line cord from the regulator into the power socket on the exposure timer. Then plug the power cord from the enlarger into power socket *SO1*. The voltage regulator is now ready for use in the production of prints. ◇

SHUTTER SPEED TIMER



A project from the amateur photographer from ETIs project team to enable accurate checking of the mechanical bits!

THE NUCLEUS of good photography is correct exposure. This is a combination of shutter speed and lens aperture as determined by an exposure meter. If either speed or aperture is not as indicated on the camera the results will be less than perfect.

While the lens aperture is a simple mechanical operation and unlikely to be in error the same cannot be said about the shutter with its springs and things. *(Typical electronic engineer's attitude!—Ed.)* Not only may the speed not be exactly as indicated on the dial, it may (probably) change as the camera gets older. Therefore it is desirable that a simple method of determining the actual speed should be available.

This project describes the design and construction of a unit which is capable of measuring times from 1 / 10 000 s to 10 s. This allows the actual speed to be measured and then used to calculate the correct aperture when taking those important photos.

SPECIFICATION

Timing range	**0.1 ms to 9.99 sec.**
Sensor	**Photo transistor**
Display	**3 digit LED**
Power supply	**9 volt batteries** **65 – 160 mA LEDs on** **20 mA LEDs off**
Battery life	**≈6 hours – normal** **≈20 hours – alkaline**

It is suitable for checking cameras with a hinged or removable back so that the sensor can be placed in the film plane. For cameras where the film fits into a slot this unit cannot be used.

Construction

Commence construction with the PCB adding initially the nine links required. Next add the resistors and capacitors in the appropriate locations as shown in the component overlay. Note that capacitor C5 is polarised and must be inserted the correct way round.

The transistors and the displays can now be soldered in place taking care with orientation of the transistors.

The ICs are the last components to be installed and these must be in the correct location and orientation. As they are all CMOS devices (except IC2) the pins should not be handled if possible to minimise the danger of static electricity damaging them. When soldering them in, solder the corner pins (the power supplies), pins 7 and 14 or 8 and 16 first as this allows the internal protection diodes to work while you solder the other pins.

The front panel can now be drilled and cut. A piece of polarised plastic helps as a display window. The switches, pushbutton and phone jack can now be fitted and connected to the PCB as shown in the component overlay. The only point which could cause problems here is that the phone jack connections sometimes vary, and you should check yours before connection.

The PCB can now be mounted onto the support bracket with 6 mm spacers and the bracket into the box with two screws. When positioned correctly, the display will be visible through the window and the battery holders will be held in position at the other end.

Sensortive

The sensor plate which contains Q1 and R1 can now be made. We used a piece of PCB material, although any non-conductive material which is opaque or translucent may be used. Start by cutting the plate to size and drilling a 6 mm hole in the centre. The phototransistor Q1 should be mounted with the curved surface (which is the active side) into the hole and R1 soldered to the leads, the whole assembly then being glued onto the plate with quick dry epoxy. Ensure that all conductive parts are covered with epoxy to prevent touching when in use.

▶

HOW IT WORKS

To measure the time the shutter is open we use a phototransistor, Q1, positioned in the film plane in the camera. When the shutter is operated and if the camera is focusing a bright light on to the transistor, the voltage across R4 will rise to about 7 V for the duration of the shutter being open. The transistor used is a Darlington type and is normally too slow for measuring times shorter than 1 ms. The addition of R1 increases the speed at the expense of sensitivity – hence the need for a bright light.

The output across R4 is squared up by the Schmitt trigger formed by IC1/1,2. The output of this controls the input to the 10 kHz oscillator IC2. This is an ordinary 555 oscillator where the frequency is set by C1, R2, R3 and RV1. The output of IC2 is divided by 10 in IC3/1 and again by 10 in IC3/2. We use the enable inputs of IC3 as they give clocking on the negative edges, which is what we need. We now have three outputs of 10 kHz, 1 kHz and 100 Hz. One of these outputs is selected by SW2/1 which is a centre off toggle switch. When it is in the off position, 1 kHz is selected via R8, while in the other positions the 1 kHz signal is swamped by the low output impedance of the other dividers.

Whichever frequency is selected clocks IC4 which is a 3 decade counter-latch-multiplexer. We are not using the latch in this application. This IC simply counts the number of pulses it receives and with the help of IC5 (7 segment decoder-driver) and Q2 – Q4 displays the result on the LED displays. During the counting period the display is blanked to prevent ripple on the supply rail upsetting the 555 timer. The ripple would occur as the current changes with different digits displayed. The decimal point is controlled by SW2/2.

Two modes, single-shot and add, are provided. In the single-shot mode when light hits Q1 operating the Schmitt trigger the monostable formed by IC1/3 gives a pulse about 50 μs long which resets the main counter IC4 and the /10 dividers, IC3. Pins 1 and 9 on IC3 which have to be low to allow clocking are taken high during the reset pulse only because it made the PCB easier and does not affect the operation. In the 'add' mode the reset pulse does not occur and unless the reset button is pressed the second and successive counts will simply add on to the previous count. This allows say ten tests to be made and the total divided by ten to find the average.

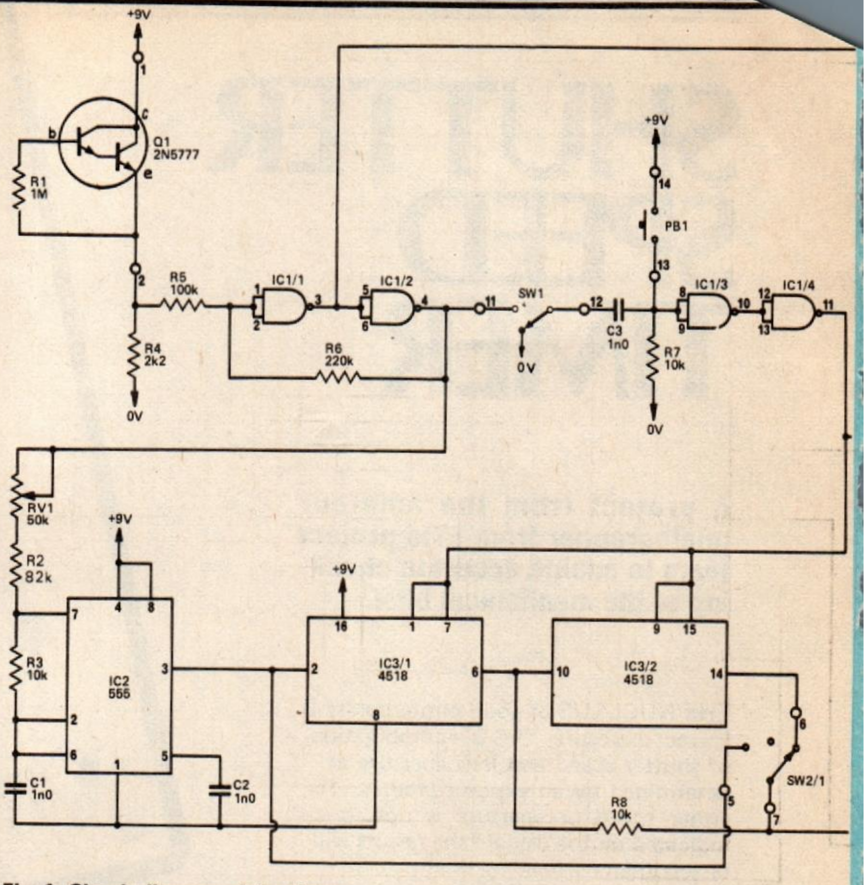
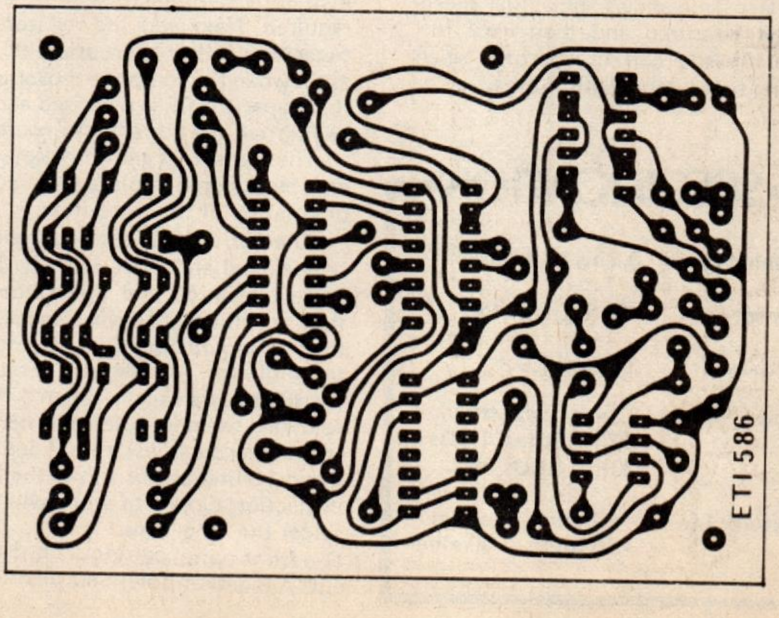
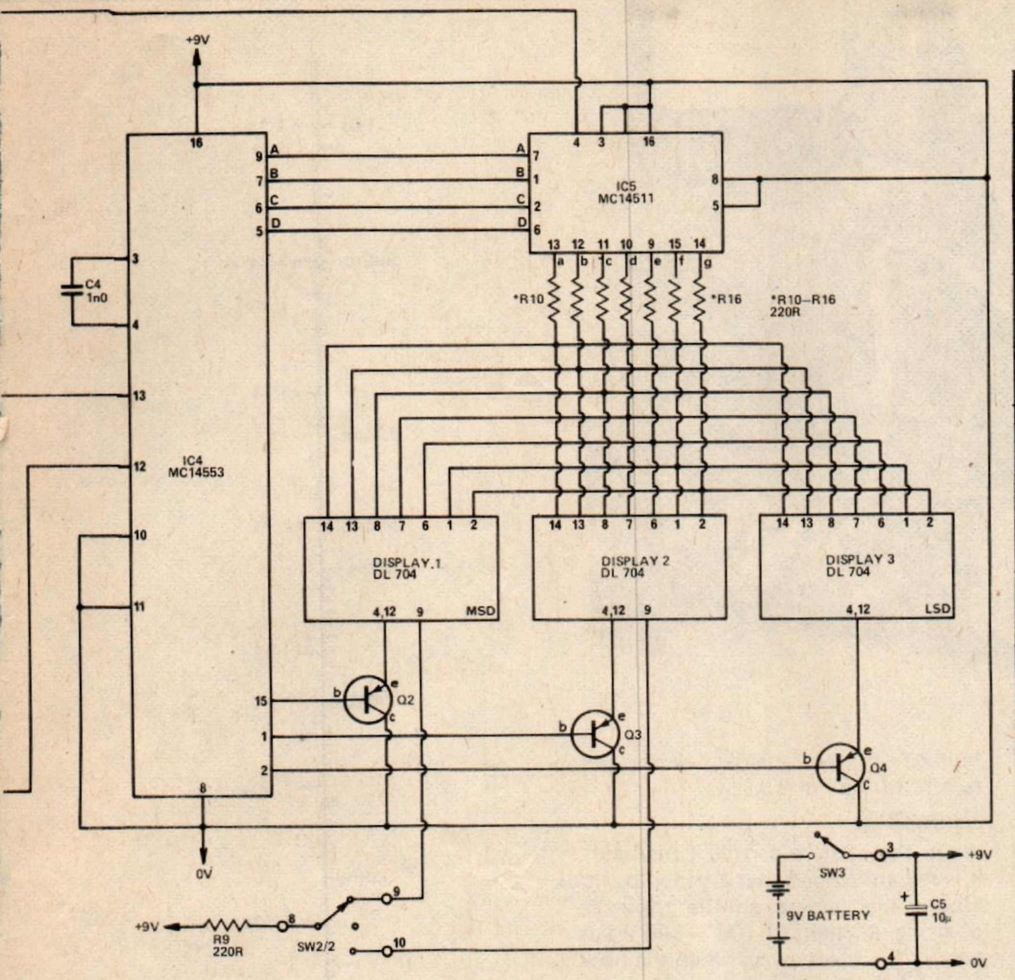


Fig. 1. Circuit diagram of the timer.

BUYLINES

All the components here are readily available. The only thing the home constructor might not have come across is the 2N5777 photo-darlington. This is not a rare device at all, however, and is stocked by Marshalls, Watford etc. etc. If you use an equivalent type of display, make sure of the pin outs with respect to the PCB. If your type does not match up, the best thing would be to fix the displays to the front panel, and wire up from the PCB mounting holes.





PARTS LIST

RESISTORS all ½ W 5%

R1	1M
R2	82k
R3	10k
R4	2k2
R5	100k
R6	220k
R7,8	10k
R9–R16	220R

POTENTIOMETER

RV1	50k

CAPACITORS

C1–C4	1n0 polyester
C5	10u 16 V electrolytic

SEMICONDUCTORS

IC1	4011
IC2	555
IC3	4518
IC4	14553
IC5	4511
DISPLAY 1–3	DL704
Q1	2N5777
Q2–Q4	BC559

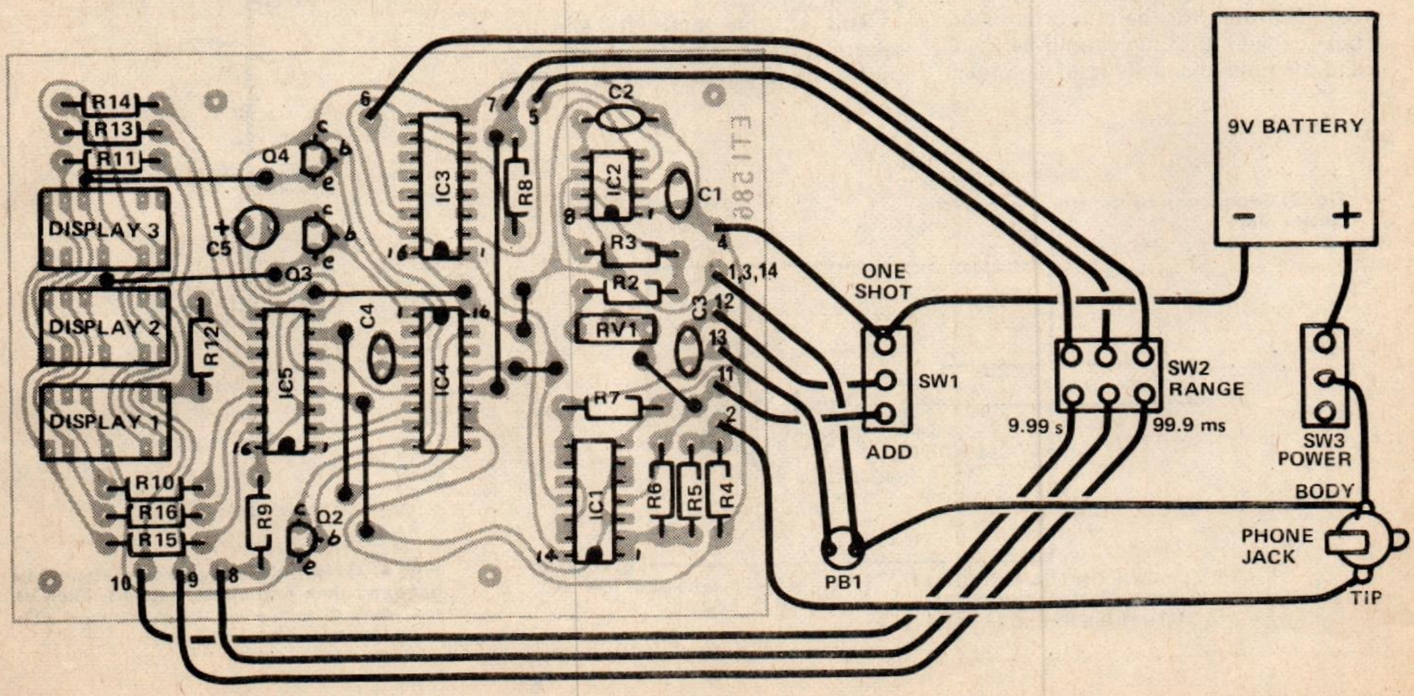
SWITCHES

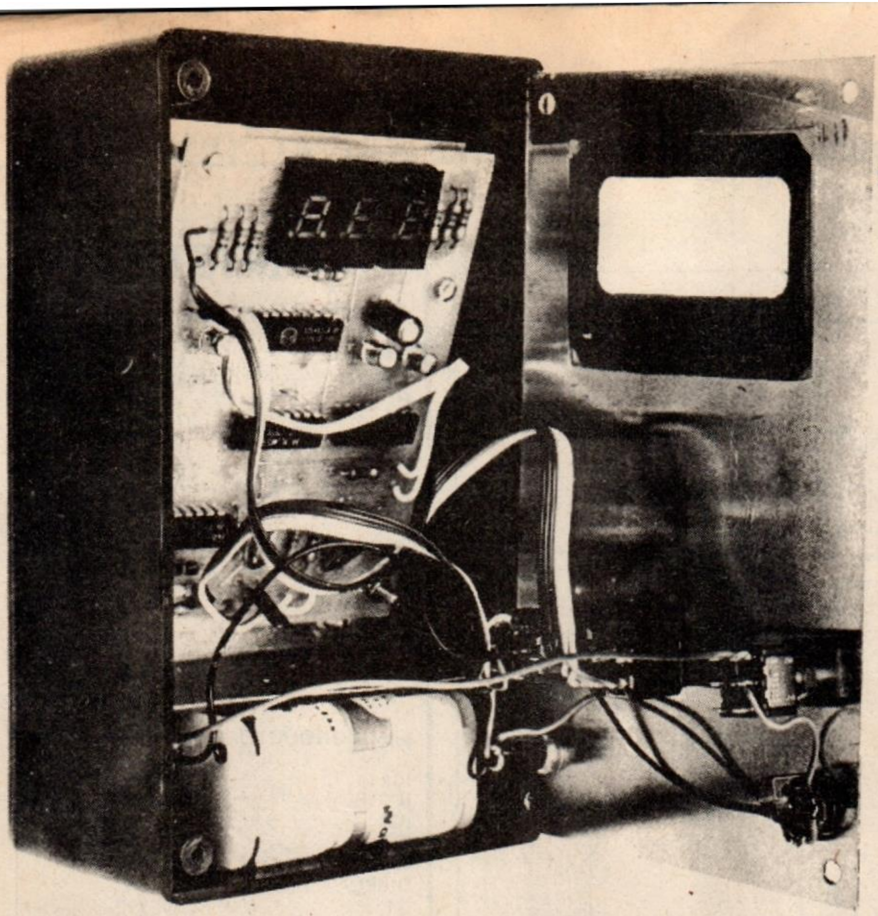
SW1,3	toggle switch SPDT
SW2	toggle switch DPDT centre off

MISCELLANEOUS

PCB ETI 586, plastic box, push button, phone jack and plug, battery holder, battery clip, support bracket, spacers, nuts, bolts, wire etc.

Fig. 2. Component overlay and wiring diagram.





Calibration

The unit can be calibrated accurately enough with the aid of a stopwatch with a second hand. Set the camera up as detailed in the operational notes and using the single-shot mode, open the lens for five seconds. By adjusting RV1 get the reading close to 5s.

Now use a longer time, say 20 s, noting that the first digit will be missing. (i.e. a reading of 8.52 represents 18.52 s while 2.31 would be 22.31 s) and finally adjust RV1.

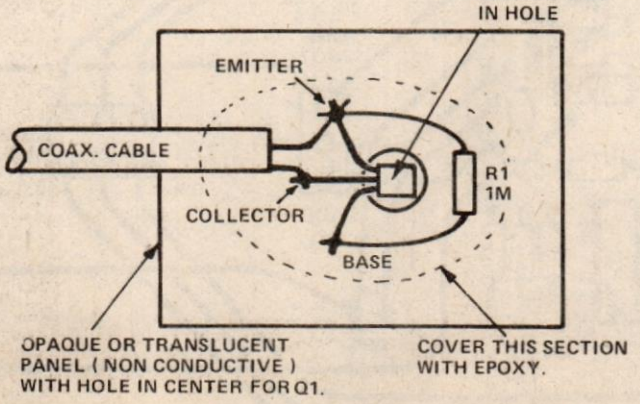
To aid setting up a push button can be substituted for the phototransistor but the 'add' position should be used and the timer manually reset as contact bounce can cause the display to reset on release of the button.

Operation

While the camera can be hand-held it is recommended that a tripod be used. Mount the camera on the tripod pointing at a light of 100 – 500 Watts about 2 – 3 feet away. Open the back of the camera and position the sensor plate so that the light is focused on the sensor. Initially, have the lens wide open; if enough light is hitting the sensor, the display will be blanked. Stop the lens down until the display comes on then go back one stop.

This sets the sensitivity and by selecting the appropriate range the shutter speed can be checked. **ETI**

Fig. 3. Connection of the transistor on the sensor plate.



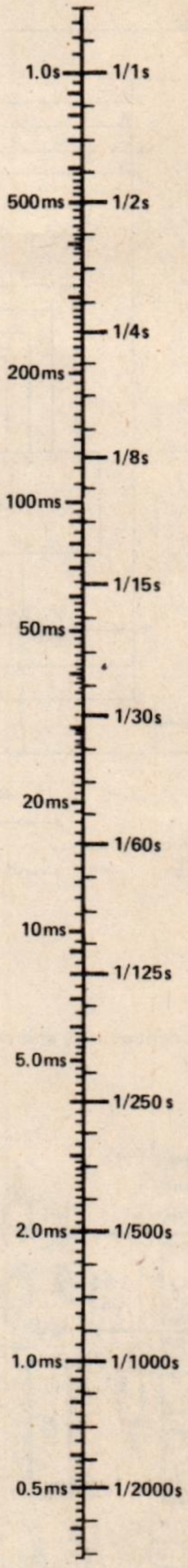


Fig. 4. Graph showing the relationship between time and shutter speed. Each of the small divisions on the right hand side corresponds with a ¼ stop.

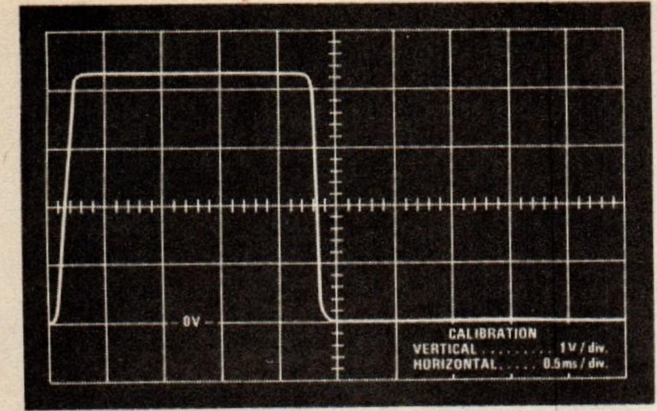


Fig. 5. Waveform on the input (point 2) with the camera on 1/500 sec. The actual time was 2.1ms.

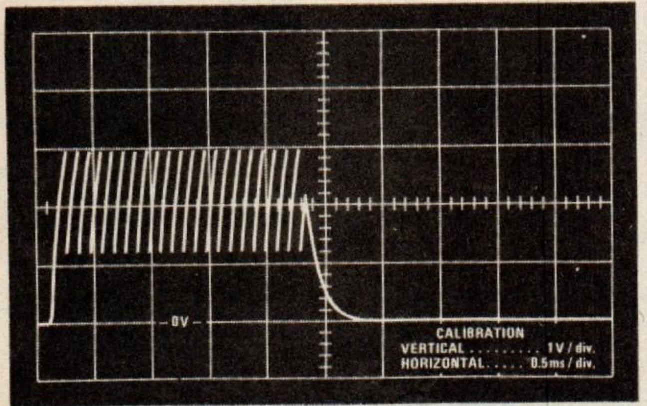


Fig 6. Voltage across C1 during operation

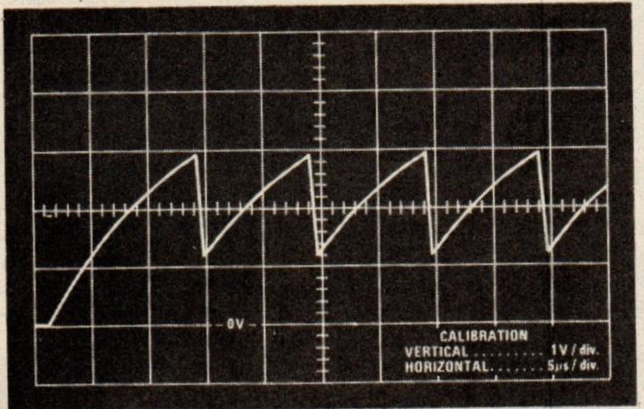


Fig. 7. Expanded view of the start above waveform.

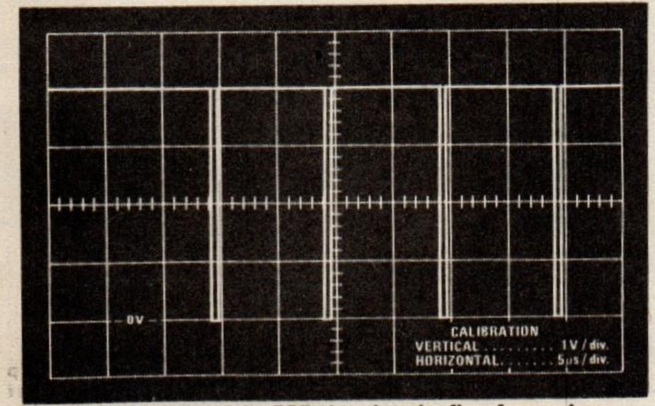


Fig. 8. The output of the 555 showing the first four pulses.

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SEMICONDUCTORS

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BC109C	13p	BC320	12p	BD519	50p	1N4148/50	5p
BC114	15p	BC478B	25p	BD520	50p	1N4002	5p
BC116	17p	BC548	22p	BD609	70p	1N5404	20p
BC147/8/9	9p	BC558	29p	ZTX109	12p	2N3053	17p
BCY32	30p	BFY52	17p	2N3055	60p	400mW Zeners	9p

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25/25	7p	4700/50	60p	10/12	6p	200/25	12p
500/25	20p	500/10	10p	640/16	12p	50/15	7p
220/10	8p	100/16	8p	100/25	9p	10/25	6p
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7408/10	17p*	7493/5	50p*
7413	39p*	74107	20p*
7417/20	25p*	74121	33p*
7430	15p*	74123	39p*
7440	15p*	74141	80p*
7441	79p*	74157	50p*
7445	49p*	74193	50p*
7447	84p*		
7470/72	29p*		
7473/74	35p*		
7475	40p*		
7476	39p*		
7480/2/5	10p*		

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ULTRASONIC SWITCH

Two-board design forms basis for a wide range of applications from door-bells to data transmission!

THE USE OF an invisible beam to transmit information or to act as an alarm system has always been fascinating. We have described light operated systems of the infra-red (invisible), normal light and laser beam types. We have also published a radar alarm system. This unit uses a high frequency acoustical beam, well above the range of human hearing, which can be used simply as a door monitor, i.e. to give an alarm if the beam is broken, or can be modulated at up to several hundred Hz. This will allow information to be transmitted — details of how to do this will be given in future issues.

Construction

The construction of the units is not

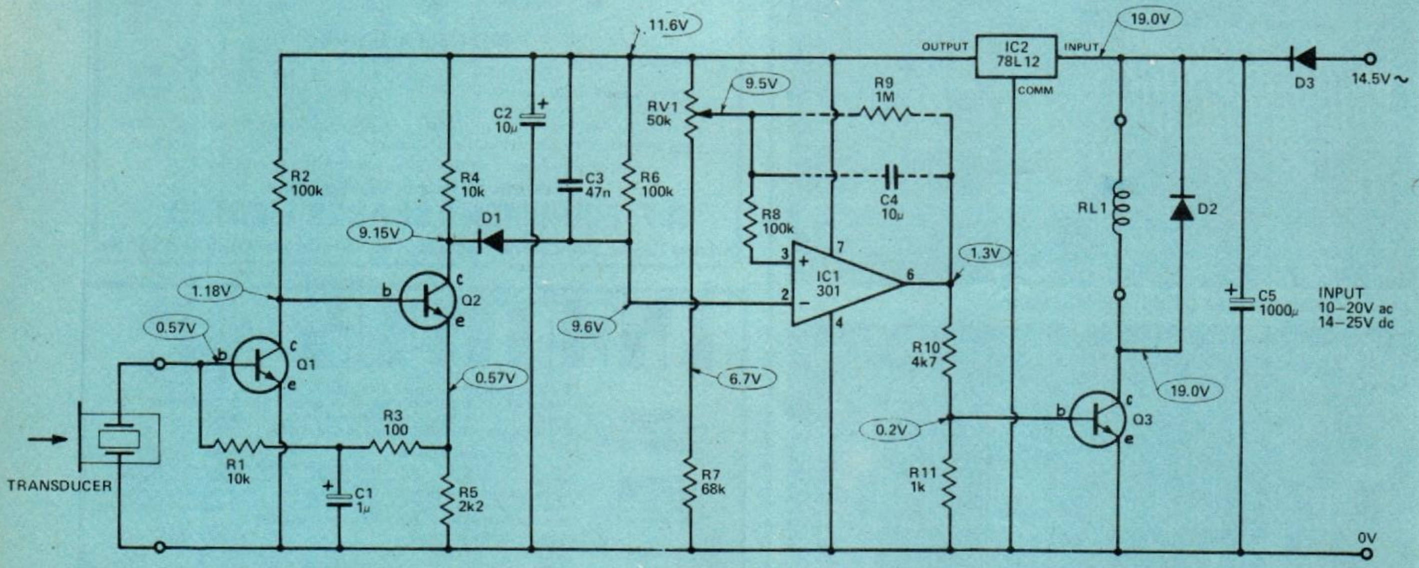


Fig. 1. Circuit diagram of the receiver.

NOTES:
VOLTAGES MEASURED WITH NO INPUT SIGNAL USING A VOLTMETER WITH 10 MEG OHM INPUT IMPEDANCE.
Q1–Q3 ARE BC548
D1 IS 1N914
D2,D3 ARE 1N4001
C4 IS USED INSTEAD OF R9 IF A MONOSTABLE ACTION IS REQUIRED.

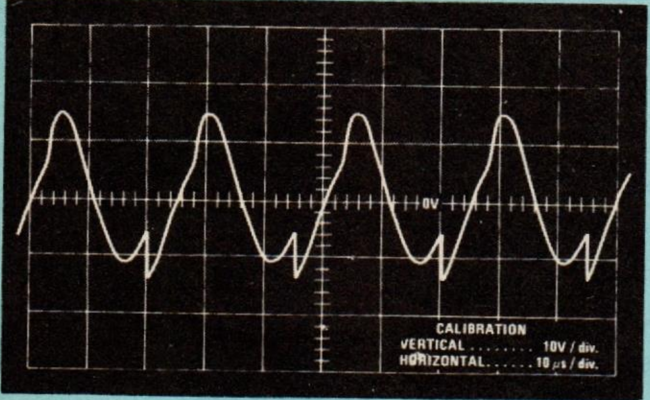


Fig. 3a. Waveform across the transducer on the transmitter.

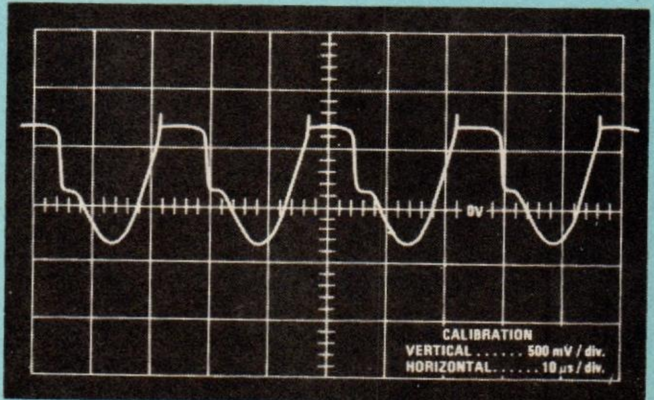


Fig. 3b. Voltage on the base of Q2 in the transmitter.

critical — any method may be used although the PC boards are recommended. We didn't mount the relay on the PCB as it can vary in size and if the unit is later used with a modulated beam, the relay will not be needed.

The only adjustment on the unit is the sensitivity control and this should be set to give reliable operation. The transmitter needs a supply voltage of 8 V to 20 V at about 5 mA. This could come from the regulated supply on the receiver board.

If it is required to extend the effect of a quick break in the beam or a quick burst from the transmitter, the resistor R9 can be replaced by C4 and this will give a minimum operation time of about 1 second.

ETI ▶

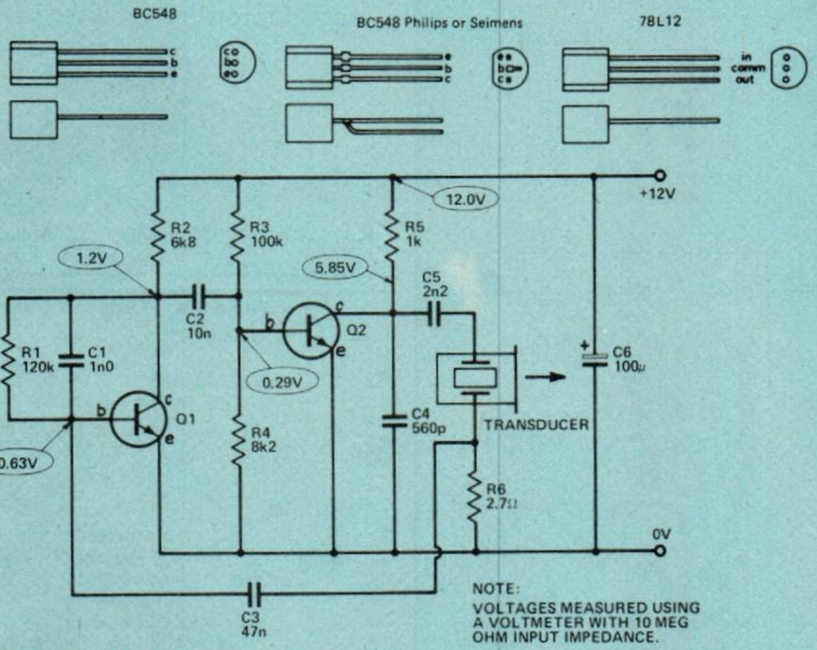


Fig. 2. Circuit diagram of the transmitter.

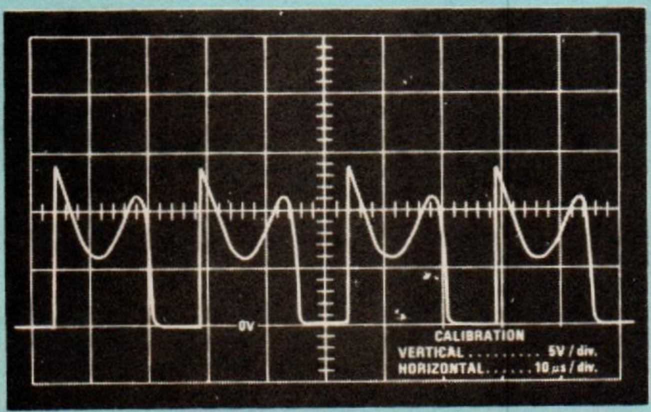


Fig. 3c. Voltage on the collector of Q2.

HOW IT WORKS

Transmitter

This is an oscillator the frequency of which is determined by the transducer characteristics. The impedance curve of the transducer is similar to that of a crystal with a minimum (series resonance) at 39.8 kHz followed by a maximum (parallel resonance) just above it at 41.5 kHz.

In the circuit the two transistors are used to form a non-inverting amplifier and positive feedback is supplied via the transducer, R6 and C3. At the series resonant frequency this feedback is strong enough to cause oscillation.

Capacitors C1 and C4 are used to prevent the circuit oscillating at the third harmonic or similar overtones while C5 is used to shift the series resonant point up about 500 Hz to better match the receiver.

Receiver

The output from the transducer is an a.c. voltage proportional to the signal being detected (40 kHz only). As it is only a very small level it is amplified by about 70 dB in Q1 and Q2. D C stabilization of this stage is set by R1 and R3 while C1 closes this feedback path to the 40 kHz A C signal.

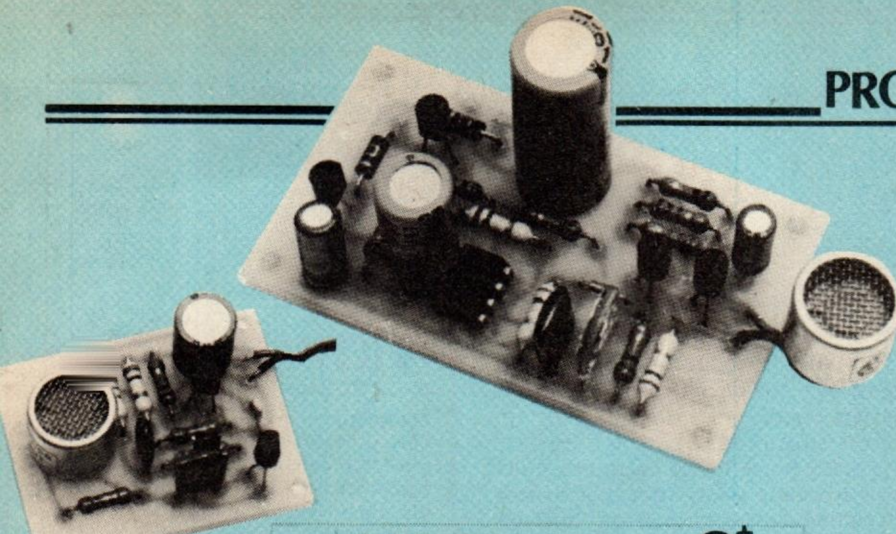
The output of Q2 is rectified by D1 and the voltage on pin 2 of IC1 will go more negative as the input signal increases. If the input signal is strong the amplifier will simply clip the output, which on very strong signals will be a square wave swinging between the supply rails.

IC1 is used as a comparator and checks the voltage on pin 2, i.e. the sound level, to that on pin 3 which is the reference level. If pin 2 is at a lower voltage than pin 3, i.e. a signal is present, the output of IC1 will be high (about 10.5 volts) and this will turn on Q3 which will close the relay. The converse occurs if pin 2 is at a higher voltage than pin 3.

A small amount of positive feedback is provided by R9 to give some hysteresis to prevent relay chatter. If R9 is replaced by the capacitor C4 the IC becomes a monostable and if the signal is lost for only a short time the relay will drop out for about 1 second. If the signal is lost for more than 1 s the relay will be open for the duration of the loss of signal.

We used a voltage regulator to prevent supply voltage fluctuations triggering the unit. The relay was not included on the regulated supply, allowing a cheaper regulator to be used.

PROJECT: Ultrasonic Switch



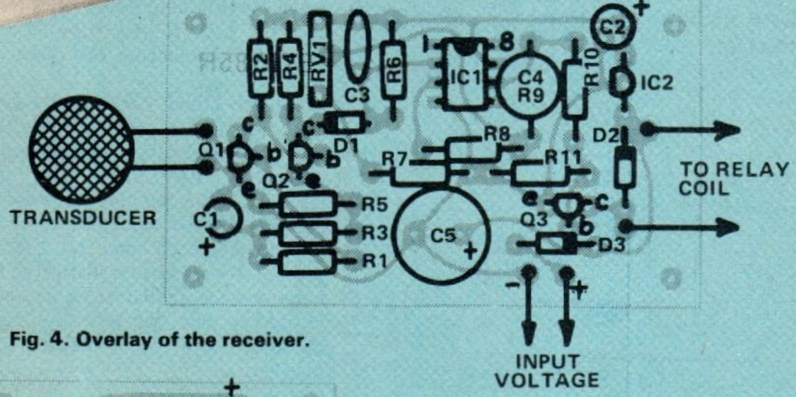


Fig. 4. Overlay of the receiver.

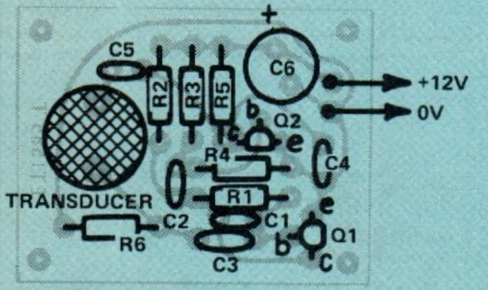


Fig. 5. Overlay of the transmitter.

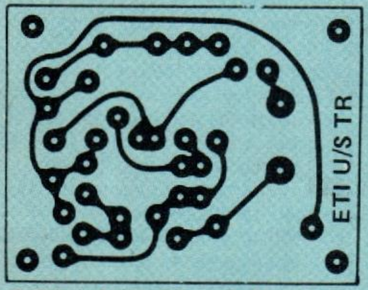


Fig. 7. Printed circuit board of transmitter. Full size 46 x 36mm.

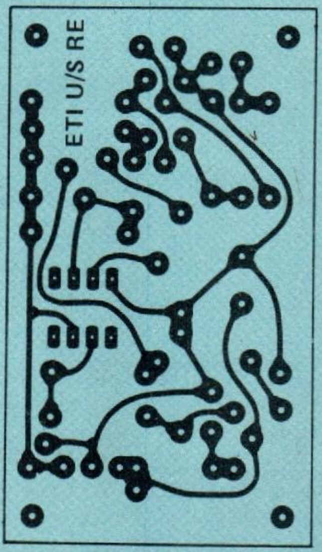


Fig. 6. Printed circuit board of receiver. Full size 70 x 40mm.

PARTS LIST

RECEIVER

RESISTORS all ½ W 5%

R1,4	10k
R2,6,8	100k
R3	100R
R5	2k2
R7	68k
R9	1M
R10	4k7
R11	1k

POTENTIOMETER

RV1	50k preset

CAPACITORS

C1	1u 25 V electrolytic
C2	10u 25 V electrolytic
C3	47n polyester
C4	10u non polarised electrolytic
C5	1000u 16 V electrolytic

SEMICONDUCTORS

Q1—Q3	BC548
IC1	LM301A
IC2	78L12
D1	1N914
D2,3	1N4001

MISCELLANEOUS

PCB as pattern, 40 kHz receiver, 12 V relay, case to suit

TRANSMITTER

RESISTORS all ½ W 5%

R1	120k
R2	6k8
R3	100k
R4	8k2
R5	1k
R6	2R7

CAPACITORS

C1	1n polyester
C2	10n polyester
C3	47n polyester
C4	560p cetamic
C5	2n2 polyester
C6	100u 25 V electrolytic

TRANSISTORS

Q1,2	BC548

MISCELLANEOUS

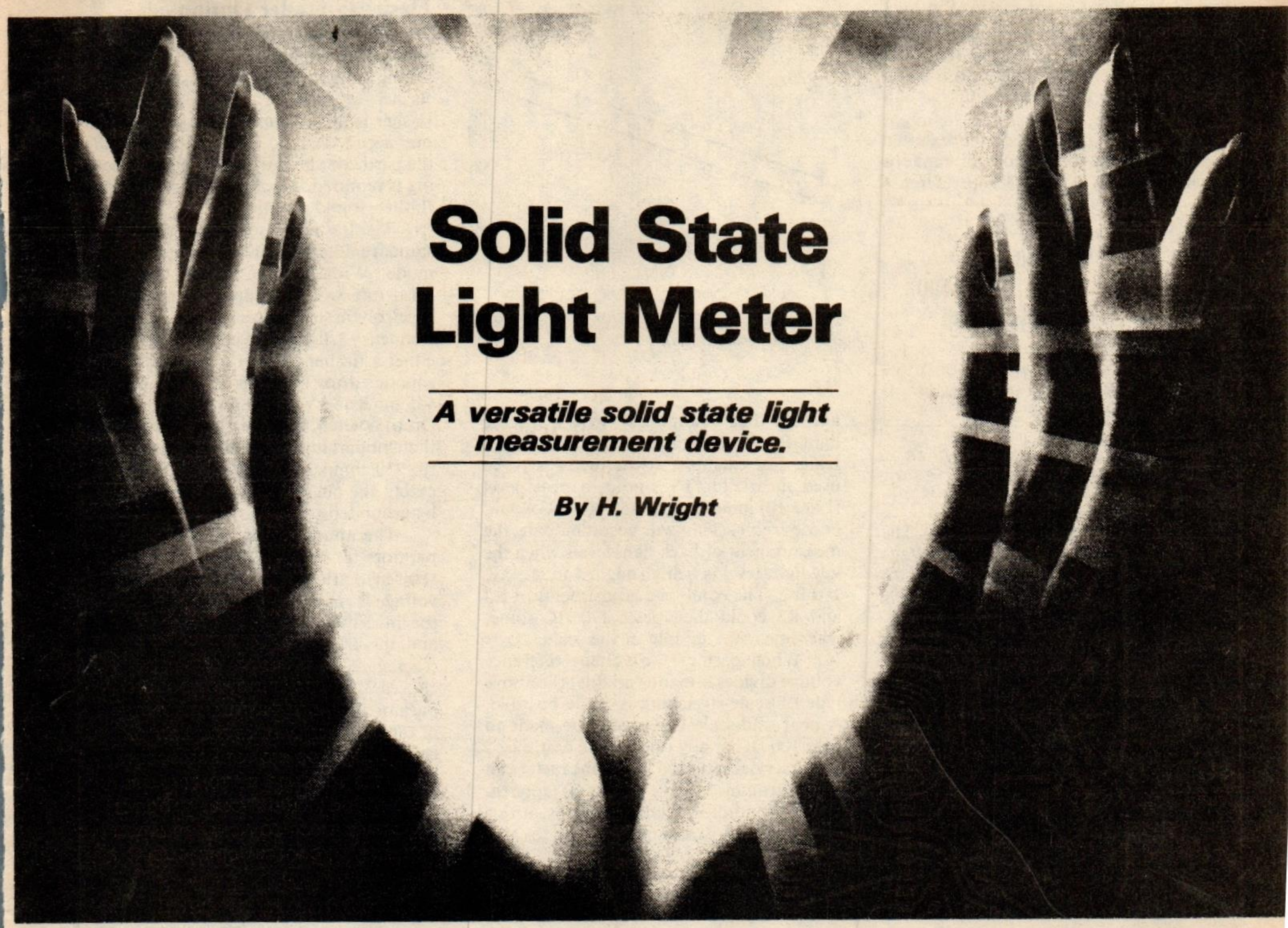
PCB as pattern, 40 kHz transmitter, case to suit.

BUYLINES

This project was designed with simplicity in mind and as a result uses components that should be available from most suppliers of electronic components. The only items likely to be difficult to obtain are the transmitter and receiver. In case of difficulty however these can be purchased from Audio Electronics at 301 Edgware Road, London.

SPECIFICATION

FREQUENCY	40 kHz
RANGE	5 metres
MAXIMUM MODULATION FREQUENCY (NOT WITH RELAY OUTPUT)	250 Hz
OUTPUT	relay, closed when beam is made
POWER SUPPLY	
TRANSMITTER	14—25 V DC 10—20 V DC
RECEIVER	8—20 V DC, 4 mA



Solid State Light Meter

A versatile solid state light measurement device.

By H. Wright

IN THE PAST, light meters used a delicate D'Arsonval analog meter movement for the readout display. These meters were easily damaged beyond repair if they were dropped on the floor or banged against a hard object. They also had no provision for calibration and groups of meters fresh from the factory frequently showed wide variations from meter to meter, and readout scales were coarse and nonlinear, requiring time consuming extrapolations between marked numbers. The result was often guesswork. **Fig. 1** is a reproduction of the scale from a once popular foot-candle meter. Note the extreme cramping on the upper end of the scale.

Solid-state technology allows the elimination of the D'Arsonval readout. This gives us a meter without delicate mechanical parts; the only moving part is the on-off switch. Calibration adjustments can be provided so that groups of meters may be made to read the same, and, if drift occurs with time, a recalibration is possible. Scales can be programmed to suit specific applications; an advantage not usually possible in a light meter that depends on the D'Arsonval readout.

The meter described here is versatile. It can be used to establish light levels in ftC., for example, in a TV studio or on a motion picture set. It will measure industrial light levels in critical factory areas or will establish correct office lighting levels, and the scale can be adjusted to measure luminence values on a cathode ray tube face. Simple modifications combined with mechanical exposure calculators make it applicable to photographic exposure measurements.

The Sensor

The sensor chosen for the meter is a Vactec blue enhanced photodiode. This photodiode was considered to be the best choice because of its fast response and its availability with a spectral response close to that of the human eye. **Fig. 2** shows the spectral response of the Vactec 9413B photodiode, and the linearity, which is also excellent over a wide range, is shown in **Fig. 3**.

The Circuit

Fig. 4 is the schematic diagram of the meter. It's built around the LM3914 which contains a string of ten comparators combined with an internal string of ten, 1,000 ohm resistors. The resistors provide the ascending set of references for the comparators, turning them on progressively with an increase in the input voltage. The light sensor provides these input voltages directly; the complications of an amplifier are avoided because the IC can be arranged to operate as a millivoltmeter.

The usual method of operating this IC is by tying the internal resistor string to the IC's internal reference voltage of 1.20 volts. When using millivolt input ranges, this method cannot be used because the reference output load resistor also determines and regulates the LED current in the range between 2.0 and 30 milliamps. Both ends of the internal resistor string are brought out to external pins on the IC. This permits use of a ground referenced external reference IC. This separates the functions of LED current control from those determining input range. Pin 9 of IC1 is connected to pin 11 to program the IC into dot mode of operation. The bargraph mode is not suited to this meter because it places a heavy load on the battery.

If Fig. 4 is examined, the external reference system for a millivolt range is easy to follow. IC2 is a 2.5 volt reference IC driven by the 9 volt battery supply. The reference output is connected to a voltage divider consisting of a fixed resistor R3 and a trimpot R2. The ratio of resistors is such that R2, the scale range adjustment, provides a good range in millivolts for application to the internal resistor string. The value of R1 now determines only the LED current and therefore the maximum value of total instrument current drain. In the prototype R1 was given the value of 470 ohms. Run-of-the-mill red LEDs were used. Some economy of battery drain could be gained if R1 was made larger and combined with narrower angle, more costly, high efficiency LEDs. Addition of a red filter or the even more effective 3M louvered neutral density filter, would also improve readability in the presence of strong ambient light.

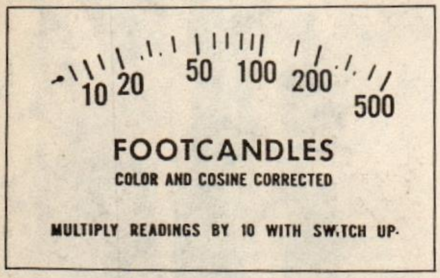


Fig. 1. A reproduction of the scale of an early type foot-candle meter.

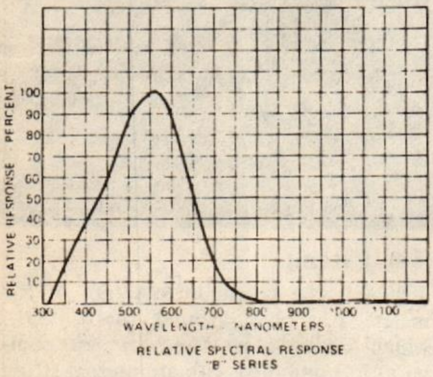


Fig. 2. Spectral response of the Vactec VTB 9413B photodiode.

The setting of R2 determines the instrument sensitivity. The actual input voltage in millivolts from the sensor, for a given light level, will be determined by the setting of R5, the calibrating load resistor. With R2 determining the full scale voltage, R5 then determines where a specific light level will indicate on the ten dot scale. For example, if the meter is to be used in a color TV studio, a peak level (LED-10) indication of 350-400 ftC would be desirable. This will accommodate the measurement of back light levels when the key light level is being roughed in at, say, 170 ftC. The combined adjustments of R2 and R5 could then place 170 ftC somewhere near the middle of the scale.

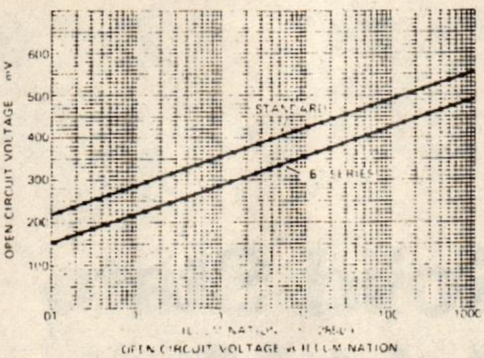


Fig. 3 Voltage vs. illumination for the photodiode (open circuit condition).

When part of the voltage reference voltage divider is made variable, the above type of scale-stretching is made possible. A near mid-scale LED could be made to read 100 ftC or any other value best suited to the service required. Thus the meter can be programmed for a variety of applications, TV studios, film operations, office and industrial lighting etc.

Flasher-Sounder Option

The basic meter of Fig. 4 is complete. Where the application requires frequent setting of light levels to the same value, a flasher or sounder can be added. The flasher is driven from a chosen LED output circuit on IC1, the one that indicates the particular level where flashing or beeping is required. **Fig. 5** is the circuit for the flasher/sounder option.

The flasher or sounder is driven by a standard 555 IC which runs in the astable mode. With the R-C values shown the flash rate will be approximately 2-3 Hz. Electrolytic tolerances could affect the frequency slightly. The 555 will drive either a flasher LED or a small solid state sounder directly. Q1 is in series with the 555 pin 8 and V+ and forms an electronic On-off switch. The switch is controlled by the comparator IC3. Only one section of the 339 comparator is used. All other pins except the pin 3 positive supply pin, must be grounded.

The non-inverting input of the comparator is connected to the 2.5 volt reference through R8. The tripping voltage from the LED circuit is applied to the inverting input through trimpot R7, and the tripping voltage is obtained by placing a 100 ohm resistor between the chosen LED anode and V+. The comparator input is taken from the junction of the LED anode and R6. When the LED is off, the junction voltage approaches the supply voltage of 9 volts. When the LED is on, the LED current produces a small voltage drop and the junction voltage drops sharply without appreciably reduc-

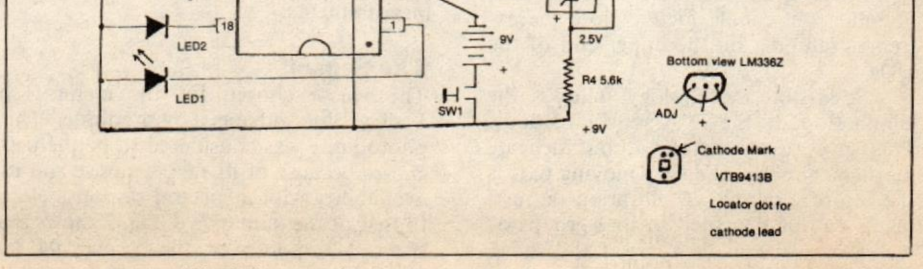


Fig. 4 Schematic of the lightmeter circuit.

ing the brightness of the LED. R7 is adjusted, with the LED off, to apply a voltage slightly greater than 2.5 volts. When that LED lights, the inverting input of IC3 drops below the reference input and the comparator trips, turning on Q1. This option increases the battery drain, but because the on-off switch is a spring loaded return push button, the extra current is only drawn when taking a reading.

The flasher circuit also doubles as a low battery indicator. If the battery voltage drops to somewhere between 7.5 and 8.0 volts, the voltage at the R6/LED junction drops low enough to trip the comparator, even though the LED may be off. It should be remembered that the flasher-low battery indicator circuits do not in any way affect the operation of the light meter. It will function normally without them. This is simply a useful option to be used or left out as the builder wishes.

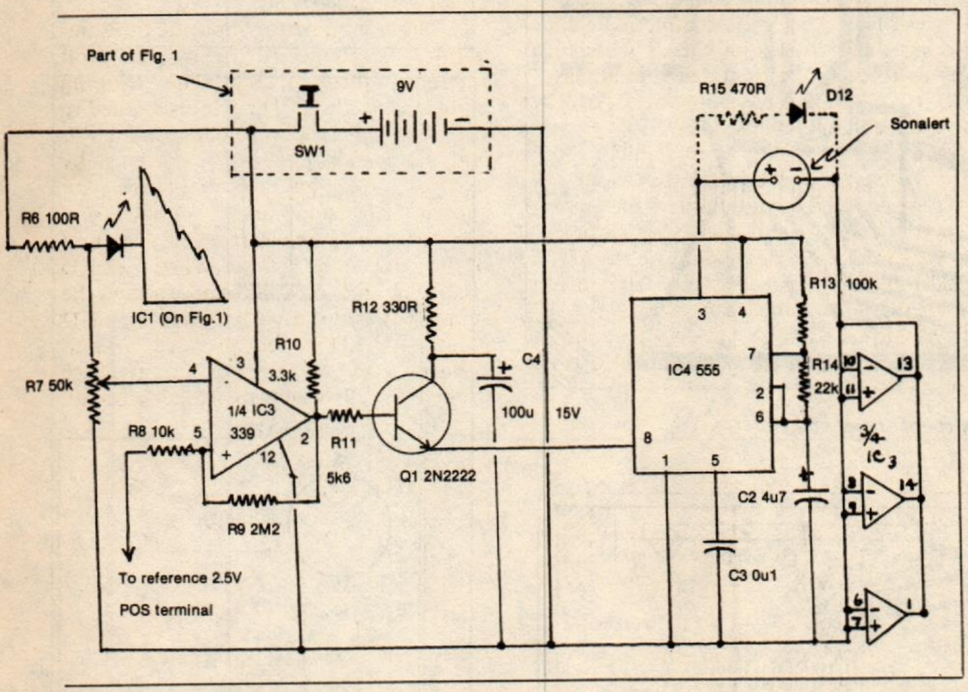


Fig. 5 Schematic for the flasher/sounder indicator.

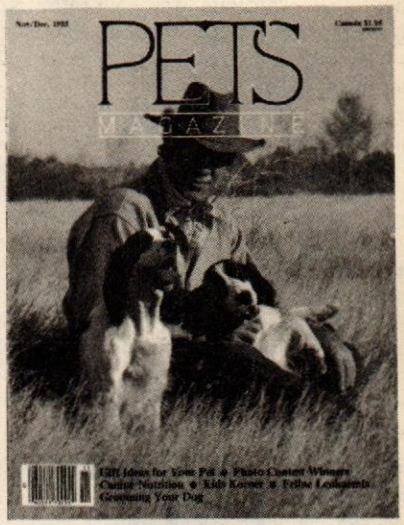
Construction

The small number of components makes this light meter an easy construction project. It will fit into a small box such as Radio Shack # 270-233 (21/2' x 5' x 11/2'). The components can be mounted on a small 41/2' x 21/4' rectangle of perf board with 0.10 hole spacing. **Fig. 6** is a pattern for either a printed circuit or one fabricated from stick-on copper patterns and tapes (Bishop Graphics E-Z system). The latter method was used for the prototype. It is simple, fast, does not require photography or chemicals and is easier to trace and check than point-to-point wiring. The LEDs are mounted on their leads, standing up in a row from the circuit side of the board. If copper tape is used, it is desirable to run a second copper tape on the component side of the board under the ten LED anode leads, to anchor them firmly in place. Sockets for the ICs, with the exception of IC2, will simplify the soldering procedure and allow for easy replacement in case of failure or damage. **Fig. 7** shows the position of components.

The aluminum bottom of the case becomes the front panel for the meter. A row of holes is drilled that will just allow the LEDs to be a very light push fit. These holes are spaced at 0.40' intervals to match the LED mounting positions. Retain the panel position that existed when the box was purchased.

In the prototype the photodiode was mounted in the end of the barrel of a miniature phone plug. A matching jack was positioned in the end of the case. Make sure the photodiode polarity is correct when mounting it. The anode should go to the tip and the cathode to the sleeve. A dab of silicone rubber will hold the photodiode firmly in place and provide some shock-proofing. If you prefer, the sensor can be mounted in a small hole in the end of the case, using a rubber grommet or silicone rubber. **Fig. 8** shows the relationship of the panel, LEDs and sensor.

Before the panel is assembled with the perf board, clean it and spray it lightly with zinc chromate. This prevents the finish coat from peeling from the aluminum. A sprayed-on coat of gold will look good with the black case. Once the instrument has been calibrated, ftC. numbers opposite each LED can be add-



ed. Rub-on numbers will give a professional look. The wear life will be improved if the panel is given a coat of clear lacquer. The prototype was calibrated for TV studio use and **Fig. 9** shows the scale.

No guide is given for the location of the on-off push button switch. It should be placed so that it lies comfortably under the thumb when the meter is held to aim it at a light source. This will put it somewhere in the lower part of the panel to the left of the LED row.

Measure the locations of the three trimpots along the edge of the circuit board and the depth of the adjusting screws from the inner face of the front panel. use these dimensions to locate and drill three holes in the appropriate side of the case. Make them large enough to admit a small jeweller's screwdriver.

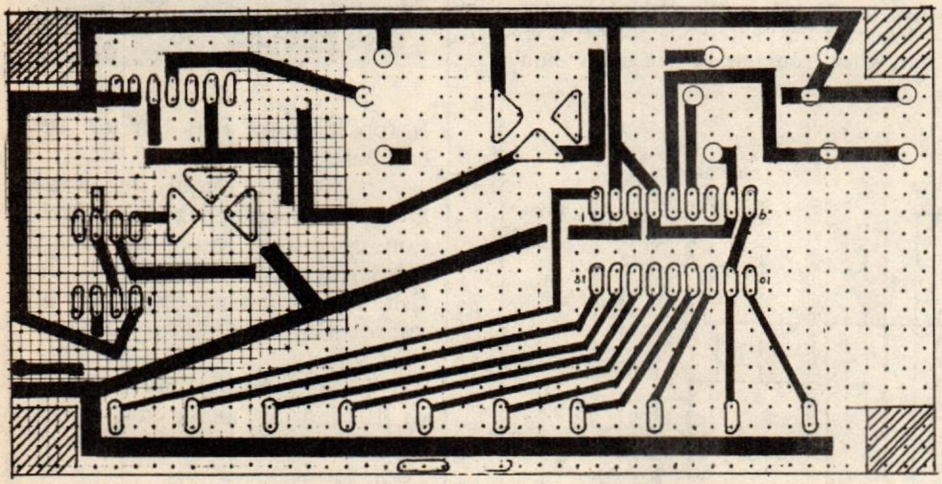


Fig. 6. Pattern for the printed circuit or E-Z system copper tapes and patterns.

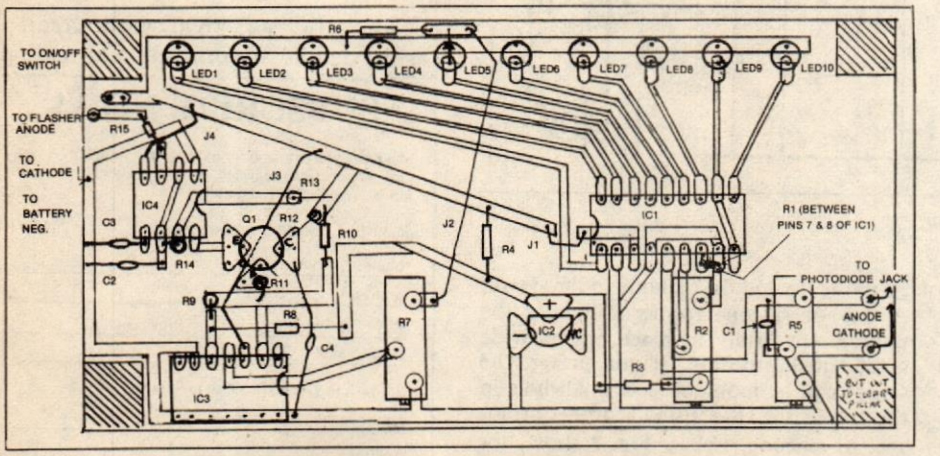
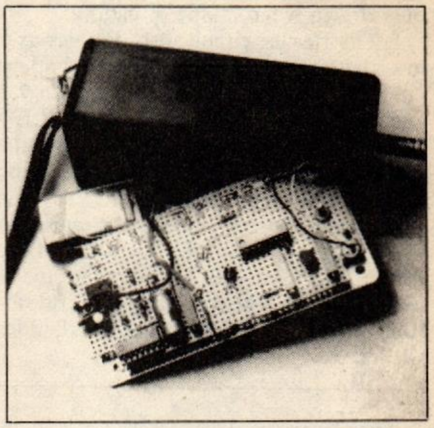


Fig. 7. Component positions for the meter and flasher/sounder option.

Calibration

If you have included the flasher or beeper in the meter, the first adjustment is to set the trip level of the comparator. With the electronics outside the case, connect a good voltmeter between R7 arm and ground. Adjust R7 for a reading of 2.6 volts. Do not be surprised if the measured reference IC output is not right on 2.5 volts. Exactly 2.5 volts is not a requirement for this application; the important point is that the reference remain constant as the battery voltage drops. To get IC2 exactly at 2.5 volts would require more components. The adjust terminal of IC2 is left unconnected.

The only way the light meter can be calibrated with good accuracy is by reference to a high quality incident light meter that reads in ftC or an exposure meter that has a foot-candle scale. If the reference light meter has interchangeable covers for the light cell, use only the flat faced cover during calibration. Many of these meters have a domed or humped translucent cover over the cell that integrates the light from an included angle greater than 180 degrees. Such a meter does not give anywhere near a true incident light reading. The meter described here has a very narrow angle of acceptance and will give an accurate indication of incident light when aimed carefully at the light source.



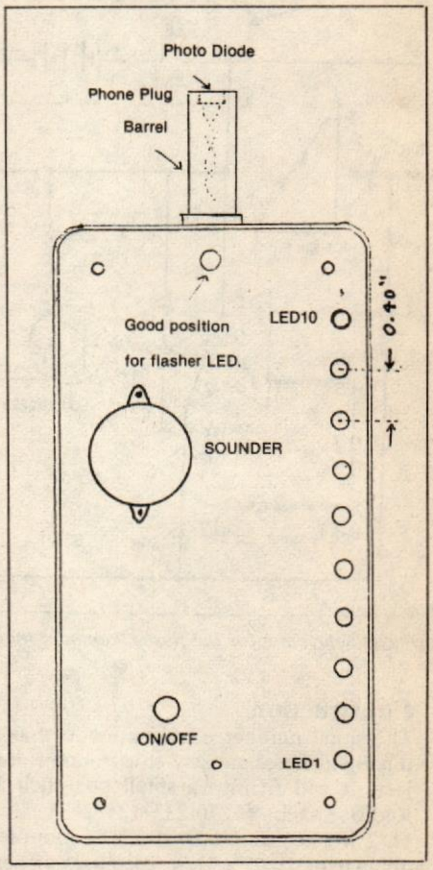


Fig. 8 Panel layout.

The most accurate calibration could be obtained if the meter is referred to a photometric laboratory foot-candle standard, but few have access to such a standard. Assuming a good meter of the D'Arsonval type is available, set up a table-top calibration procedure. The surface of the table should be covered by a dark, low reflectance material and there should be no other lights besides the test lamp and no uncovered windows. Use a desk or worktable lamp with a conical reflector and fit it with a diffuse 60 watt bulb. Lay this light source flat on the table as shown in **Fig. 10.** Further diffuse the light by taping a piece of good quality

Continued on page 42

Continued from page 24

bond typing paper or letter paper over the front of the reflector. This is to get rid of bulb filament 'hot' spots. Provide a small box to support the meter at a level in line with the center of the light reflector and a weight to hold it in position. Set R5 to mid-range and establish a light level reading on the reference meter that is to bed your peak reading. This is done by moving the box closer to or further away from the source. Adjust R2 until LED 10 lights. Now check some mid-range LED that you wish to have indicate some special level. This can be done by sliding the box again. Adjust R5 and recheck the peak reading. The two adjustments interact, so it will be necessary to go back and forth between them a few times. For example, in the prototype, LED 5 was set at 170 ftC. and LED 10 at 360 ftC. Spacing of the other indicators was surprisingly linear at approximately 30 ftC intervals with some slight cramping at the top end. It should be remembered that the 3914 IC responds in a series of discrete steps. A halfway point between LEDs is usable. This is where one LED is starting to extinguish and the next one is starting to light. This characteristic must be taken into account when going through the calibration procedure. It is particularly important when going through the calibration procedure to have the sensor faces on both instruments in exactly the same horizontal and vertical planes and at exactly the same distance from the light.

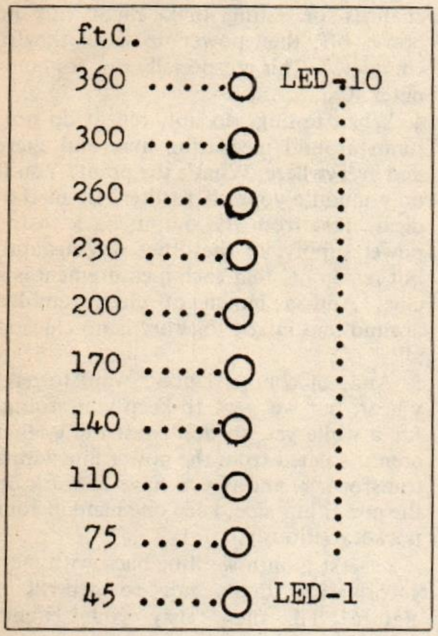


Fig. 9 The scale graduations used on the prototype.

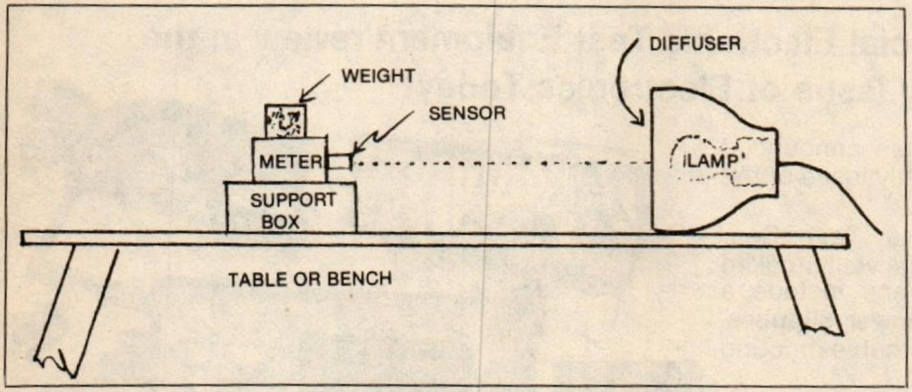


Fig. 10 Table top set-up for meter calibration.

If a calibrating reference meter is not available a crude calibration can be performed with the same desk light. It should be diffused as before. With the meter on its support a level of approximately 100 ftC. will be present when the sensor face is about 11 inches away from the paper diffuser surface. 200 foot candles will be at 71/2 inches and 400 ftC. at 41/2 inches. This is a very rough calibration. If you do it this way, try to have it checked against a known meter before any critical measurements are made with it.

Operation

It is a good precaution to equip the meter with a neck cord. The ranges encountered in TV studios will center around 100 to 200 ftC. with the highest reading seldom above 400 ftC. If the meter is to be used outdoors, it is easy to double or quadruple the range by mounting a piece of Kodak neutral density filter (N.D. filter) over the photodiode sensor. A filter of 0.30 N.D. will double the range because it has a transmission factor of 50. if the meter had been calibrated to a peak reading of 400 ftC., the 0.30 N.D. filter will raise it to 800 ftC. and all other LED indications will be doubled. A 0.60 filter will quadruple the range to 1600 ftC and both filters will raise it to 3200 ftC. If the phone plug mounting has been used for the sensor, the filter could be mounted in a small cap over the end of the plug.

Photographic Use

The meter could be adapted to photographic use. It can be used as it is if only ftC readings were required. A mechanical converter of the sort found on most exposure meters would be required to translate the readings into shutter speeds, lens apertures and film speeds. it might be necessary to have an integrating dome over the sensor. This field has not yet been explored with the prototype and it could be an interesting experiment for the builder to pursue.

Parts List

Resistors (all 1/4W)	
R1,R15	470R
R2	20k trimpot
R3	8.2k
R4,R11	5.6k
R5	100k trimpot
R6	100R
R7	50k trimpot
R8	10k
R9	2.2M
R10	3.3k
R12	330R
R13	100k
R14	22k
Capacitors	
C1,C3	0.1uF 16V ceramic
C2	4.7uF 16V
C4	100uF 16V
Semiconductors	
IC1	LM3914 dot/bargraph driver
IC2	LM336Z 2.5V reference
IC3	LM339 Quad comparator
IC4	555 timer
D1-D10,D12	Red LEDs (Preferably high efficiency)
D11	Vactec VTB 9413B blue enhanced photodiode
Q1	2N2222
Miscellaneous	
Sounder	Electrosonic #A1-250
B1	9V battery
S1	SPST push-button, N.O. spring return, shallow profile.

case (Radio Shack #270-233); copper tape materials, or perfboard, or PCB; bolts; sleeves etc.

■

LOW-COST COLORIMETER

Identify more than 1000 colors with this $39 circuit.

JOSEPH SCHNABLE, GEORGE ALESSANDRO, AND ROBERT ORR*

COMMERCIALLY AVAILABLE COLOR-formulation systems, colorimeters, and spectrophotometers are suitable for identifying the visible color of a surface. These instruments typically scan a surface with 400–700 nanometer (nm) visible light, compare the sample with color references, and determine the best color match based on a set of built-in standards. Most commercial instruments depend on expensive optics and cost $1000 or more. This article describes a $39 color-identifier circuit that can easily identify 1000 or more colors with 100% accuracy. For $39 it's impossible to build a very intelligent device. However, most of us own personal computers; why not use it as the brain? That's what we did here.

A hardware/software combination activates, in turn, one of several LEDs; each emits a portion of the visible spectrum. A phototransistor measures the light reflected by the surface being measured, and an 8-bit analog-to-digital converter (ADC) translates the phototransistor's output into a digital format that the computer can interpret. Seven LEDs (blue, aqua, green, yellow, orange, crimson, and red) provide a range of readings across the visible spectrum. Lack of spectral continuity among adjacent LED colors could skew results, so the circuit provides built-in compensation for this error.

Two simple BASIC programs control the circuit's operation. One allows you to define a set of standards by measuring known color samples and recording the values with an associated name. The other program measures unknown samples and provides the best match with the defined standards, as well as a relative error factor.

Circuit description

Figure 1 shows the complete circuit. Three ICs do the work. First is IC1, a 74HCT688 8-bit comparator that provides a low-going signal on pin 19 when the values on IC1's P and Q inputs are equal. That happens when there is no direct-memory access (DMA) occurring (i.e., AEN is low), when address line A9 is high, and when address lines A3–A8 are low. If you work out the math, you'll see that this occurs whenever any I/O port in the range 512–519 is accessed. If those port addresses are used on your system, you can easily change the values by connecting different Q inputs to ground and +5-volts DC. You will also need to change the value of ADR as defined in line 2 of both BASIC programs.

Every time pin 19 of IC1 goes low, IC3 latches the current contents of the 8-bit data bus. These latched values in turn drive the seven LEDs. (LED2 is a dual unit containing both red and yellow LEDs, so there are only six actual devices.) Pin 19 of IC1 also drives the $\overline{RD}$ input of IC2, an 8-bit ADC. That causes IC2 to sample the voltage appearing at its input pin 6.

That voltage depends primarily on the amount of light shining on Q1, a general-purpose phototransistor. The authors used a PN168PA-ND sold by Digi-Key Corp. The phototransistor must be mounted so that when a measurement is taken, it will only detect light from the LED array. The input voltage to the ADC also depends on the state of pin 19 of IC3. When that pin is low, resistor R3 is effectively in parallel with R2, thus changing the bias on the phototransistor, hence the voltage at pin 6 of the ADC. The ADC's clock frequency depends on the values of R1 and C1, which gives a frequency of about 400 kHz.

Note that an A/D conversion occurs whenever the system accesses I/O port 512–19. But other events happen as well, depending on whether an I/O read ($\overline{I/OR}$) or an I/O write ($\overline{I/OW}$) has occurred.

If CPU signal $\overline{I/OR}$ goes low, pin 3 of the ADC in turn goes low,

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*Delaware Valley College Chemistry Department, Doylestown, PA

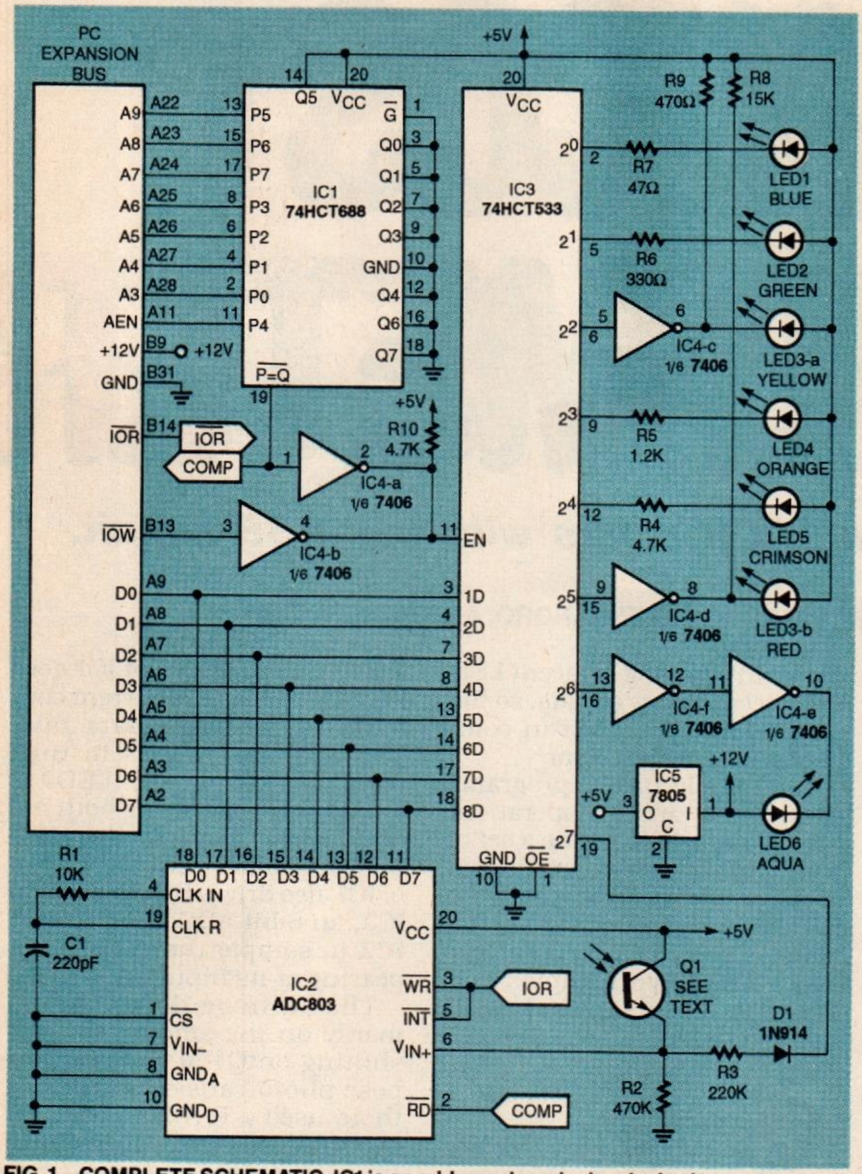


FIG. 1—COMPLETE SCHEMATIC. IC1 is an address decoder hard-wired to respond to I/O ports 512–519. IC2 is an A-to-D converter that measures the voltage across R2, which depends on the amount of light shining on Q1. IC3 is an 8-bit inverting latch that the software drives to successively light each LED during a scan.

forcing the ADC to present its most recently collected value to the data bus. On the other hand, if CPU signal $\overline{IOW}$ goes low, pin 11 of IC3 goes high, thereby latching the values on the data bus into IC3. Each register in IC3 provides a latched, inverted output capable of sinking 35 milliamperes.

LEDs

Table 1 summarizes important information about the LEDs. The activation code is the value that must be set into the assigned I/O port to activate or deactivate a given LED. Values can, of course, be summed to enable or disable several LEDs at once.

Note that LED6, the aqua emitter, requires direct connection to +12V. At $12.50, it was rather expensive when first introduced, but the price has dropped slightly. (The LED is available, as part 48-6E for $10.26 plus shipping from Parts 1, 1995 County Rd. B2, Roseville, MN 55113; 800-424-6204.)

Both LED3 and LED4 are dual units. The circuit includes both the yellow and red units in LED3, but it uses only the orange unit in LED4.

The values of R4–R9 were selected to provide an ADC response range from approximately 5 (for a black surface) to 200 (for a white surface) for each LED. That will provide a maximum response range for most colors. Higher ADC values might cause the phototransistor to saturate, thereby preventing the circuit from reliably distinguishing different colors.

Although there is some overlap between the two, there is a large spectral gap between the aqua (LED6, 482 nm) and green (LED2, 560 nm) LEDs. We solved the problem by energizing both LEDs simultaneously and decreasing ADC sensitivity. By keying a value of 194 (128 + 64 + 2), both LEDs are turned on and R3 is enabled via diode D1. This increases the number of colors that can be identified from a few hundred to more than 1000.

The authors used a separate 7805 voltage regulator, driven by the host computer's +12-volt supply, to power the other ICs in the circuit. This minimized inconsistent results obtained by running the circuit in different computers with slightly different +5-volt supplies. Thus calibration is generally much machine independent.

Software considerations

Listings 1 and 2 present the calibration and identification programs, respectively. (These files are available on the *Electronics Now BBS*, 516-293-2283, 9600 baud, as file 1KCOLOR.ZIP.) The calibration program uses two external files, CAL1 and CAL2, to store information. CAL1 stores standard values, and CAL2 stores corresponding names.

TABLE 1—LED COLORS AND CODES

LED	Wave-length	Color	Activation Value
LED1	470 nm	Blue	2^0=1
LED2	560 nm	Green	2^1=2
LED3-a	590 nm	Yellow	2^2=4
LED3-b	700 nm	Red	2^3=8
LED4	630 nm	Orange	2^4=16
LED5	665 nm	Crimson	2^5=32
LED6	482 nm	Aqua	2^6=64

LISTING 1—CALIBRATION PROGRAM

```
10 'CALIBRAT.BAS calibration program
20 CLS:KEY OFF:N=0:ADR=512:OPEN"R",1,"CAL1",16:OPEN"r",2,"cal2",24
30 FIELD 1,2AS B$,2AS G$,2AS Y$,2AS O$,2AS C$,2AS R$,2AS A$,2AS AG$
40 FIELD 2,24AS ID$
50 PRINT "reference number",N+1:OUT ADR,255:BEEP:INPUT "Enter Name of Standard
or 'E' To End";TEMPID$
60 IF TEMPID$="E" OR TEMPID$="e" THEN N=0: GOTO 200
70 IF TEMPID$="n" THEN INPUT"enter n to redo ",N:N=N-1:GOTO 50
80 N=N+1:FOR H=0 TO 7:K=0:IF H<7 THEN Z=2^H ELSE Z=194
90 OUT ADR,Z:FOR I=1 TO 500:NEXT I
100 FOR J=1 TO 50:K=K+INP(ADR):NEXT J
110 IF H=0 THEN LSET B$=MKI$(K)
120 IF H=1 THEN LSET G$=MKI$(K)
130 IF H=2 THEN LSET Y$=MKI$(K)
140 IF H=3 THEN LSET O$=MKI$(K)
150 IF H=4 THEN LSET C$=MKI$(K)
160 IF H=5 THEN LSET R$=MKI$(K)
170 IF H=6 THEN LSET A$=MKI$(K)
180 IF H=7 THEN LSET AG$=MKI$(K)
190 NEXT H:LSET ID$=TEMPID$:PUT 1,N:PUT 2,N:CLS:GOTO 50
200 N=N+1:GET #1,N:GET #2,N:IF N>(LOF(1)/16) THEN END
210 B=CVI(B$):G=CVI(G$):Y=CVI(Y$):O=CVI(O$):C=CVI(C$):R=CVI(R$):A=CVI(A$):
AG=CVI(AG$)
220 PRINT N,ID$:GOTO 200
```

LISTING 2—IDENTIFICATION PROGRAM

```
1 'IDENTIFY.BAS  identification program
10 ADR=512:OUT ADR,255:PRINT:INPUT "Hit Enter To Scan/Identify Unknown
Color";A
20 IF A=9 THEN RUN"fcal"
30 ERP=1E+20:OPEN"R",1,"call",16
40 FOR H=O TO 7:K=0:IF H<7 THEN Z=2^H ELSE Z=194
50 OUT ADR,Z: FOR I=1 TO 500:NEXT I
60 FOR J=1 TO 50:K=K+INP(ADR):NEXT J
70 IF H=0 THEN BU=K ELSE IF H=1 THEN GU=K ELSE IF H=2 THEN YU=K
80 IF H=3 THEN OU=K ELSE IF H=4 THEN CU=K ELSE IF H=5 THEN RU=K
90 IF H=6 THEN AU=K ELSE IF H=7 THEN AGU=K
100 NEXT H:BEEP
110 OUT 512,255:OPEN"r",2,"cal2",24:FIELD 1,2AS B$,2AS G$,2AS Y$,2AS O$,2AS
C$,2    AS R$,2AS A$,2AS AG$:B=LOF(1)/16
120 FOR N=1 TO B:GET #1,N:IF ABS( CVI(B$)-BU)>400 THEN 140
130 ER=(CVI(B$)-BU)^2+(CVI(G$)-GU)^2+(CVI(Y$)-YU)^2+(CVI(O$)-OU)^2+(CVI(C$)-
CU)^    2+(CVI(R$)-RU)^2+1*((CVI(A$)-AU)^2)+2*((CVI(AG$)-AGU)^2):IF ER<ERP
THEN ERP=     ER:NN=N
140 NEXT N
150 FIELD 2, 24AS ID$: GET #2,NN
160 CLS:PRINT "Best Color Match",ID$:PRINT"Relative Error",ERP:PRINT"reference
number",NN:RUN
```

To create the calibration files, run CALIBRAT.BAS. The program will ask you to enter the name of a standard, or press "e" to end calibration. If you enter "e," the program will end, displaying a list of currently calibrated color standards. Otherwise, it will create a new standard using the name you entered. It creates the standard values by enabling each LED (or the LED2/LED6 combination) in turn, then reading 50 times in succession the value sensed by Q1. Each color value (which is summed in variable K) is plugged back into the appropriate field of the data file in lines 110–180, then written to disk in line 190. If you want to re-do a standard value, enter "n" at the prompt. The program will ask you the numerical value of the standard you want to re-do, and then update the appropriate numerical values.

To identify an unknown color, run IDENTIFY.BAS. As in the calibration program, IDENTIFY samples each LED (or combination) 50 times and sums the results. The program then compares the sum against the values stored in the standard file and finds the closest match. The program calculates error as the sum of the squares of the differences, with double weighting given to the dual (aqua/green) LEDs. On a 20-MHz 286-based PC, it takes less than three seconds to determine the closest match from a list of 1000 values.

Construction

The authors built the prototype on two cards. One is an interface card that can be inserted in any standard 8-bit PC expansion slot. This card contains everything except the LEDs and phototransistor. They are located in a separate box called the reflectance probe; it connects to the interface card via a 12-conductor ribbon cable.

To save money, the authors built the interface card on a $4.99 72-pin prototype card. If you use the specified interface card (see the Parts List), *carefully* file exactly ½" from the edge connector to make it fit the 62-pin PC slot. The complete board should appear as shown in Fig. 2. (Note that the authors split the cable in two, attaching the separate sections with a pair of 25-pin, D-style, I/O connectors.)

Figure 3 illustrates the reflec-

PARTS LIST

All resistors are ¼-watt, 5%, unless otherwise noted.
R1—10,000 ohms
R2—470,000 ohms
R3—220,000 ohms
R4, R10—4700 ohms
R5—1200 ohms
R6—330 ohms
R7—47 ohms
R8—15,000 ohms
R9—470 ohms
Capacitors
C1—220 pF disk capacitor
C2—0.1 µF disk capacitor
Semiconductors
D1—1N4148 diode
IC4—7406A hex inverter with open collector outputs
IC1—74HCT688E octal comparator
IC3—74LS533E octal latch with inverted outputs
IC2—ADC803LCN analog-to-digital converter (Burr-Brown)
IC5—7805 5-volt regulator
LED1—470 nm blue LED (DigiKey 103CR-ND or equiv.)
LED2—560 nm green LED (DigiKey P312 or equiv.)
LED3—590/700 nm yellow/red LED (DigiKey P394 or equiv.)
LED4—565/630 nm green/orange LED (DigiKey P509 or equiv.)
LED5—665 nm crimson LED (DigiKey P405 or equiv.)
LED6—482 nm aqua LED (Ledtronics, Torrance, CA, L200CWGB6 or equiv.)
Q1—phototransistor (Digi-Key PN168PA-ND or equiv.)
Miscellaneous: 14-pin DIP socket (1), 20-pin DIP sockets (3), 5-foot length of 14-conductor ribbon cable, box (Radio Shack 270-230 or equiv.), plug-in PC board (Radio Shack 276-192 or equiv.), hookup wire, wire cutters, soldering iron, solder, drill, ½" drill bit, small drill bit, file, glue gun, and black plastic electrical tape.

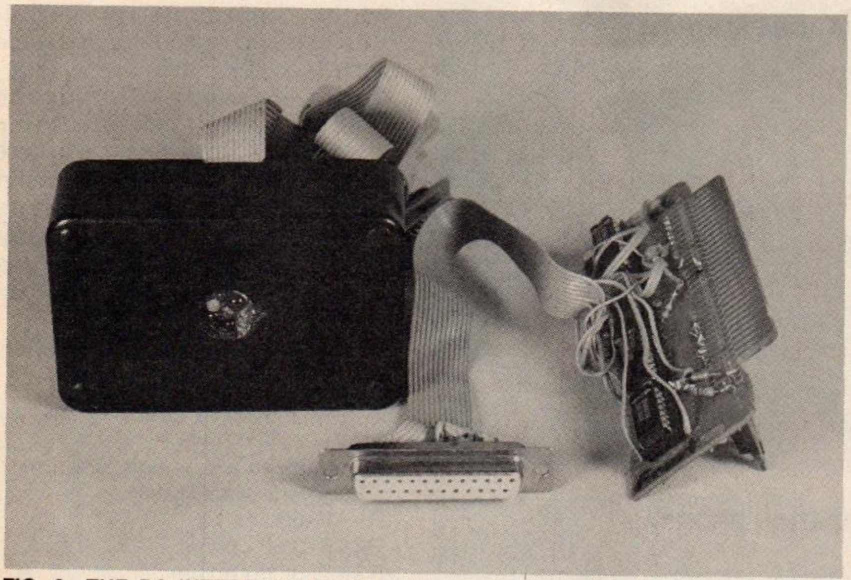


FIG. 2—THE PC INTERFACE CARD requires just enough space for five ICs, ten resistors, a couple of capacitors, and a diode. The reflectance probe contains six LEDs and the phototransistor cemented together with hot-melt glue and sealed in a light-tight box.

tance probe, which contains the six LEDs arranged in a circle around the phototransistor. All components are mounted on perforated construction board, which could be removed from the top of the interface card. Each LED must be tilted so that the brightest emission from each LED illuminates the sample and reflects back into the phototransistor. Tilt angle is particularly critical for the blue LED.

Glue a 6-centimeter (cm) piece of perforated construction board into the bottom of the box with the solder pads up. Then drill a small pilot hole, followed by a larger ½ inch hole, through both the board and the box, in the approximate center of the box. Cut the shorter leads of the LEDs and phototransistor to about a 1 centimeter length, and the longer leads to about 1.5 cm. Spread the phototransistor leads 180° and solder the phototransistor so that it points straight out the center of the hole. Now solder in the LEDs. All devices should be almost flush with, but not protrude through, the bottom of the box.

Connect all the common LED leads and the collector of the phototransistor to a common +5-volt line. Connect the remaining LED and phototransistor leads to the individual wires of the ribbon cable.

Testing and final assembly

Test the unit before gluing the optics in place. First check all wiring carefully. An inadvertent wiring error or short circuit could cause your PC to crash, or even damage it. Turn off PC power, install the circuit card, turn the power back on, and start BASIC. By typing a series of statements in the following form, you should see each LED light up in turn.

```
out (512,n)
```

where 512 is the address at which you wired IC1 to respond (default=512), and N is 1, 2, 4, 8, 16, 32, or 64, which should in turn illuminate the blue, green, yellow, orange, crimson, red, or aqua LED.

Now run the calibration program (Listing 1) and calibrate a few values. Next run the IDENTIFY program (Listing 2) and verify that the unit works. Read the usage notes before concluding that it doesn't work.

When you're satisfied that it works correctly, seal the LEDs and phototransistor in the box with hot-melt glue. Attach the cover on the box with screws, and seal the box with electrician's black vinyl tape to prevent stray light from leaking in and corrupting the results.

Usage notes

Thermal stability is an issue with this circuit. You should always turn it on several minutes before using it. The larger the number of standard colors you have defined, the longer you should let the tester warm up. The authors found that with a 1000-sample standard file, a warm-up time of one hour was required for accurate results. The authors also found that the best thermal stability was achieved by leaving the LEDs on. This is the reason for the OUT ADR,255 instructions in the initialization sections of both programs. Of course, during a scan, the software turns on only one LED at a time.

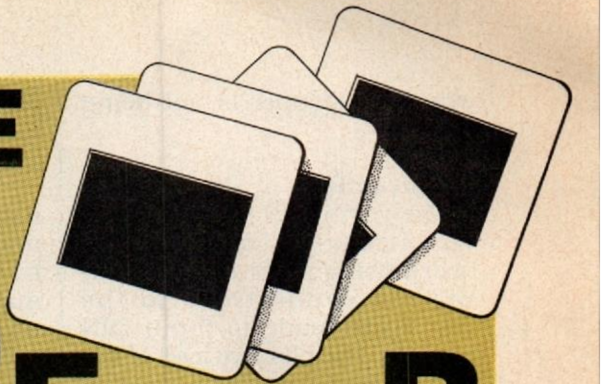
The methodology paid off. After it was calibrated, the authors' prototype was able to identify 900 shades of Sears' standard paint colors, plus an additional 100 "Weatherbeater Premium" paint sample colors. In addition, the circuit gives reasonable matches for typical random color samples. For example, the best match to the blue background on page 37 of the September 1992 issue of *Radio-Electronics* was identified as "Oriental Blue."

Magazines typically print colors as discrete dots of a specific color, not as continuous tones. Under normal circumstances, the dots shouldn't affect the color-matching process. If the dots are very large, or if for any other reason you have trouble getting consistent results, try covering your sample with a thin sheet of clear plastic.

"Gloss" and texture are, however, subjects of concern. Samples with slight texture or gloss can usually be matched fairly well, but don't use textured, glossy, or plastic-covered samples for calibration.

Identifying 1000 colors with 100% accuracy is an impressive feat for so simple a device. We hope that someone will develop the idea further by improving the statistics, writing the software in a language more powerful than BASIC, developing a serial (RS-232) version for laptop computers, and even a pocket-size EPROM version. Ω

THE SLIDE STEPPER



Put on an automatic slide show with this simple stepper circuit.

JOHN W. SWANCARA

THE REQUIREMENTS FOR THIS project were determined when our club historian assembled a slide show to run during an upcoming banquet. Everyone wanted to eat, and no one wanted the responsibility of operating the slide projector and advancing the slides. Unfortunately a slide projector that would sequence them automatically was not available. The circuit described here solved the problem by adapting a standard carousel slide projector for automatic operation. Only the remote control cable that plugs into the slide projector must be modified—the projector is left in its original form.

The circuit for the unmodified remote control of the Kodak carousel projector is shown in Fig. 1. The remote originally provided forward and reverse advancing of the slides. It was replaced by a variable timer and a relay that simulated the remote's forward switch and controlled the projector.

Theory of operation

The timer circuit is shown in Fig. 2. A 555 timer, IC1, is the heart of the circuit. The value of resistor R3 determines a minimum time delay, and potentiometer R4 sets the maximum delay. The values indicated provide a time delay that is variable from 1 to 15 seconds. If only one time delay is required, R3 and R4 may be replaced with one equivalent fixed resistor. The reset time of IC1 is sufficient to energize relay RY1 for a duration roughly equivalent to a person momentarily depressing the forward button on the original remote control. Resistor R1 provides current limiting for the 5-volt reed relay, also extending the life of the battery.

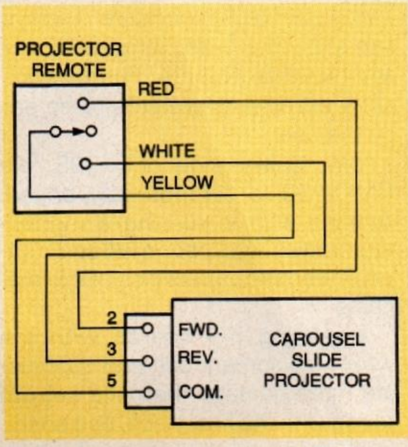


FIG. 1—ORIGINAL CONFIGURATION of the slide projector's remote control.

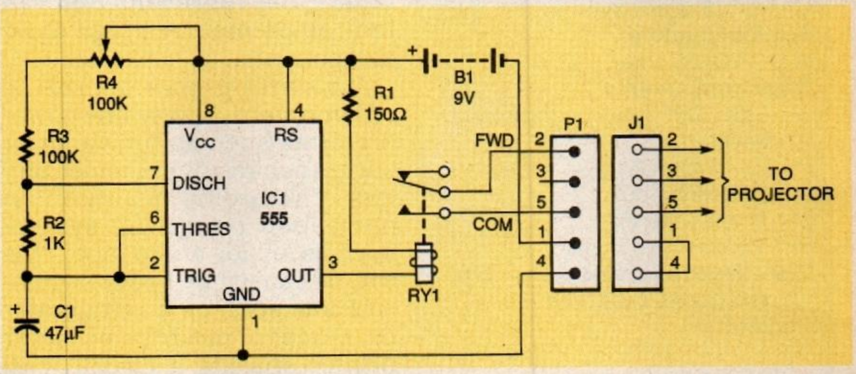


FIG. 2—SCHEMATIC DIAGRAM. The stepper circuit replaces the remote and will automatically advance the slides with a variable time delay.

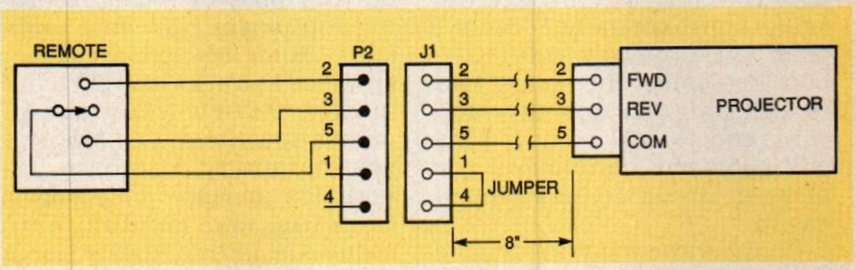


FIG. 3—CABLE MODIFICATION. This will allow the remote and the stepper circuit to be swapped easily.

No power switch is required. Power is supplied by a 9-volt battery (B1) and it is switched on when pins 1 and 4 of DIN plug P1 are shorted by DIN jack J1 as shown. The circuit works only when connected to the projector. This saves parts and labor and eliminates the chance of forgetting to turn off power when the stepper is not being used.

Construction

The parts can be assembled on perforated construction board using point-to-point wiring. All connections to the board are made to 5-pin DIN plug P1. The positive lead of the battery connector connects to the circuit board, while the negative lead connects to pin 1 of plug P1. The board can be installed in any suitable case, as long as there's room for the 9-volt battery, too.

PARTS LIST

All resistors are ¼-watt, 5%.
R1—150 ohms
R2—1000 ohms
R3—100,000 ohms
R4—100,000 ohms, potentiometer
Capacitors
C1—47 µF, electrolytic
Semiconductors
IC1—TLC555 timer
Other components
J1—5-pin DIN jack (or equivalent connector)
P1, P2—5-pin DIN plug (or equivalent connector)
B1—9-volt battery
RY1—5-volt, SPST relay
Miscellaneous: 9-volt battery clip, circuit board, case, one 8-pin IC socket

The projector's remote control cable must be modified to work with the timer circuit. Cut the cable approximately 8 inches from the projector connector end. Reconnect the remote end to DIN plug P2, and the projector end to DIN jack J1. This will allow the remote and the stepper circuit to be swapped easily.

Connect the modified remote control cable to the projector and make sure that the forward and reverse functions of the remote control still work. With the projector turned off, disconnect the remote from J1 and connect the stepper circuit. You should hear the relay click with a steady time delay. Potentiometer R4 should vary the time delay. Now you can turn on the projector, set the advance delay, and join the party. Ω

MAGNETIC STORAGE

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magnetized screwdriver near magnetic heads. Magnetic heads should be cleaned and demagnetized according to manufacturers' specifications.

The effect of a dirty head varies greatly in different storage technologies. Floppy disk drives rarely fail due to dirty heads, whereas many tape drive failures can be corrected simply by cleaning the heads.

Laboratory-grade alcohol and a cotton swab will clean most recording heads and tape paths. Special cleaning and demagnetizing kits are available for the various media. These kits use alcohol substitutes due to regulation of shipment of flammable substances. Avoid using rubbing alcohols containing oily lubricants that can foul or prematurely age drive components.

Maintain proper operating environment. Severe line power problems such as brownout or surges can result in momentary loss of recording quality in an open-loop recording system such as analog audio tape. This can be caused by heavy switched loads such as a refrigerator or certain models of laser printer sharing a circuit with recording equipment.

In dry climates static buildup on your body or inside recording equipment can cause problems. Some equipment is not specified to work below 20% humidity. Review your equipment's specifications. Monitor your humidity. Purchase humidifiers or employ anti-static carpeting and handling procedures as indicated. Discharge your body before handling magnetic media.

Park your media. Tape media should be parked at the beginning of tape position or at the end of tape position before being removed from the drive.

Long term storage of a cartridge in a drive can cause the drive or cartridge roller hubs to deform. This deformation can be repaired by performing multiple retension passes. Ω

EQUIPMENT REPORTS

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penser tube under precisely controlled air pressure. The amount of time that the air pressure is applied to the dispenser is also precisely controlled and can be varied to adjust the amount of solder paste deposited on a board.

Surface-mount components are difficult to handle, and conductive tools such as tweezers can damage parts that are sensitive to electrostatic discharge or ESD. An SMD (surface-mount device) vacuum handling tool is also included with the SMD-250 to eliminate the danger of ESD damage. Interchangeable vacuum tips are used to pick up and place all kinds of surface-mount parts. Vacuum is applied to pick up and place the part, and when the part is in position, the vacuum is released and the part stays put.

A hot thermal jet-flow attachment allows a temperature-controlled blast of air to be directed at SMD parts to melt the solder paste. This allows surface-mount parts to be replaced without heating the entire board.

Holder assemblies mount on the top of the SMD-250 to hold the accessories when they are hot. A wet and dry tip maintenance kit is also included that mounts on top of the unit to keep all kinds of tips clean and ready for use.

The front panel of the SMD-250 contains most of the unit's controls and displays. A lighted on/off switch indicates when power is on. Two separate temperature displays can show the exact temperature of any two attachments. Pushbuttons allow exact temperatures to be set by the user.

With a list price of $1995, the SMD-250 is competitively priced. Anyone who is running a modern electronics repair shop will undoubtedly need the capabilities of this machine.

Repairing PC boards with the wrong equipment can end up causing more damage than one set out to repair in the first place, and so the SMD-250 could pay for itself in time saved and in damage not done. Ω