Inexpensive but sophisticated electronic flashguns have been available for some years now, and they offer what on the face of it is an ideal system of lighting for many applications. In practice there are problems that can make flash lighting a little difficult to use. Probably the most formidable of these is obtaining the correct exposure. Many cameras have a built-in exposure meter these days, but in most cases the meter does not function properly with flash lighting, and a special flashgun is needed for the few cameras which do support TTL automatic flash. Ordinary automatic flashguns can often solve exposure problems, but the sensor's wide light reception angle means that it may not always give accurate results, and the number of aperture options available is usually very limited. Also, automatic flashguns are only intended to be used singly, and the use of two or more guns can easily cause under exposure due to the light from each flashgun activating the cutoff circuit of the other.

When using electronic flash lighting the most reliable way of determining the correct exposure is to use a flash exposure meter, but even the more simply ready-made units of this type tend to be quite expensive. However, the circuitry involved is less complex than one might think and a home constructed flash meter can be built at a comparatively low cost. This flash meter design covers a range of six or seven stops and is suitable for use with any normal electronic flashguns, including the variable power type. It is very simple to use and does not require any connection from the camera to the meter.

By Robert Penfold

★ Simple to construct. ★ Can be used with variable power electronic flashguns. ★ No connection to camera required. ★ Makes finding the correct exposure easy.

FLASH METER

Operating Principle

Metering flash obviously poses a more difficult problem than metering available light. Instead of a continuous light level it is necessary to measure a short pulse of light. Furthermore, it is not just the intensity of the light that determines the exposure, but the duration of the light pulse. In fact with variable power flashguns there is no significant difference in the intensity of the flash between full and minimum power; the power of the gun being varied by controlling the duration of the flash.

Figure 1 shows the block diagram for the flash meter project, and this helps to show the way in which the problem of measuring both flash intensity and duration are solved. The light detector circuit makes use of an inexpensive phototransistor. This has a suitably fast response time plus reasonably good sensitivity. A diffuser is used over the phototransistor to give the unit a wide response angle despite the rather narrow response of the phototransistor. A voltage regulator gives a well stabilised supply to the photocell circuit so that variations in the battery voltage do not significantly affect the sensitivity of the unit. The output of the photocell circuit is capacitively coupled to the next stage of the unit. A DC coupling would not be satisfactory as it would result in the ambient light level activating the circuit. The AC coupling blocks any small DC component on the output from the photocell circuit, but efficiently couples the pulse caused by the flashgun through to the next stage. Variations in the ambient light level will result in a signal being coupled through to the next stage, which is a rectifier circuit. This uses silicon diodes, and the forward threshold voltage of these is high enough to block the small signals produced by changes in the ambient light level, but does not block the larger signals caused by the light pulses from the flashgun. This system relies on the light level from the flashgun being substantially higher than the ambient light level, but this should always be the case in practice as flash lighting would otherwise be unnecessary, and almost certainly unusable. There is actually an alternative way of doing things, where the output of the photocell circuit is only coupled through to the rest of the circuit when the flash contacts of the camera are closed. This method seems to have fallen from favour in recent years, and although it is superior in certain respects, it is less convenient in use as it requires connections from the camera to the flashgun.

The next stage of the unit is a Miller Integrator. This is perhaps not one of the best known circuit blocks, but is nevertheless a very useful type of circuit. Figure 2 shows the circuit for a Miller Integrator. Initially the input and output are both at earth potential. If a positive signal is applied at the input, this unbalances the two input voltages of the operational amplifier and sends the output negative. What actually happens is that Ca charges via Ra, and the output of the operational amplifier goes negative by an amount equal to the charge voltage on Ca in order to keep the input voltages balanced. An interesting and useful property of this type of circuit is that the inverting input is maintained at earth potential, so that with a constant input voltage the charge current through Ra and into Ca remains constant. Ca therefore charges in linear fashion and not in the normal exponential manner so that the output voltage goes negative at a constant rate. This is ideal for our present purposes, since the output voltage is governed by both the amplitude and duration of the input pulse. A high input voltage gives a fast change in output voltage, and thus a large output voltage for a given pulse duration. A long pulse duration results in the output swinging negative for a relatively long time, and therefore produces a large output voltage. The unit accordingly gives accurate and consistent results regardless of whether the flashgun in use has a short but powerful output, or a relatively weak but long flash output.

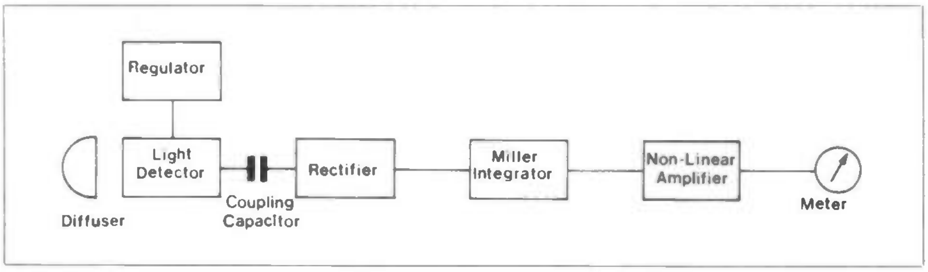


Figure 1. Flash Meter Block Diagram

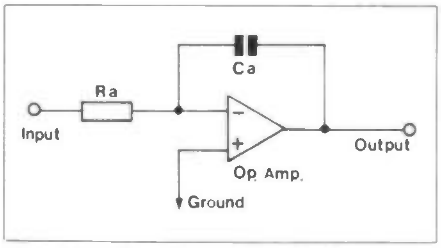
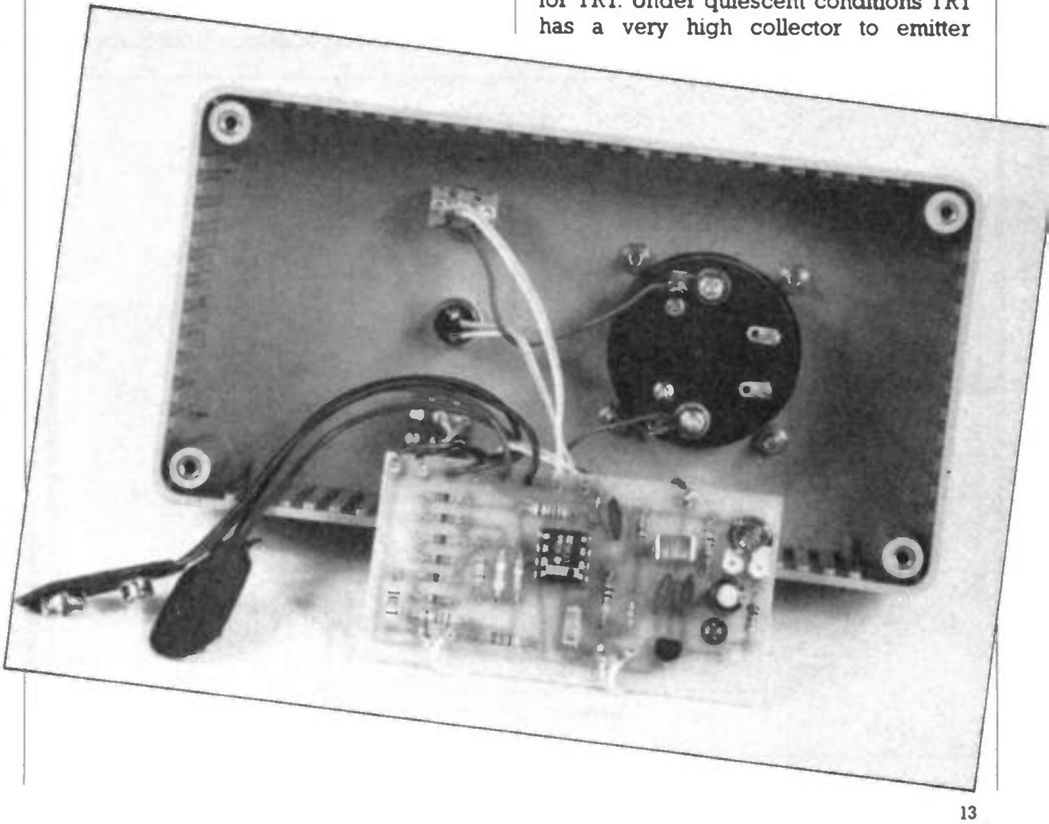


Figure 2. Miller Integrator Circuit

The final stage of the unit is a non-linear amplifier which drives an ordinary moving coil panel meter. The output voltage from the Miller Integrator is non-linear, with the difference between F stops being large at the high end of the scale, and small at the low end. This is simply because the amount of light is halved each time the exposure is reduced by an F stop. In other words, one stop down from full scale deflection would be half scale deflection, two stops down would be one quarter of full scale deflection, and so on. This type of scaling makes it impossible to cover a wide exposure range with good accuracy. The non-linear amplifier has a level of gain that reduces as the input voltage is increased, and this spreads the calibration points out more evenly across the scale of the meter, giving better accuracy and making the unit much easier to use.

The Circuit

Figure 3 shows the full circuit diagram for the flash meter. IC1 is a small 5 volt monolithic regulator which is used to provide the stabilised supply for the photocell circuit. The latter utilizes the collector to emitter resistance of phototransistor TR1, and R1 is the load resistor for TR1. Under quiescent conditions TR1 has a very high collector to emitter



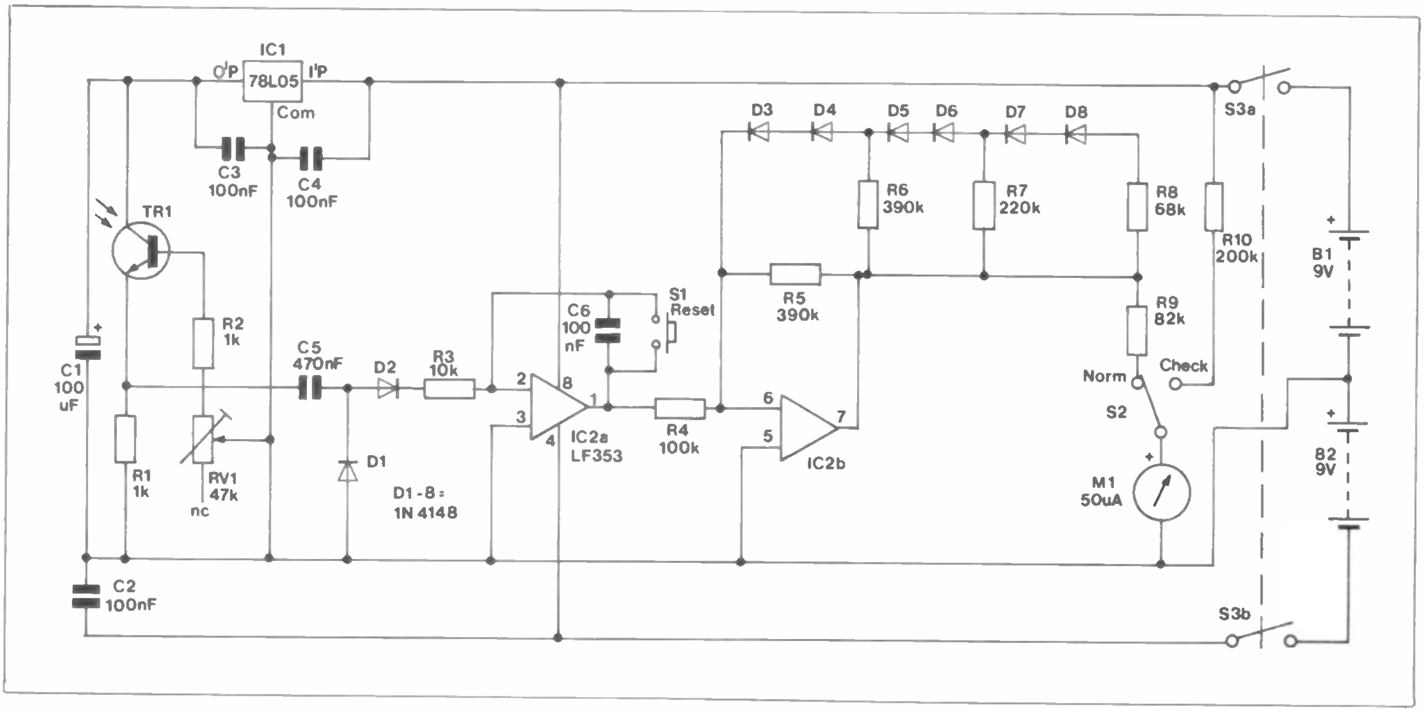


Figure 3. Circuit Diagram of Flash Meter

resistance, but this falls to a low level when TR1 is subjected to the high light level from the flashgun. This gives a positive pulse across R1, and provided TR1 is not driven into saturation the amplitude of the pulse is roughly proportional to the light level. R2 and RV1 reverse bias the base of TR1 and enable the sensitivity of the photocell circuit to be set at a suitable level.

C5 couples the output of the photocell circuit to a simple rectifier circuit using D1 and D2. The output of these is fed to the Miller Integrator based on IC2a. S1 can be used to discharge C6, and it therefore acts as the reset control. Obviously the charge on C6 will gradually leak away, but provided C6 is a good quality component and the specified ultra-high input impedance (JFET type) operational amplifier is used in the IC2 position, readings will be held accurately for a minute or more. This is obviously more than long enough to enable the meter to be read.

IC2b is used in the non-linear amplifier which is basically an ordinary operational amplifier inverting mode circuit. R4 and R5 are a negative feedback network which set the voltage gain of the circuit at 3.9 (390k divided by 100k = 3.9) with small input voltages. If the output goes positive by more than about 1 volt the first two diodes in the chain (D3 to D8) are biased into conduction, and R6 is shunted across R5 so that the gain of the circuit is reduced to only about half its previous level. Higher output voltages cause R7 and R8 to be switched into circuit as the other diodes in the chain are brought into conduction, giving the circuit a suitably non-linear transfer characteristic.

Meter M1 can either be switched to register the output voltage of the flash meter circuit, or it can be connected across the positive supply via R10. This resistor converts the meter to a simple 0 to 10 volt type so that the positive supply potential can be checked. A dual 9 volt supply is needed, and this is obtained from two small (PP3 or equivalent) batteries. Both batteries should be replaced when the positive supply voltage drops to about 7.5 volts. Note that the battery check facility only operates when the unit is switched on, but this is correct as it is the loaded supply voltage that should be checked. The current consumption of the circuit is approximately 7 milliamps from

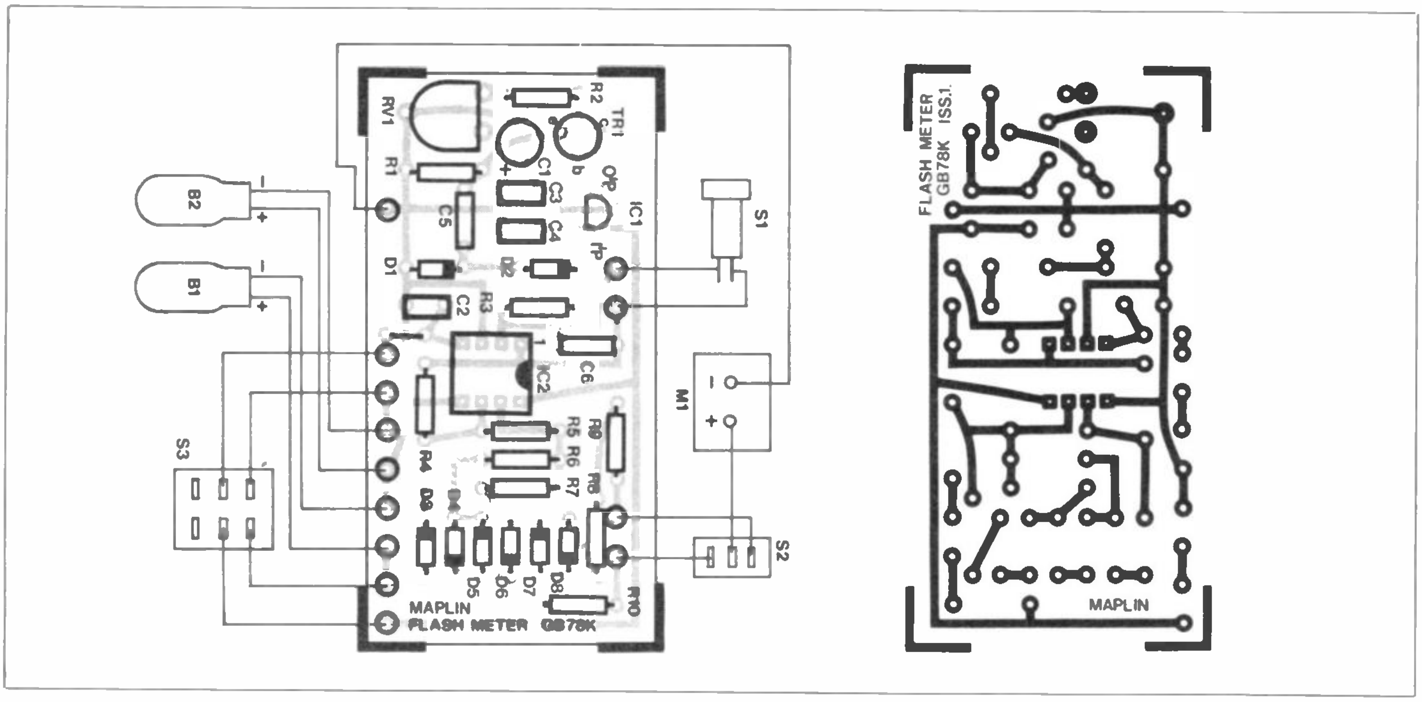


Figure 4. PCB Artwork and Layout

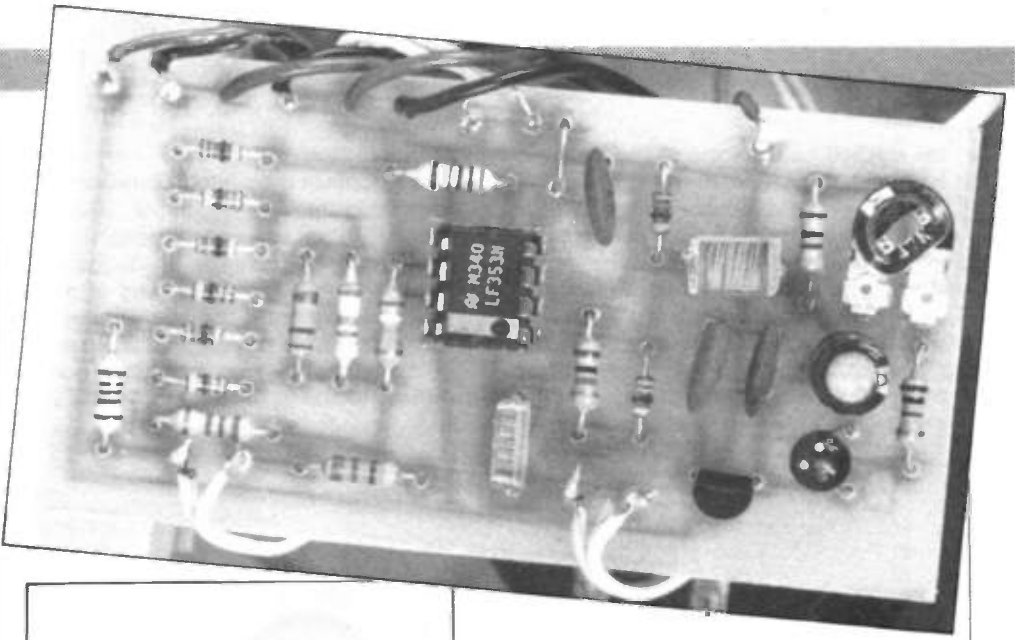
the positive supply and 4 milliamps from the negative supply.

Construction

All the small components are mounted on a printed circuit board, as detailed in Figure 4. Construction of the board does not present any real difficulties, but be careful to fit all the diodes on to the board with the correct polarity. Leave the leadout wires of TR1 at full length. Veropins are fitted to the board at the points where connections will eventually be made to the meter and switches. A plastic box having dimensions of 150 by 80 by 50 millimetres is used as the housing for this project, and this case has printed circuit guide rails which the circuit board is designed to fit. The case is used vertically, with the removable lid becoming the rear panel of the case. The printed circuit board fits into the second highest set of guide rails with the component side of the board facing upwards.

A hole about 10 millimetres in diameter is drilled in the top of the case to enable light to pass through to TR1. A diffuser of some kind must be fitted over this hole, and on the prototype the diffuser was made by carefully cutting a table tennis ball in half using a scalpel. This was then simply glued in place using a good quality general purpose adhesive. Ideally the diffuser would be somewhat smaller than a table tennis ball (say about 15 millimetres in diameter), and you might be able to improvise something better. Note though, that the diffuser must let a reasonable amount of light through to TR1 if the unit is to cover a useful exposure range. In fact a table tennis ball is fairly dense, and will result in the unit being fairly insensitive. This is perfectly alright if your main interest is something like close-up photography where high aperture values are needed, but something less dense would be better for general photographic work. Fine sandpaper can be used to slightly thin down the diffuser if necessary. Of course, the sensitivity of the circuit can be adjusted over a fairly wide range, but the adjustment range is inadequate to cope with a diffuser that is much too dense or too thin.

The meter and three switches are mounted at any convenient places on the front panel. The meter needs a main cutout 38 millimetres in diameter. This can be cut using a fretsaw or a miniature round file, or an alternative is to drill a ring of small holes (about 3 millimetres in diameter) just inside the perimeter of the required cutout, spacing the holes as close together as possible. A sharp knife is then used to join the holes, after which a large half-round file is used to tidy up the cutout and enlarge it to the required size. The four 3.3 millimetre diameter mounting holes are then drilled, and the meter can be utilized as a sort of template to assist with the marking of the positions of these holes on the front panel. To complete the unit the small amount of point to point wiring is added. A piece of foam material can be used to keep the batteries in place inside the case.



Adjustment

The basic method of calibrating the unit is to first set it up on a table in an average size room and not within about one metre of any walls. Start with the flashgun 0.5 metres away from the flash meter and take a reading. Remember that reset switch S1 should always be used to zero the meter before a reading is taken. What we require here is a reading at something in the region of the full scale value, and if a suitable reading is not obtained try repeating this procedure with RV1 at different settings until a suitable reading is obtained. If you are using a powerful flashgun it might be necessary to use it at half or quarter power. Then move the flashgun to distances of 0.7 metres, 1 metre, 1.41 metres, 2 metres, 2.82 metres, and 4 metres from the flash meter, being careful to accurately measure the distances and noting the readings at each distance.

Depending on whether or not a reading is obtained at the top maximum distance, this gives six or seven readings at one stop intervals. Ideally the front of the meter should be removed and these points should be carefully marked onto the scale plate, but it is not essential to do this. One way of using the meter is to make up a chart of the type shown in Table 1.

ASA	1	2	3	4	5	6
25	5.6	8	11	16	22	32
50	8	11	16	22	32	45
100	11	16	22	32	45	64
200	16	22	32	45	64	90
400	22	32	45	64	90	

Table 1.

This shows the aperture required for given film speeds and exposure values read from the meter, but the figures in the table are only intended as a guide. To find the correct values it is necessary to consult the exposure calculator of the flashgun used to calibrate the unit. It is advisable to take some test shots using the meter to determine the exposure, and then examine the results. Obviously the 'typical' surroundings used when calibrating the unit might not produce completely accurate results, and the only way to test this and make any necessary adjustments to the calibration is to try a practical test.

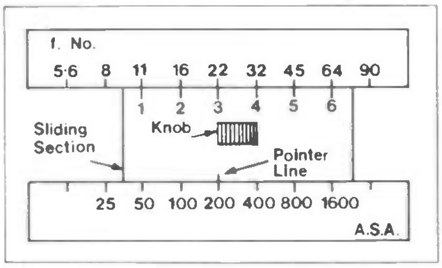


Figure 5. A Sliding Exposure Calculator

The unit will be more convenient in use if the exposure chart is replaced by some kind of exposure calculator. Figure 5 shows the basic set-up for a sliding exposure calculator. The divisions on all three scales are at one stop intervals, and the same spacing should therefore be used on all three scales. The idea is to set the sliding pointer to the appropriate film speed, and then the corresponding aperture for each exposure value can be read from the upper scale. Again, the values shown are only intended as examples, and might need to be altered to suit the particular diffuser and setting for RV1 that you have used. If exposure values are not marked on the scale of the meter, in both the exposure chart and on the calculator the exposure values would have to be replaced with the relevant meter readings. This would be much slower and more difficult in use though.

The meter should work well with variable power flashguns, apart from the types which cover a very wide power range. The problem with these is that the flash duration at the very low output power settings is extremely brief (usually something in the region of 1/15000th second). The response speed of the phototransistor may be inadequate to cope with this accurately, and of more importance, there is the problem that the light output from the flashgun is purposely made too high at very low power settings to compensate for the loss of film sensitivity that occurs at very short exposure times. This is obviously a factor that the flash meter does not take into account, and it would consequently give an accurate but misleading reading. When using a variable power flashgun with the unit it is therefore advisable to only use power levels of about ⅛th power or more so that very short flash durations are avoided.

PARTS LIST FOR FLASH METER

RESISTORS: All 0.4W 1% Metal Film

R1,2	1k	2	(M1K)
R3	10k	1	(M10K)
R4	100k	1	(M100K)
R5,6	390k	2	(M390K)
R7	220k	1	(M220K)
R8	68k	1	(M68K)
R9	82k	1	(M82K)
R10	200k	1	(M200K)
RV1	47k Hor S-Min Preset	1	(WR60Q)

CAPACITORS

C1	100μF 10V PC Electrolytic	1	(FF10L)
C2,3,4	100nF Minidisc	3	(YR75S)
C5	470nF Polycarbonate	1	(WW49D)
C6	100nF Polycarbonate	1	(WW41U)

SEMICONDUCTORS

TR1	Infra-Red Sensor	1	(YY66W)
IC1	μA78L05AWC	1	(QL26D)
IC2	LF353	1	(WQ31J)
D1-8	1N4148	8	(QL80B)

MISCELLANEOUS

S1	Push Switch	1	(FH59P)
S2	Sub-Min Toggle J	1	(FF70M)
S3	Sub-Min Toggle E	1	(FH04E)
M1	2in. Pan Meter 50μA	1	(RW91Y)
	Printed Circuit Board	1	(GB78K)
	PP3 Clip	2	(HF28F)
	DIL Socket 8-pin	1	(BL17T)
	Veropin 2145	1 pkt	(FL24B)
	Hook-up Wire	1 pkt	(BL00A)

OPTIONAL

ABS Box 2005	1		(LH61)
	Diffuser – see text		

A kit is available to build this project (not including Optional items).
Order As LK58N (Flash Meter Kit) Price £13.95

The Flash Meter PCB is available separately.
Order As GB78K (Flash Meter PCB) Price £1.75