sensitive lightmeter

The lightmeter described in this article utilises a silicon photodiode, the most up-to-date method of light measurement, and may be used either for photographic purposes or for the measurement of illumination.

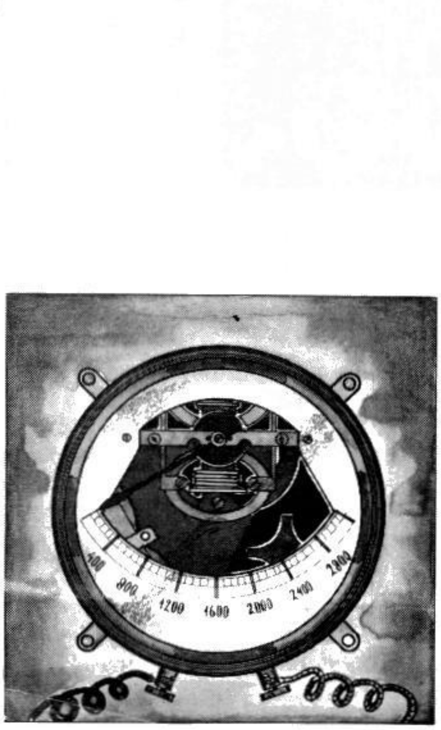
Most commercially available lightmeters still use cadmium sulphide photoresistive cells, which suffer from such disadvantages as slow response time, especially at low light levels, and a spectral response that does not match that of the human eye. A lightmeter using a silicon photodiode has considerable advantages over meters using photoresistive cells: the spectral response can be made much closer to that of the human eye (and of photographic film), the response time is sufficiently fast, and finally, the response to light is linear.

Unfortunately, from the photographer's point of view, silicon photodiode metering is available only in the most expensive cameras with built-in metering, so a design for a home-built, hand-held silicon photodiode lightmeter would seem to be a good idea. The circuit given here will measure light levels from 10 lux to 10,000 lux in four ranges, which is adequate both for the measurement of illumination and for photographic purposes.

The complete circuit of the lightmeter is given in figure 1, and operates as follows: light falling on photodiode D1 causes it to generate a negative voltage with respect to the 0 V rail. This causes the output of IC1 to swing positive, driving current round the feedback loop into D1. This current causes a voltage drop across the diode's internal resistance, which is in opposition to the voltage generated by D1. The output of IC1 takes up a positive voltage such that the two voltages cancel, i.e. the voltage at the inverting input of IC1 assumes the same potential as the non-inverting input – zero volts.

The output voltage which IC1 assumes is proportional to the feedback loop current required to cancel the photodiode voltage. This is proportional to the photodiode voltage, which in turn is proportional to the light falling on the photodiode. In other words, the output voltage of IC1 is proportional to the amount of light falling on D1.

Since the current through the photodiode is fairly small, if the feedback resistors were connected direct to the output of IC1 they would have to be impossibly large to obtain a reasonable



output voltage from IC1. To overcome this difficulty the output of IC1 is attenuated by a factor of 10 by R4 and R5. This also gives the possibility of an extra range, as will be explained later.

Three basic ranges are provided, 10 lux, 100 lux and 1000 lux, selected by means of S1 and calibrated by P1, P2 and P3. Pressing S2 shorts out the attenuator on the output of IC1, thus allowing a times ten multiplication of the ranges, or a maximum reading of 10,000 lux. If this highest range is not required then S2 can be omitted; R5 can be 1 k in this case. If, on the other hand, the lowest range is not required, S2 and R5 can be omitted and R4 replaced by a wire link.

Construction

A printed circuit board and component layout for the sensitive lightmeter are given in figure 2. The compact layout allows the lightmeter to be housed in a very small case, with ample room for a small 9 V battery such as a PP3. The current consumption of the lightmeter is only a few mA, so the battery should last for many months of normal use. S3 may be a non-latching pushbutton to avoid the possibility of the meter being left switched on.

Calibration

This is always a problem with any home-built measuring instrument, especially a lightmeter, which should be calibrated against a standard light source. Fortunately, a sufficiently accurate calibration for most purposes can be achieved using ordinary domestic lamps. A normal 240 V, pearl, incandescent lamp has a light output between 10 and 15 lumens per watt. If it is assumed that the lamp radiates uniformly in all directions then the illumination at any distance from the lamp is easily found. The point at which the illumination is to be measured is taken as being on the surface of a sphere, at the centre of which is the lamp. The illumination in lux (lumens per square metre) is found simply by dividing the light output of

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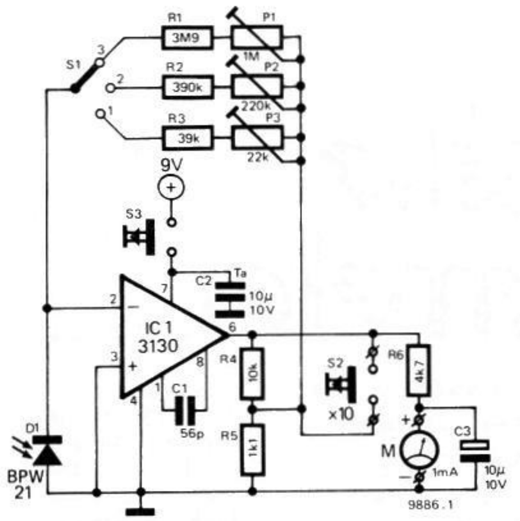

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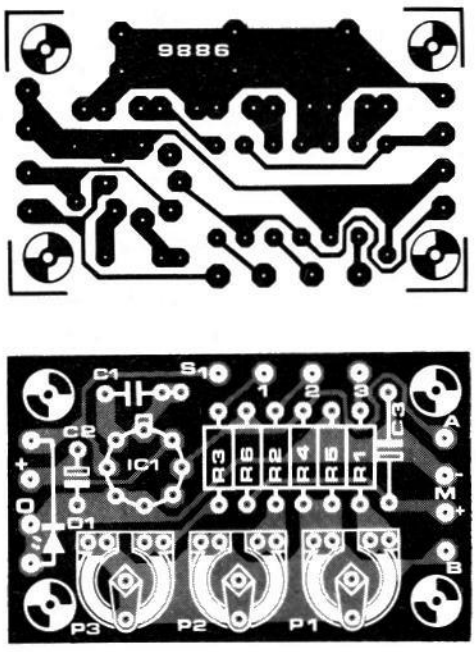

Figure 1. Complete circuit of the sensitive lightmeter.

Figure 2. Printed circuit board and component layout for the sensitive lightmeter (EPS 9886).

Figure 3. When used for photographic purposes the acceptance angle of the photodiode is too great and must be reduced by a lens or tube.

Table 1.

lamp	distance from lamp to photodiode	illumination
60 W	240 cm	10 lux
60 W	105 cm	50 lux
100 W	100 cm	100 lux
100 W	45 cm	500 lux
100 W	30 cm	1000 lux
(100 W	13 cm	approx. 5000 lux)

Parts list for figures 1 and 2.

Resistors:
R1 = 3M9
R2 = 390 k
R3 = 39 k
R4 = 10 k
R5 = 1k1 (see text)
R6 = 4k7
P1 = 1 M
P2 = 220 k
P3 = 22 k

Capacitors:
C1 = 56 p
C2 = 10 µ/10 V tantalum
C3 = 10 µ/10 V

Semiconductors:
D1 = BPW 21 (Siemens)
IC1 = 3130

Miscellaneous:
S1 = single-pole 3-way switch
S2 = push-to-make switch
S3 = push-to-make switch
M = 1 mA meter

the lamp by the surface area of the sphere, i.e.

$$I = \frac{\Phi}{4\pi r^2}$$

where I is illumination in lux
Φ is light output in lumens
r is distance from lamp in metres.

This equation is valid only if the lamp radiates uniformly, and for this reason only standard pearl lamps must be used for the calibration procedure. Spotlamps, high output lamps or lamps with any other internal reflector or coating are not suitable. Table 1 gives a list of useful distances with corresponding illumination levels.

Two lamps are required for the calibration procedure, a 60 W lamp and a 100 W lamp. The lamp must be mounted in a plain lampholder without reflector, and should be the only source of illumination. The calibration procedure must be carried out away from reflecting surfaces such as mirrors or light painted walls.

The calibration procedure is as follows:

1. Set the lightmeter to the 10 lux range and place it at a distance of 240 cm from the 60 W lamp. Adjust P1 for full-scale deflection of the meter. Now place a piece of thick card between the lamp and the lightmeter, when the reading should drop to less than 10% full-scale. If it does not then something in the room is reflecting light onto the photodiode.
2. Change to the 100 W lamp and set the lightmeter to the 100 lux range. Place the lightmeter 100 cm away from the lamp and adjust P2 for full-scale deflection.
3. Set the lightmeter to the 1000 lux range and place it 30 cm from the lamp. Adjust P3 for full-scale deflection.
4. Check that the calibration still holds when the x10 button is pressed, e.g. the same reading is obtained on the 1000 lux range as on the 100 lux range with the x10 button pressed.

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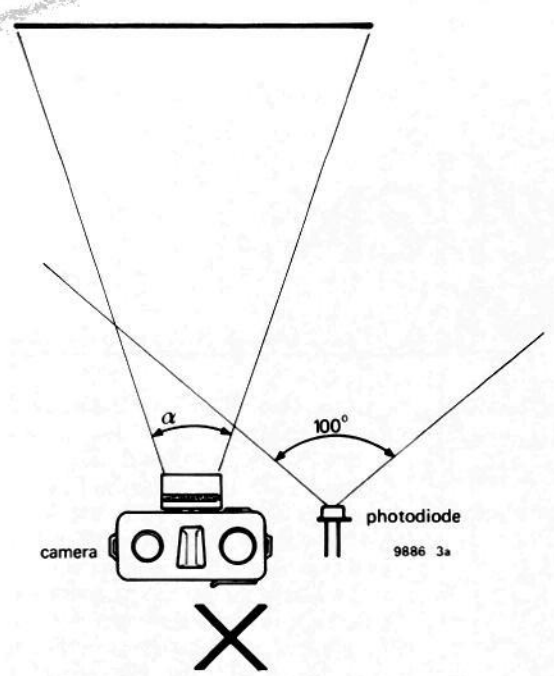

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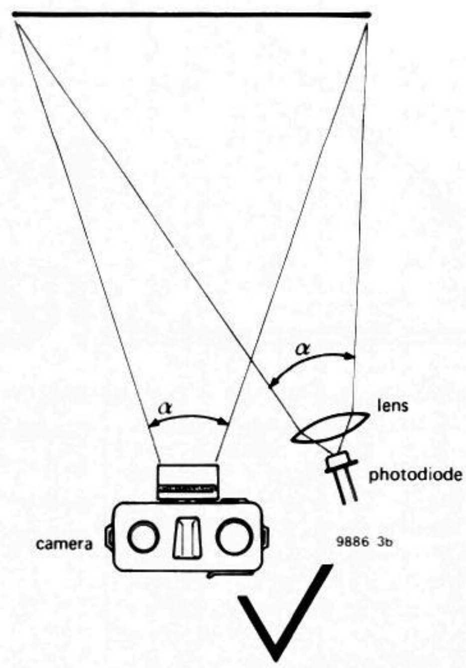

Table 2. Recommended illumination values in lux for various tasks.

class of visual task	example	recommended illumination (lux)
casual seeing	hallway	100
ordinary tasks, medium size detail	making cabinets for electronic projects; domestic living room	400
severe prolonged tasks, small detail	building a project on a p.c. board; studying	800
very severe tasks, very small detail	building a maximum-component-density prototype; detailed drafting	1500
exceptionally severe tasks, minute detail	watchmaking	3000

Photographic use

Calibration for photographic use presents further problems, since an absolute calibration procedure is almost impossible. The best method of calibration is to beg, borrow or steal an existing exposure meter to use as a reference.
Another problem exists with acceptance angle, since the BPW 21 photodiode will accept light over an angle of about 100°. This is much wider than the acceptance angle of the average camera lens, and means that the lightmeter will 'see' a different scene from that seen by the camera, including large areas of bright sky. This can easily result in false readings. The acceptance angle of the lightmeter must therefore be reduced by putting a convex lens in front of the photodiode, or by putting it in a tube. This principle is illustrated in figure 3.
To calibrate the lightmeter against a commercial exposure meter, the two are placed side by side and pointed at scenes of varying brightness. A table of lightmeter reading versus exposure meter reading is made, and this can later be used to calibrate the scale of the lightmeter. The lightmeter reading is then used in conjunction with the photographic film speed to find the correct exposure, which is basically the correct combination of shutter speed and aperture setting.

Unfortunately it is not possible to give a detailed calibration procedure for this method, since the scales of commercial exposure meters vary greatly, some giving a light reading that must be translated into an exposure value, and others giving a direct readout of shutter speed and aperture setting.
However, the calibration should not pose too much of a problem for the experienced photographer.

A second calibration procedure is possible, based on the calibration as luxmeter given above. The 'calibrated' lux scale can be converted to a photographic lightmeter scale on the basis of the following knowledge:

- for a 21 DIN (100 ASA) film, 120 lux on the scale is equivalent to a lens aperture of f16 at a 1 sec. exposure time;
- an increase by a factor 2 of the illumination reading in lux corresponds to a 1-stop increase in lens aperture, or a decrease by a factor 2 of the exposure time, or an increase of 3 points on the DIN scale, or doubling of the film sensitivity value on the ASA scale.

To give an example: if a 24 DIN (200 ASA) film is used (an increase by a factor 2 in sensitivity) and the lightmeter gives an indication of 240 lux (also an increase by a factor 2), correct exposure could be obtained at f16/¼ sec, or f11/⅛ sec, etc.
Regrettably, this calibration will probably prove insufficiently accurate for photographic use: it may well be one or two stops out. For this reason, it will be necessary to make a few test exposures for final calibration. ◀