From: The Departments of Periodontology
and Oral Pathology,
The Royal Dental College, Århus,
Denmark.

A SIMPLE AUTOMATIC EXPOSURE DEVICE FOR PHOTOMICROGRAPHY

by

KLAUS NUKI

ARNE JEPSEN

INTRODUCTION

The ability to take photomicrographs rapidly and with accurate exposure times is a facility frequently required in many laboratories. A common aid to exposure time assessment is a light sensitive cell of either the selenium or cadmium sulphide type, connected to a microammeter. The operator then transfers the reading obtained to a camera shutter. For longer intervals of time, a stop watch is employed and the shutter is opened and closed manually. Some of these devices require to be removed bodily from the microscope before exposure of the film commences, while others require to be switched out of the optical path by means of prisms attached to levers built either into the exposure meter or the microscope.

In recent years, automatic devices have appeared which sense the amount of light transmitted to the film plane and, directly by means of electronic delay circuitry, give the required exposure on the depression of a button. These automatic devices utilize exceedingly sensitive photomultiplier tubes, are capable of great accuracy and do not require removal from the optical pathway. Some of these devices are built into the microscope together with a special camera in which the film is also automatically advanced between exposures.

Such machines are, however, costly and, moreover, produce far greater accuracy in exposure than the wide latitude of modern film emulsions require. Black and white films have a latitude of at least ± 50 % in exposure and most colour emulsions have a latitude of ± 15 %.

It was therefore decided to try to develop an inexpensive device with an accuracy commensurate with most requirements.

MODE OF OPERATION

The principle employed is the well-known one used in many timing circuits of charging a capacitor to a predetermined potential through a variable resistance. The time taken to reach the required potential varies as the resistance, which in this device consists of a cadmium sulphide photo-resistance. The resistance of this type of photocell varies inversely with the intensity of the light falling upon it, this relationship being linear within certain limits.

When the predetermined voltage has been reached, a system of relays activates a solenoid attached to the microscope camera, thus effecting the exposure.

One disadvantage of many capacitance/resistance (CR) timing circuits utilizing a relay as a switch is that the current flowing through the relay coil decreases at a slow rate at the end of the timing period. Therefore, for accurate periods of time, the exact cut-off current must be carefully controlled. However, this is extremely difficult due to mechanical factors such as friction on the relay pivots which may vary from time to time and electrostatic forces upon the contacts. These factors come into operation during the timing cycle when relay energizing current lies between the level required to energize the relay and the level at which the relay de-energizes. During this time, the relay tends to be unstable. A simple solution lies in arranging the circuit in such a way that the relay current changes rapidly towards the end of the timing period. This allows greater accuracy well within the required limits and reduces the unstable time to a minimum.

In order to produce greater sensitivity in the relay coil switch circuit, it is normal to employ a transistor as an earthed emitter amplifier coupling the CR circuit to the base in order to keep the relay energized during the »on» cycle.

With the relay utilized in this device an energizing current of approximately 10 mA was required, which corresponds to a transistor base current of 0.2 mA assuming a current amplification factor of 50 for the transistor specified. The CR circuit specification would therefore call for a current of 0.2 mA which, in turn, would require a high energizing voltage for the photoconductive cell. This, at low light levels, has a resistance as high as 1 Megohm. Since 80—90 volts is an inconveniently high voltage and increases the cost of many components, it was decided to add a second transistor with a further amplification factor of 50. The base current required then drops to 4 μ amps, which can easily be supplied by a CR circuit utilizing a phototransistor even at the lowest level of illumination likely to be required. The second transistor, moreover, increases the overall sensitivity of the circuit, this increasing also the speed of relay operation.

Varying film speeds are catered for by the use of a bank of five capacitors of different values. The capacitor of choice may be switched into circuit by depressing the appropriate push-button switch.

THEORETICAL OPERATION OF THE CIRCUIT

When TR_1 is biased »off» sufficient current flows in the base-emitter junction of TR_2 to allow the relay RE_1 to energize. When TR_1 passes current, the collector circuit of TR_2 has reduced current flow and the relay de-energizes. This is the basic »switch» for the main relay (RE_1). A secondary relay (RE_2) carrying heavier contacts is switched by means of RE_1.

Fig. 1 shows the cycle in the »off» position with the contacts of RE_1 open as are the contacts »A» and B_2 of RE_2. In this condition, the capacitor C_1 (selected by means of PB_2) is in the discharged state through R_4 and relay contact B_1. Also, the base of TR_1 is coupled to the negative supply line via R_3, R_5 and the cadmium sulphide cell and meter, Ma. Under these conditions, TR_1 passes sufficient current for TR_2 to remain biased »off» and the relay to remain de-energized.

When PB_1 is depressed momentarily, the capacitor of choice (C_1) is connected to the positive supply line at one end and, since it is also connected to the negative line, a current flows from right to left through R_4, thus reducing the bias to TR_1 which is therefore »off» allowing current to flow in the collector circuit of TR_2. The relays RE_1 and RE_2 thus energize. This simultaneously opens contact B_1, disconnecting the shorting resistance R_4, and C_1 thus commences to charge. Contact B_2 is also closed, thus allowing C_1 to be connected without depressing PB_1. Contact »A», which closes at the same time, completes the circuit to the solenoid (SO).

LEGENDS

Fig. 1. Circuit Diagram.

TR_1, TR_2	— OC72 transistors
RE_1	— SSC mini-relay type 1130. 500 ohms with one set of contacts.
RE_2	— Rapa relay type Z33G, 122 ohms with two sets changeover contacts.
D_1	— AEG rectifier type B30 (V) C2000 (mA).
D_2	— AEG rectifier type B30 (V) C30 (mA)
C_1	— Electrolytic Capacitor 200 μF.
C_2	— Electrolytic Capacitor 500 μF.
C_3	— Electrolytic Capacitor 1000 μF.
C_4	— Electrolytic Capacitor 2000 μF.
C_5	— 2 Electrolytic Capacitors 2000 μF.
C_6	— Electrolytic Capacitor 1 μF.
R_1	— 1K ohm, ¼ watt.
R_2	— 22K ohms, ¼ watt.
R_3	— 10K ohms »trimmer» type, ¼ watt (bank of 5).
R_4	— 30 ohms, 2 Watt.
MA	— 2 mA moving coil meter.
CdS	— Philips type LDR 03 or LDR 04.
T	— Low voltage transformer with 12 and 6 volt secondary windings.
PL_1	— Neon bulb, 230 volts.
PL_2	— .01 amp. bulb, 12 volts.
S	— Single pole, single throw switch, 250 volts, ½ amp.
SO	— Robot camera solenoid, 12 volts.
PB_1	— Bell push type switch.
PB_2	— Push button tuning unit.
CD	— Crystal diode, type OA70.

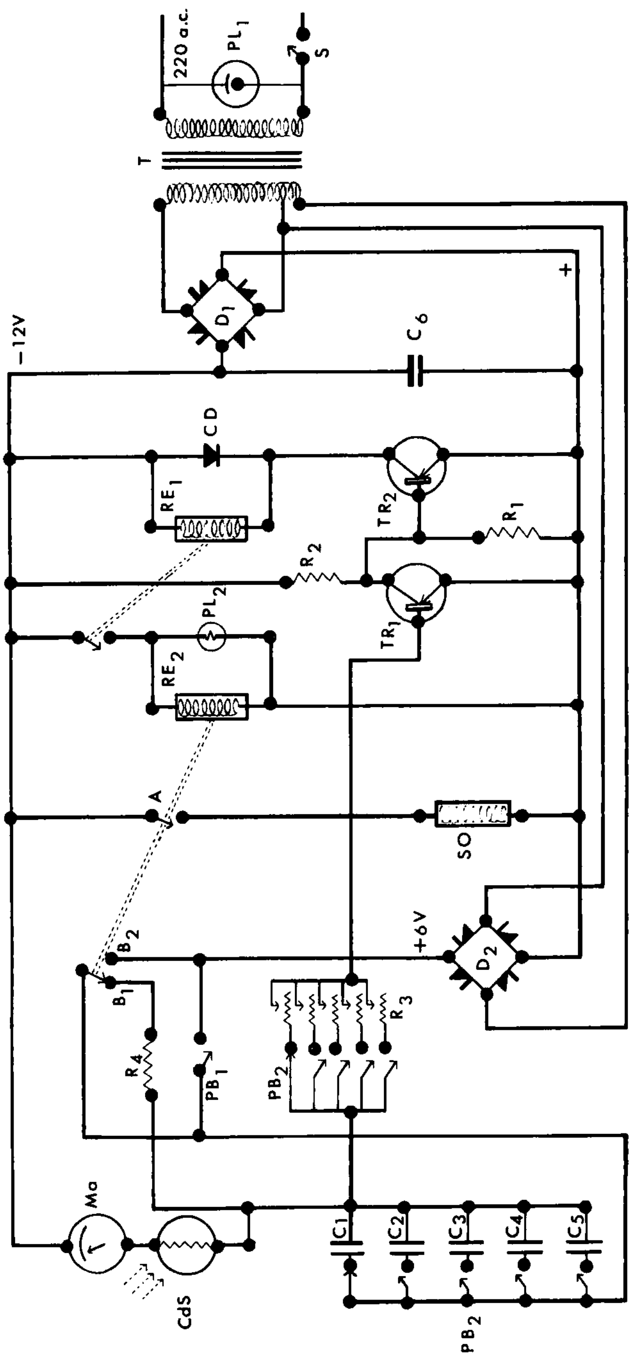
220 a.c.
PL1
S
T
D1
−12V
+
C6
CD
RE1
TR2
R1
R2
PL2
TR1
RE2
A
SO
+6V
D2
B2
B1
R4
PB1
PB2
R3
Ma
CdS
C1
C2
C3
C4
C5
PB2

Fig. 1.

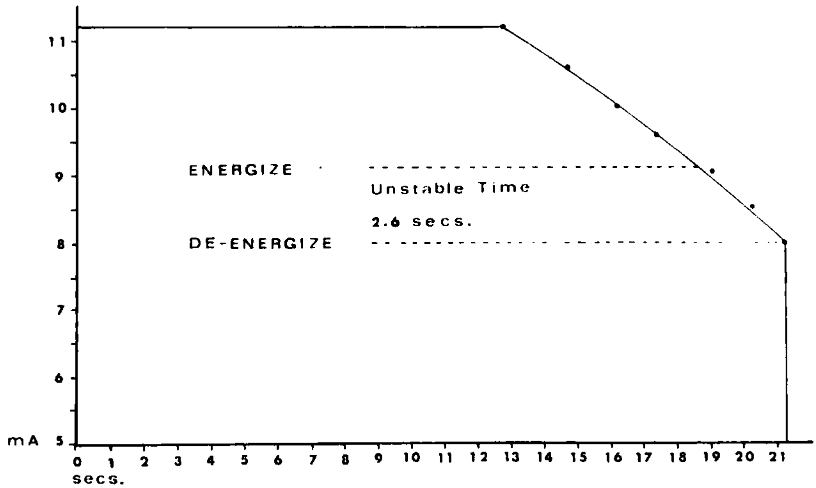

Fig. 2. The curve obtained when measuring current flowing in the coil of RE_1 during a 21.2 sec. cycle.

The potential to the left of R_3 approaches zero volts as the potential of the capacitor rises towards 18 volts. When it does so, TR_1 passes current and the relay is de-energized restoring the initial condition.

It can be seen that TR_1 passes no current during all but the last part of the timing period, in fact until the potential across C_1 rises above 12 volts. This it does with great speed due to the »holding back» effect of the reverse potential of 6 volts (Fig. 2).

PRACTICAL CONSIDERATIONS

It can be seen that there are some components utilized in the circuit, the actions of which are not described in the above section. These have been included for the following reasons:

1. The crystal diode connected across RE_1 limits high reverse voltages generated on de-energizing of the relay.
2. The milliampere meter is placed in circuit for two reasons — one being that the electrolytic capacitors used have a leakage current thus preventing a charge developing in them when the CdS cell passes very low currents, i.e. when the light intensity is very low. The meter indicates this and thus warn the

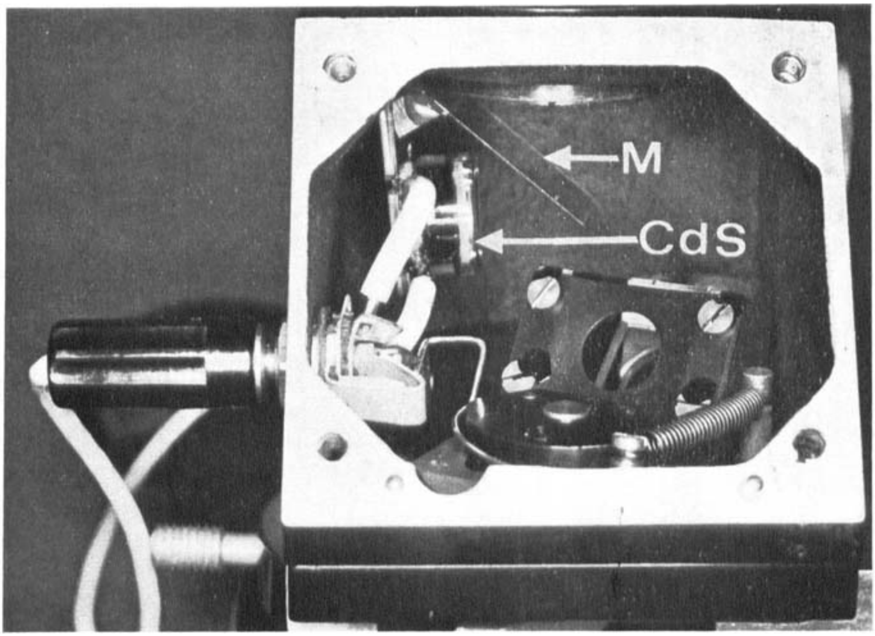

Fig. 3. The prism housing of a Zetopan microscope with the binocular viewing tubes and cover plate removed. M = half-silvered mirror. CdS = photoresistor. The prism is shown in position for photography.

operator before an attempt at an exposure is made. The second reason for inclusion of the meter is that the mechanical functioning of the solenoid and relays takes a short time so that very short exposures with this device are not accurate, i.e. when the light falling on CdS is high and much current flows through it. The meter also indicates this and can be corrected by a neutral density filter in the light path of the microscope which restores the meter to a suitable reading.

3. R_3 consists of a bank of trimmer resistors, one for each push-button and connected to a set of spare contacts on PB_2. Since the value of R_3 in no way affects the time constants of the circuit, it is possible to allow of much higher light levels when the switched-in capacitance is high. Conversely, lower levels of illumination can be tolerated by low capacitance due to less leakage resistance with smaller capacitors. These

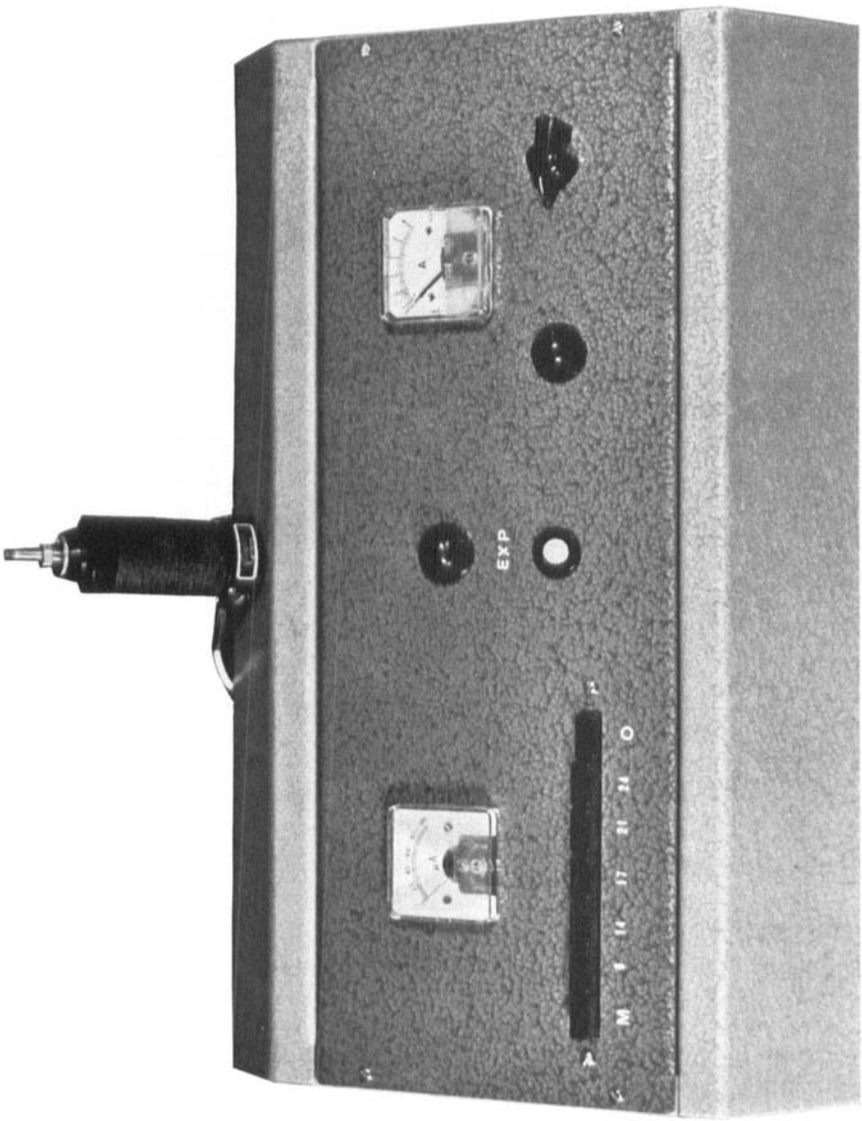

Fig. 4. The complete apparatus with microscope lamp control on the right and film speed selector buttons and "high-low" meter on the left. The solenoid normally attached to the camera is seen standing on top of the cabinet.

trimmers are used to adjust the meter high/low limits for each position of PB_2.

The device described is being used in conjunction with a cadmium sulphide cell which has been mounted into the prism casing of a Reichert »Zetopan» microscope (Fig. 3). A piece of aluminized cover-slip reflecting approximately 50 % of the total light onto the CdS cell is positioned above the movable prism. This obviates the necessity of removing the photo-sensitive cell from the optical path. The lever which moves this prism has been fitted with a piece of wire which shorts the CdS cell when the prism is in the binocular viewing position, thus preventing accidental exposure when the microscope is being used for viewing only.

Calibration was achieved by the use of a »Remiphot» exposure photometer mounted in the place of the camera. Small additional capacitors were used connected in parallel to C_1, C_2, C_3, C_4 and C_5 as required to give slightly longer exposure times than had been calculated.

The values given for these, in the components list for Fig. 1 are therefore approximate depending upon the transmission of the half-silvered mirror, the ocular used and the exact supply voltages achieved with standard components.

However, calibration presented no difficulty and in use the device produces a satisfactory exposure range between 1 second and 4 minutes, the accuracy being ± 3 % within these limits.

To minimise the number of wires near the microscope, the transformer and meter controlling the microscope lamp have been built into the same cabinet (Fig. 4).

The total cost of the apparatus was approximately £20. It is in routine use at this Dental School with completely satisfactory performance both for colour and black and white film.

SUMMARY

An inexpensive transistorized light-sensing device is described which, coupled to a solenoid operated camera shutter, is capable of rendering the exposure of the film in photomicrography fully automatic.

The cadmium sulphide cell has been built into a Reichert Zetopan microscope but may equally well be built into any other make.

The time range is from 1 second to 4 minutes, accuracy being ± 3 % within these limits.

RÉSUMÉ

DISPOSITIF AUTOMATIQUE SIMPLE POUR L'EXPOSITION DE MICROPHOTOGRAPHIES

Les auteurs décrivent un dispositif photo-sensible à transistors, d'un prix peu élevé, et qui, monté avec un obturateur photographique actionné par un solénoïde, est en état de rendre entièrement automatique l'exposition du film en microphotographie.

La cellule au sulfure de cadmium a été incorporée à un microscope Zetopan de Reichert, mais peut tout aussi bien être incorporée à n'importe quelle autre marque.

Le temps de pose varie de 1 seconde à 4 minutes, la précision étant de ± 3 % à l'intérieur de ces limits.

ZUSAMMENFASSUNG

EIN EINFACHES AUTOMATISCHES LICHTMESSUNGSGERÄT FÜR DIE MIKROPHOTOGRAPHIE

Ein leicht eingebautes, einfaches Lichtmessungsgerät für die Mikrophotographie ist beschrieben.

Die Basis besteht aus einem Transistor Netz, die mit der in das Mikroskop eingebautem Kadmiumsulfid Zelle verbunden steht. Das Transitor Netz aktiviert einen Solenoidkameraverschluss, und auf diese Weise ist die mikrophotographische Aufnahme vollautomatisch.

Das Gerät ermöglicht Belichtungszeiten zwischen 1 Sekunde und 4 Minuten mit einer Präzision von ± 3 %.

Addresses:

Klas Nuki
The London Hospital Medical College
Turner Street,
London, E. 1., England.

Arne Jepsen
Århus Tandlægehøjskole
Vennelyst Boulevard,
Århus C, Denmark.