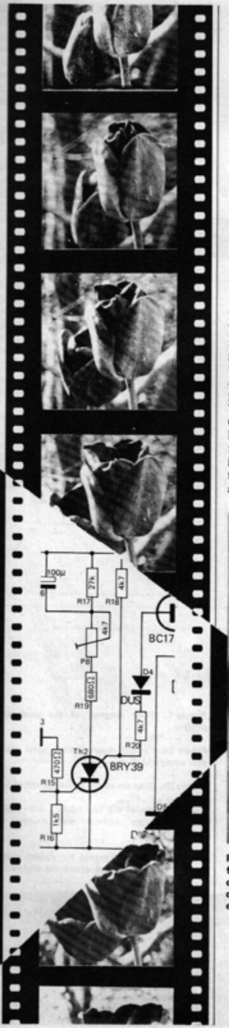

H.U. Heinz

time machine

Slowly-developing technological processes or natural events cannot be perceived because the eye is generally not able to distinguish the separate stages. Such events and processes can, however, be visualised by means of cinematographic time compression. An interval switch linked with a camera enables it to make single exposures at set intervals. When run at normal speed the film then shows a process or event apparently developing continuously, but in a much shorter time.

The block diagram of the interval switch is given in figure 1; it consists of a pulse generator, two monostable multivibrators and a stabilizing circuit. A mechanism controls the automatic diaphragm and shutter of the camera.

The pulse generator consists of a UJT (unijunction transistor) relaxation oscillator with adjustable pulse recurrence frequency. The output pulse drives two interconnected monostable multivibrators (MMVs) which control the mechanism for diaphragm adjustment and camera shutter. Because the circuit must be suitable for battery supply, a stabilizing circuit ensures a constant voltage throughout the battery life. Of course, the circuit can also be fed from a mains power supply.

MMV1 controls the automatic diaphragm of the camera. This diaphragm setting is maintained until MMV2 operates the shutter and resets the entire circuit to its initial state.

The stabilizing section included a battery voltage indicator which operates with an 'expanded scale' and 'suppressed zero' so that it only reads from about 12-20 V. Since the circuit will not function correctly if the battery voltage falls below 12 V, there is no point in measuring below 12 V. It is simply a waste of meter scale space.

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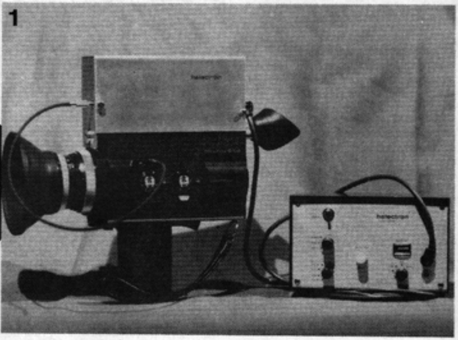


Photograph 1. The time compressor system for film cameras. The box mounted on the camera contains the relays and the shutter drive motor; the box beside it contains the electronics.

The pulse generator

Figure 2a shows the principle of the pulse generator. Capacitor C_1 charges via R_1 to the breakdown voltage of the UJT, to discharge again via resistor R_2

and the E-B_1 junction of the UJT. The breakdown voltage of a UJT is an almost fixed percentage of the supply voltage; usually between 60% and 85%, depending on the type.
Positive pulses appear across resistor R_2 with a repetition frequency that can be adjusted within certain limits by changing R_1.
In the circuit of figure 2b, P_1 is the potentiometer with which the repetition frequency is adjusted. The adjustment range of P_1 is determined by the series connection of R_1 and P_2 in parallel with P_1. Via the selector switch S_2 this combination is connected to the series circuits $R_3 + P_3 \ldots R_6 + P_6$ which are connected to the supply.
Terminal B_2 of the UJT is connected to the supply via resistor R_7. This resistor serves to reduce the temperature dependence of the UJT.
In the blocked condition, the E-B_1 junction of the UJT has a very high resistance so that it is possible to achieve relatively long pulse times with large capacitances (220 μ) and high resistances (maximum 1 M).
Switch $S_{1.1}$ is combined with the on/off switch; in the centre position C_2 charges rapidly via R_2, so that the UJT can produce the first pulse the moment the on/off switch is operated. If the capacitor were not given an initial charge in this way, the waiting time for the first pulse would be 4 minutes in the worst case.
Transistor T_2 serves as an inverter, so that the pulse generator supplies both positive and negative pulses.

The Monostable Multivibrators (MMVs)

The two MMVs connected after the pulse generator are equipped with thyristors with anode- and cathode-gates because these can fire on positive as well as on negative pulses. Both MMVs are of the same design, differing only in component values.
Figure 3 shows the circuit of an MMV. Once thyristor Th_1 has been fired by negative-going pulses on the anode-gate, it remains on until the current drops below the so-called holding current. If in the anode circuit of the thyristor a resistor is included of such a value that the holding current of the thyristor cannot be reached, the thyristor will not fire.
If, however, a capacitor (C_4) is now connected parallel to this resistor, the thyristor will fire and the capacitor will begin to charge. Since, however, the charging current of a capacitor decreases as the charge increases, there comes a certain moment when the current flowing through the parallel circuit of resistor and capacitor drops below the holding current, and the thyristor blocks again. The capacitor then discharges through the parallel resistor R_{10} (figure 3).
A variable series resistance ($P_7 + R_{11}$) determines the charging time of the capacitor and thus the time during which the thyristor remains on. In addition, this series resistance protects the thyristor against excessive switch-on currents. Via R_{14} and D_1 the thyristor drives switching transistor T_3 which energises relay RLA. Diode D_2 protects the transistor against voltage surges when the relay cuts out.

Current supply and measuring circuit

The supply voltage is stabilized at about 11 V by ZD_1 and T_5 (figure 4). All battery voltages can be measured under loaded and no-load conditions via switch S_4. As long as the measured voltage is higher than the zener voltage, a current I flows through the parallel circuit ($R_{22} + P_{12}$); the resulting voltage drop is measured with the measuring instrument. The meter is adjusted to full-scale deflection (f.s.d.) by means of P_{12}. The currents through the zener diodes $ZD_2 \ldots ZD_4$ can be adjusted with the potentiometers $P_9 \ldots P_{11}$. These zener diodes ensure that only voltages higher than the minimum voltages on which the apparatus functions properly are measured. The meter thus has a 'suppressed zero', i.e. it only reads from (say) 12 V upwards since voltages below this are of no interest. The whole meter scale may then be calibrated for 12-20 V.
The residual battery charge can be estimated on the basis of the difference in meter deflections when readings are taken with and without load.
The extra positions on S_4 are for testing other batteries in the camera. The diodes ZD_3 and ZD_4 can be chosen to give a suitable 'suppressed zero' value for other battery voltages.

The complete circuit

The complete circuit given in figure 5 is intended for a Zeiss G.S-8 synchronous camera. In this case the diaphragm is adjusted by a motor, so that it remains in the set position when the control current is switched off. The camera is fitted with two external connections for electrically-operated remote release; one for single exposures and one for running exposures. Before the release is operated, the diaphragm must be properly adjusted.
The negative pulse produced at the collector of T_2 first starts MMV1 which, via RLA1 (figure 6) switches on the automatic aperture control for about 2 sec., giving ample time for this control to find its setting before the shutter opens. The moment MMV resets, a positive pulse starting MMV2 occurs at the anode-gate resistor (R_{13}). As a result RLB is activated, closes contacts RLB1, and starts a motor which drives the camera shutter.
Although RLA is no longer energised, the diaphragm motor will hold the aperture at its correct setting. The diaphragm drive can be switched off altogether with S_3, so that, for example, an electronic flash can be used with a preset aperture. S_5 operates RLB directly and can therefore be used for manual shutter operation.
There are almost as many automatic exposure devices as there are camera types. Consequently the matching of the automatic operating equipment to the camera diaphragm and shutter mechanisms often calls for considerable care.
Another type of automatic exposure control which is found in most cameras nowadays uses a moving coil (as in a meter) to control the diaphragm according to the photocell response. In this case, the circuit operating the diaphragm control must remain switched on while the shutter opens. This can be achieved by providing an extra pair of contacts

Figure 1. Block diagram of the time compressor.

Figure 2a. Circuit diagram of a pulse generator using a UJT.

Figure 2b. Diagram of the pulse generator.

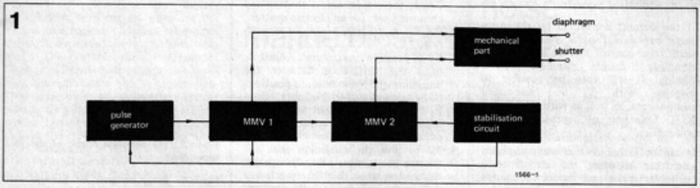
Figure 3. One of the two MMV's with which the diaphragm control and shutter are operated.

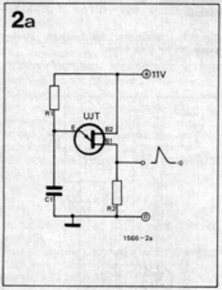
Figure 4. This stage serves for voltage stabilizing and checking the operating conditions of the batteries.

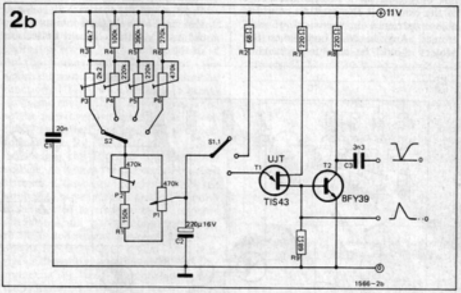
RLB2 on the shutter relay RLB: these will be in parallel with the contacts RLA1 of relay RLA which turn on the automatic exposure control before the shutter opens (figure 6). At the moment when MMV1 resets and de-energises RLA, RLB will keep the diaphragm control in operation, by contacts RLB2, until the shutter has closed.

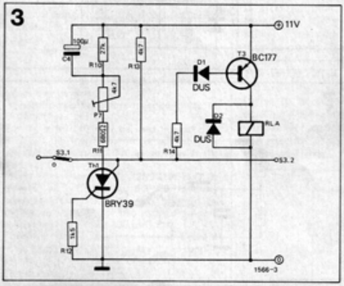
At the indicated value for C_6, a camera which had no single-exposure facility would expose about 10 frames. The value of C_6 for single exposures would be about 8 μ. The number of frames transported during a single pulse from MMV2 can be ascertained by pressing a numbered strip of leader film, with the finger, against the film gate and traction claws.

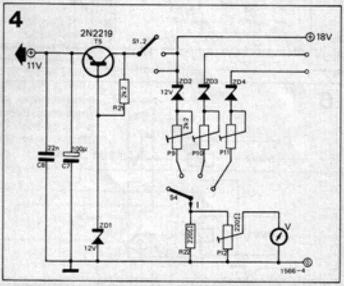
The camera can be switched to 'filming' by S_5. If single manual exposures are required for trick shots, MMV2 can be turned on by a switch as shown in figure 7. If the automatic diaphragm











is also required to function for these shots, three components must be added to the cathode gate circuit of Th_2: a 3n3 capacitor, a 470 Ω resistor and a diode (DUS). This must be done in the same way as with MMV2 (here it is C_5, D_3 and R_{15}). The push-button of figure 7 must then be connected direct to the additional capacitor.

If the current consumed by the automatic exposure control is known to be small, the control can be left on continuously during time-compressed filming. It will then be possible to dispense with T_2 and associated components, as well as with MMV1 and RLA. One pair of contacts on RLB will suffice.

It can be gathered from what has been said that adapting the circuit to a particular make and model of camera not only calls for a precise knowledge of the camera; it also requires considerable experience in the field of electronics. Anyone who undertakes this project should be capable of tackling any precision engineering work that may have to be done on the camera.

Aligning the circuit

Before the apparatus can be used, the following adjustments must be made.

1. P_1 to zero, P_3 to give maximum pulse interval. This will be about 2 sec. for a mechanical shutter and about 0.5 sec. for an electric shutter.
2. P_4, P_5, P_6 to 1, 2, 3 minutes respectively.
3. P_1 in position 'maximum'. Adjust P_2 until the difference between the minimum and the maximum positions of P_1 corresponds to 1 minute.
4. P_7 to a time which enables the automatic exposure control to re-adjust by two stops.
5. P_8 to give the minimum time the shutter mechanism needs to operate the shutter when the battery is low.
6. Adjust S_1 and S_4 to 'off' position, P_9, P_{10} and P_{11} to give 2.5 . . . 5 mA measured between the contacts of S_4. Adjust P_{12} to full-scale deflection of the meter.

When choosing the zener diodes (ZD_2 . . . ZD_4) take into account the minimum voltages at which the equipment will still function properly at low temperatures. If the zener voltages are changed, other values may have to be chosen for the adjustment potentiometers.

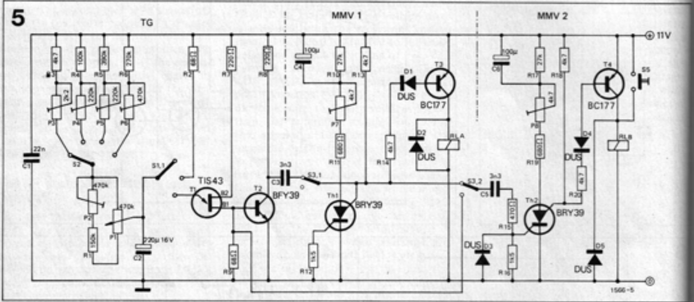


Figure 5. The complete circuit of the time compressor.

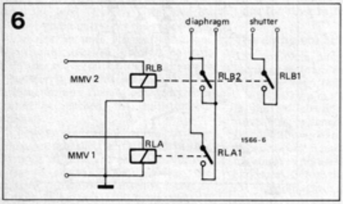


Figure 6. Relay contacts for cameras with motor-driven or moving-coil diaphragm control.

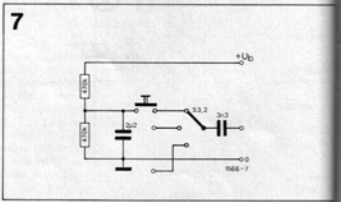


Figure 7. Additions for manual single exposures for trick films.

The shutter mechanism (for mechanical shutters)

As is apparent from the previous examples, cameras with electric shutters are easily modified by bridging the the release contacts by the relay contacts. With mechanical shutters however the release button must be operated by a servo or other device. No detailed data can be given on the release mechanism because the construction depends largely on the camera used. The author used a Graupner Varioprop-Servo from which the feedback potentiometer had been removed. This was used to drive the shutter release via a Bowden-cable type remote release. Limit switches were incorporated to limit the servo travel. A model control servo which may be adapted to a shutter drive for most cameras will be obtainable in a shop for model builders.

Exposures with the time compressor

To conclude with, some remarks about the exposure technique. To ensure a flowing motion, calculation of the intervals should be based on 900 frames, so that at a projection speed of 18 frames per second the projection time is 50 seconds.

If the interval is indicated as t seconds per frame (F), and the time in which the compressed event takes place is T hours, we have:

$$t = \frac{T}{900} \times 3600 = 4\,T\ (s)$$

in which T is in hours, and t is in seconds.

For an opening rose the interval for an exposure time from 0530 to 2030 (exactly 15 hours) is

$$t = 4 \times 15 = 60 \text{ seconds per frame.}$$

When filming outdoors, don't forget to immobilize the flower in case it should sway in the wind.

Editorial note

A number of notes as regards component values may be made:

All electrolytic capacitors must be of the 16 or 25 V type.

For T_2 a BC 140 may be used instead of a BFY 39. Furthermore, it is advisable to connect a resistor of 1 k in series with the base of T_2.

In figure 4 transistor T_5 (2N2219) may be replaced by a BD 137 or BD 139. In many cases this transistor will also have to be cooled, certainly if the two relays draw considerable current (over 100 mA).

Finally it should be noted that in figure 4 '+V_b' is the output of the stabilized supply. So this point is the supply point ('⊕') in figures 5 and 7. The voltage is about 11 V.