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Transient Lamp Load on Triacs

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A method for determining the inrush current of incandescent lamps and the maximum limit of such lamp loads on a triac, even when the data sheet of the device does not include the transient thermal impedance curve, is discussed. It is observed that simple lamp dimming circuits may be modified for soft-start operation, where the phase angle of triggering the triac is gradually advanced automatically from 180° to 0° in a desired time interval, decreasing the demand on the triac and extending the life of the lamps.

IT is well known that the inrush current of an incandescent lamp is 8-15 times its steady state current[1,2] [Fig. 1(a), (b)]. The inrush current is only 8-10 times the steady state current in low power incandescent lamps, such as 100 W lamps and 10-15 times in the case of high power lamps, such as 1000 W lamps. It also depends on the initial phase angle at which the lamp is switched 'ON'. The steady state is attained only after about 8 cycles [Fig. 1(a)], but the maximum junction temperature rise of the triac occurs only during the first or second half cycle after switching the lamps through the triac. The heating effect is more during the first half cycle, when the initial conduction angle is over about 90° and the second half cycle, when the initial conduction angle is less than 90°.

Though a triac may be capable of withstanding the steady state current in lamp dimming circuits, care should be taken to ensure that the triac is capable of withstanding the inrush current while designing the circuit and hence the necessity for this experiment.

A unique circuit (Fig. 2) has been designed such that the test triac TR_1 (RCA 40576) can be triggered 'ON' at any phase angle from 0° to 180° during a positive half cycle, after which it stays continuously 'ON' for the following cycles. The circuit of Motorola Engineers is such that the triggering angle is the same for subsequent half cycles also[1].

Circuit Operation

Switches SW_2 and SW_3 are closed first and then the push button switch SW_1 (NO) is closed. If this happens during the ac voltage going positive, diode D_1 blocks the charging of capacitor C_2 and when the voltage goes negative, C_2 is charged through D_1 and R_2, and discharges through R_2, R_1 and the gate of TR_2, triggering it 'ON' at the same time. A Tektronix storage oscilloscope type 549 is used to obtain the load current waveform and is triggered by the same pulse through R_3 and C_3. Since this takes place during the negative half cycle, diode D_2 is reverse biased and R_4 provides an alternate path for the holding current of TR_2. As C_2 is a large capacitor, it continues to discharge even during the next positive half cycle, when D_2 is forward biased, providing a path for the charging current of C_1 through potentiometer R_6 and resistor R_5. D_3, a 4-layer diode (Motorola), has a breakover voltage of 10 V and hence C_1 discharges through D_3 and the gate of Q_1, when its voltage reaches 10, triggering Q_1 'ON', which in turn switches TR_1 'ON'. Q_1 provides a continuous gate current to TR_1, because its anode supply is from a dc source. An accurately measured nichrome resistance wire of 0·05 ohm is connected in series with the 1000 W lamp load and the voltage across it is given as the 'Y' input to the storage oscilloscope. The stored traces of the current waveforms are photographed and two are shown in Fig. 1(a), (b).

From the current waveform for one lamp, the current wave for n lamps [(Fig. 3(a)] is determined after making necessary correction for mains voltage drop [Appendix, (1a), (1b)].

The transient I versus t curves are drawn for three consecutive half cycles immediately after switching the lamp 'ON' for various conduction angles from 0° to 180°. Fig. 3(a) is one such curve for a conduction angle of about 117°.

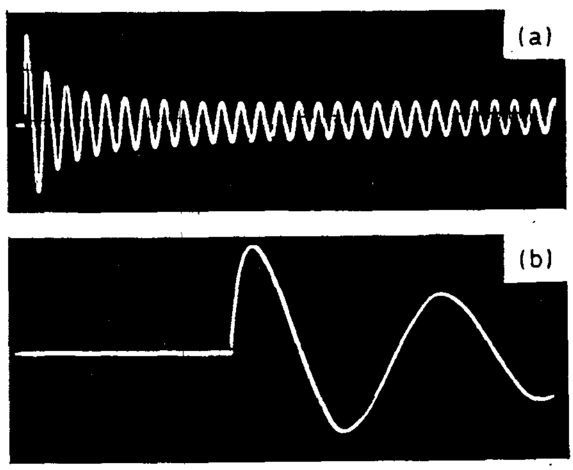

Fig. 1 — (a) Oscillogram 1: Transient current through the lamp and triac, showing current amplitudes during the initial half cycles and at steady state; x scale: 50 ms/cm, y scale: 20 A/cm. (b) Oscillogram 2: Transient current waveform for first three half cycles for an initial triggering angle of 54°; x scale: 5 ms/cm, y scale: 20 A/cm

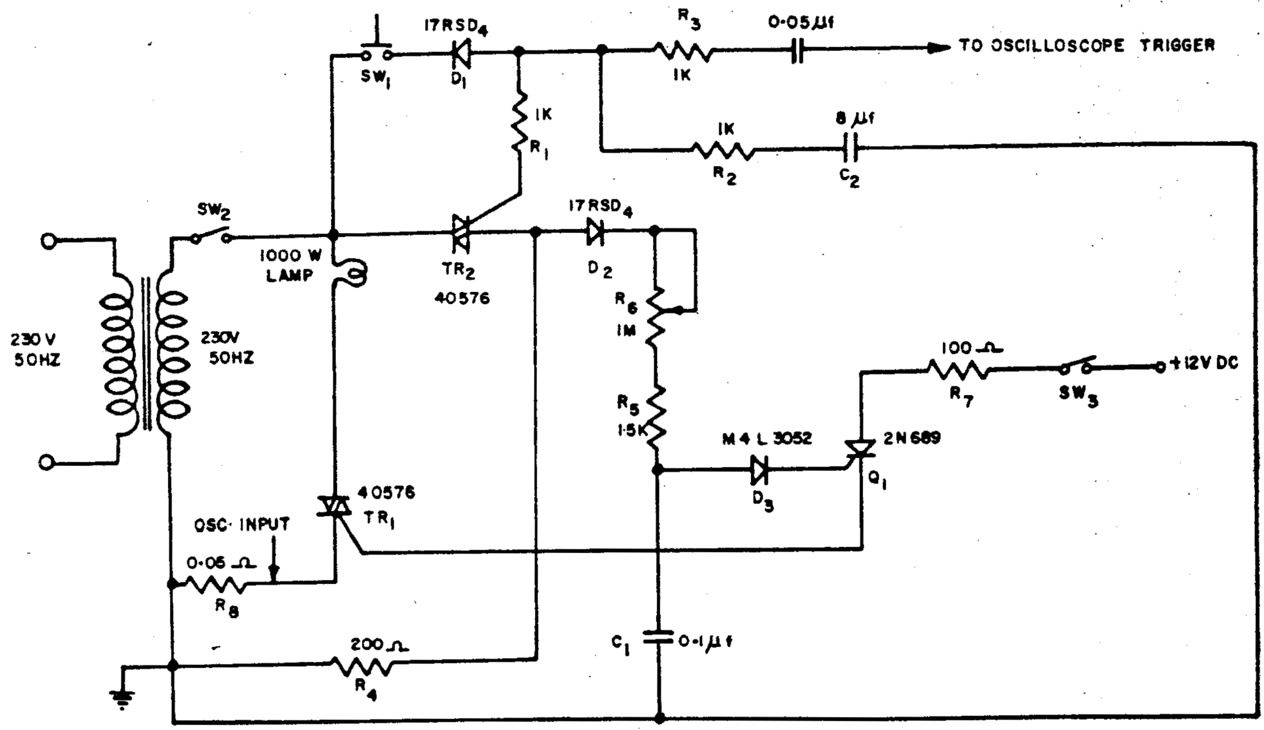

Fig. 2 — Test circuit for measuring incandescent lamp-in-rush current

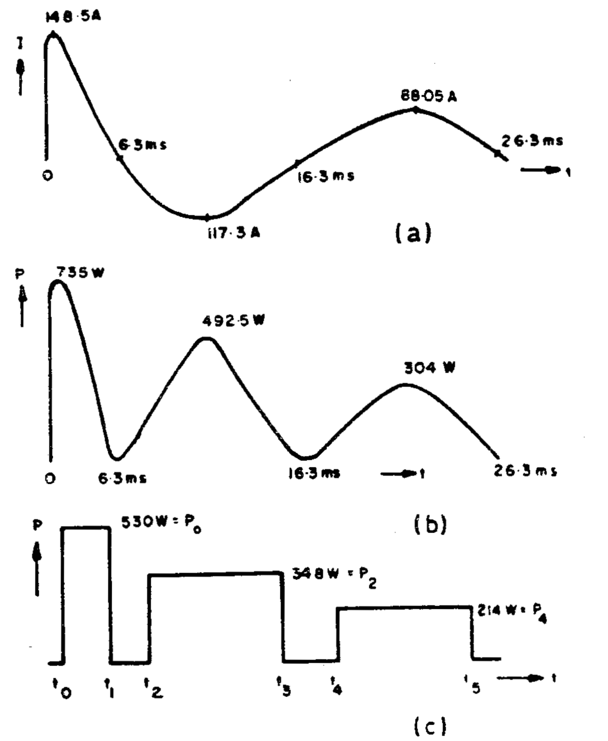

Fig. 3 — Transient current and power curves [(a) Lamp-in-rush current through the triac versus time curve; (b) transient power dissipated in the triac; and (c) equivalent rectangular power pulses]

The transient P versus t curve [Fig. 3(b)] is derived from the transient I versus t curve (Appendix 2). The equivalent rectangular power pulses [Fig. 3(c)] are then obtained from the area under each power pulse[3,4].

If the transient thermal impedance curve is included in the data sheet of the device, ΔT, the junction temperature rise over the case temperature (Appendix 3) is calculated from

$$\Delta T_0 = P_0 \Upsilon_{t_1} \quad \text{for the first half cycle}$$

$$\Delta T_2 = P_0(\Upsilon_{t_3} - \Upsilon_{t_3 - t_1}) + P_2(\Upsilon_{t_3 - t_2}) \quad \text{for the first two half cycles}$$

$$\Delta T_4 = P_0(\Upsilon_{t_5} - \Upsilon_{t_5 - t_1}) + P_2(\Upsilon_{t_5 - t_2} - \Upsilon_{t_5 - t_3}) + P_4(\Upsilon_{t_5 - t_4}) \quad \text{for the first three half cycles}$$

where P_0, P_2 and P_4 are the equivalent power pulse amplitudes for the first, second and third half cycles respectively [Fig. 3(c)]; and Υ_t, the transient thermal impedance at t sec[3].

When the transient thermal impedance curve is not included in the data sheet, the formulae for the junction temperature rise are modified as

$$\Delta T_0 = P_0 \frac{\Delta T_{\max}}{P_{\max} \text{ at } t_1} \quad \text{for the first half cycle}$$

$$\Delta T_2 = P_0 \Delta T_{\max}\left[\frac{1}{P_{\max} \text{ at } t_3} - \frac{1}{P_{\max} \text{ at } (t_3 - t_1)}\right] + P_2 \frac{\Delta T_{\max}}{P_{\max} \text{ at } (t_3 - t_2)} \quad \text{for the first two half cycles}$$

$$\Delta T_4 = P_0 \Delta T_{\max}\left[\frac{1}{P_{\max} \text{ at } t_5} - \frac{1}{P_{\max} \text{ at } (t_5 - t_1)}\right] + P_2 \Delta T_{\max}\left[\frac{1}{P_{\max} \text{ at } (t_5 - t_2)} - \frac{1}{P_{\max} \text{ at } (t_5 - t_3)}\right] + P_4 \frac{\Delta T_{\max}}{P_{\max} \text{ at } (t_5 - t_4)} \quad \text{for the first three half cycles}$$

where $\frac{\Delta T_{\max}}{P_{\max} \text{ at } t} = \Upsilon_t$ in terms of the maximum allowable junction temperature rise $\Delta T_{\max}$, and the maximum power that can be dissipated in the device for t sec obtained from its maximum power versus duration cycles curve (Appendix 4).

TABLE 1 — $\Delta T/\Delta T_{max}$ VALUES FOR VARIOUS INITIAL CONDUCTION ANGLES WHEN THE TRIAC IS LOADED BY THREE 1 kW LAMPS

Initial conduction angle deg.	Power pulse amplitude (W) P_0	P_2	P_4	1st half cycle $\Delta T_0/\Delta T_{max}$	1st two half cycles $\Delta T_2/\Delta T_{max}$	1st three half cycles $\Delta T_4/\Delta T_{max}$
66·3	265·0	520	287·0	0·17	0·97	0·80
99·5	427·5	413	215·0	0·48	0·89	0·65
117·0	530·0	348	214·0	0·69	0·92	0·80
147·0	556·0	318	197·5	0·86	0·83	0·65
180·0	427·5	287	197·5	0·75	0·73	0·63

The equivalent power pulse amplitudes for the first three half cycles for various initial conduction angles and the corresponding $\Delta T/\Delta T_{max}$ values are given in Table 1. If $\Delta T/\Delta T_{max}$ is always less than unity, it may be concluded that the number of lamps taken into consideration may be switched through the device.

Acknowledgement

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References

1. DALE, R. G., FAY, G. V., FREYLING, E. N. (Jr) & HAVER, R. J., *Semiconductor power circuits handbook* (Motorola Publication, New York), 1968, 6.
2. HAVER, R. J. & ZINDER, D. A., *Conventional and soft start dimming of incandescent lights* (Motorola Semiconductor Products Inc., New York), 1968, Application Note 436.
3. GUTZWILLER, F. W. & SYLVAN, T. D., *Power semiconductor ratings under transient and intermittent loads* (G.E. Semiconductor Products Dept. G.E.), Application Note 1961.
4. GUTZWILLER, F. W., *G.E. SCR Manual*, 4th edn (G.E. Publication, New York), 1967, 20.

APPENDIX

(1a) The current wave for n such lamps may be determined if the triacis capable of withstanding the steady state current of n lamps.

(1b) The mains voltage dropped by 30% of its normal voltage during the experiment.

(2) $P = VI$, where I is current through the triac, and V, the voltage drop across triac for I. V is determined from the $V_T I_T$ characteristic of the triac. This is a straight line for high values of I for RCA 40576.

(3) The case temperature is assumed to be the same as that of the ambient at the time of switching the lamps 'ON'.

(4) The maximum power versus duration cycles curve is drawn from the surge current versus duration cycles and the $V_T I_T$ characteristic of the device.