A METHOD FOR CONVERTING VOLTAGE LEVELS¹

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A phenomenon indicated by changes in electrical potential may have to be monitored by a device requiring, at its input terminals, a voltage change of a different magnitude. This situation might occur when low voltage solid state equipment is being used to monitor a higher operating voltage device utilizing electron tubes or electro-mechanical units. This article describes a method for converting these voltage levels while providing complete electrical isolation between the two devices.

The circuit was designed to transform a square wave (0 to 120 v, 50 ma capability, 35 ms pulse width, variable repetition rate from 30 to 300 ppm) to a square wave with -3 to 0 v level changes with the same frequency characteristics as the original signal. Figure 1 illustrates the transformation.

The 120 v square wave is the output of a digital cardi tachometer and each pulse indicates a heart beat. For each heart beat the output of the cardi tachometer is 120 v. Between heart beats the output is at 0 v. The corresponding -3 to 0 v pulses were required for compatibility with the logic levels of the LINC digital computer. An additional requirement was that the cardi tachometer be electrically isolated from the LINC.

Fig. 1. The transformation is from A to B.

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The circuit isolation was accomplished by having the 120 v square wave operate a neon lamp, which in turn modulated a photoresistive device physically near the lamp. Figure 2 shows this arrangement. Although the part shown in Fig. 2 was constructed in the laboratory, similar devices may be obtained from Raytheon, Industrial Components Division, Newton, Massachusetts, under the name Raysistor and from Opto-Electronic Devices Inc. (division of Sigma Instruments Inc.), Braintree, Massachusetts, under the name Logitron Opto-Electronic Relays. Raysistors are single pole devices (one cell-one lamp) while the Logitron Relays are available in up to four poles (four cells, one lamp). All of these devices are available for a wide range of input and output conditions. Since the lamp and photocell are optically coupled, complete electrical isolation is achieved. The photocell serves as the input to a transistorized switching circuit which produces the desired logic levels.

Figure 3 illustrates the switching circuit designed for 0 to -3 v logic levels. For 0 to -12 v logic levels only two changes to Fig. 3 are required: V_{cc} and V_{bb} would now be -12 v and R_1 would be changed to 6.8 K ohms. The photocell, R_o , R_1 , and Q_1 form a common emitter amplifier switch. Q_2 and R_2 form an emitter follower (the solid state analog of the cathode follower used with vacuum tubes) which provides a high impedance load for the switch and a low output imped-

LAMP (L) NES1
RESISTOR (R) 270K $\frac{1}{2}$ W
PHOTOCELL (P) CL 407-S

Fig. 2. The neon lamp modulates the photocell.

ance for maximum drive capability. By using the emitter follower, the desired logic levels are kept relatively unaffected by environmental transients and external loading conditions.

When the neon lamp is off (no heart beat) the resistance of the photocell is large (dark resistance). Under this condition, there is no effective current drawn from the base of Q1 and its output (collector of Q1) is at Vcc. The emitter of Q2, which follows the collector of Q1 will also be at Vcc plus a few tenths of a volt. Q1 is then said to be in the "off condition". When the neon lamp is on (each heart beat), the resistance of the photocell decreases (light resistance). Under this condition, there is an appreciable current drawn from the base of Q1 causing its collector to emitter resistance to become negligible. The potential of the collector of Q1 is then Vee and the emitter of Q2 approximately the same. In this condition Q1 is said to be "on" or in the saturated condition (the collector current is saturated or maximum). In this way, the original change in voltage levels is converted to a change of Vcc to Vee. This arrangement has been used with the LINC in sessions of 8 hr with no failures.

The following general design considerations are given but it must be remembered that each application is different and the circuit components must be chosen accordingly. Details of using transistors as switches may be found in the references below.

1. The lamp (L) must turn on and off as the original signal changes voltage levels.

Fig. 3. Switching circuit and emitter follower.

2. R limits the current through the lamp in order to control its intensity.

3. Vee = most positive logic level desired.
Vcc = most negative logic level desired.

4. R0, although not necessary, helps to turn Q1 off.

5. The current through the photocell turns Q1 "on" and equals (Vee-Vcc) divided by the light resistance of the cell. This is the saturating base current Ib.

6. When Q1 is "on" the collector to emitter resistance is negligible. The collector current (Ic) will then be Ib times hfe min (hfe min is the minimum dc forward current transfer ratio and is found from the transistor's specification sheet).

7. R1 = Vcc divided by Ic determined above.

REFERENCES

- General Electric Corp. *2N1305 Data Sheet*.
 Ryder, John D. *Electronic Fundamentals and Applications*, 3rd Edition.
 Texas Instruments Corporation. *Application Notes: Transistors as Switches*.