'Infrared' Light-Emitting Diode Application Circuit

SERIAL CONNECTION AND PARALLEL CONNECTION

Figure 1 shows the most basic and commonly used circuits for driving light-emitting diodes.

In Figure 1(A), a constant voltage source (V_{CC}) is connected through a current limiting resistor (R) to an LED so that it is supplied with forward current (I_F). The I_F current flowing through the LED is expressed as $I_F = (V_{CC} - V_F)/R$, providing a radiant flux proportional to the I_F. The forward voltage (V_F) of the LED is dependent on the value of I_F, but it is approximated by a constant voltage when setting R.

Figures 1(B) and 1(C) show the circuits for driving LEDs in serial connection and parallel connection, respectively. In arrangement (B), the current flowing through the LED is expressed as $I_F = (V_{CC} - V_F \times N)/R$, while in arrangement (C), the current flowing through each LED is expressed as $I_F = (V_{CC} - V_F)/R$ and the total supply current is $N \times I_F$, where N is the number of LEDs.

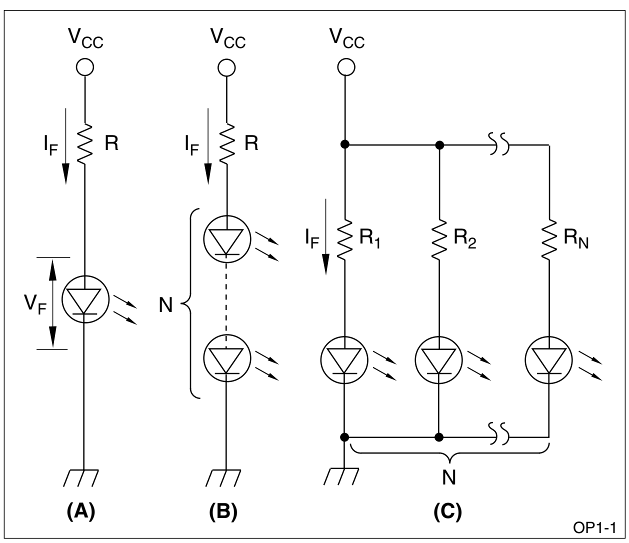

Figure 1. Driving Circuit of Light-Emitting Diode (LED)

The V_F of an LED has a temperature dependency of approximately -1.9 mV/°C. The operating point for the load R varies in response to the ambient temperature as shown in Figure 2.

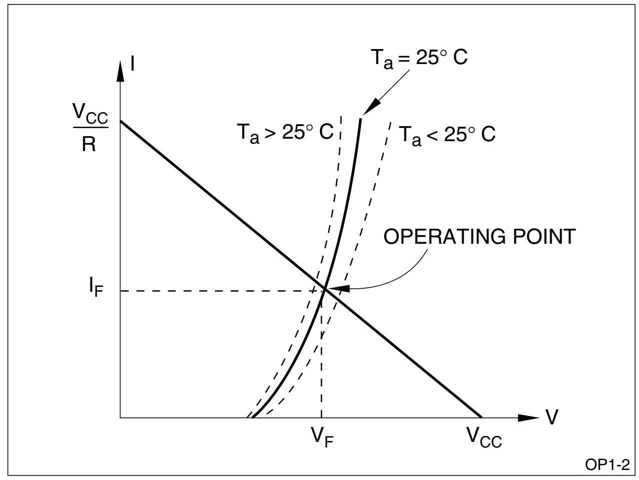

Figure 2. Current versus Voltage of Light-Emitting Diode (LED)

CONSTANT CURRENT DRIVE

To stabilize the radiant flux of the LED, the forward current (I_F) must be stabilized by using a constant current source. Figure 3 shows a circuit for constantly driving several LEDs using a transistor.

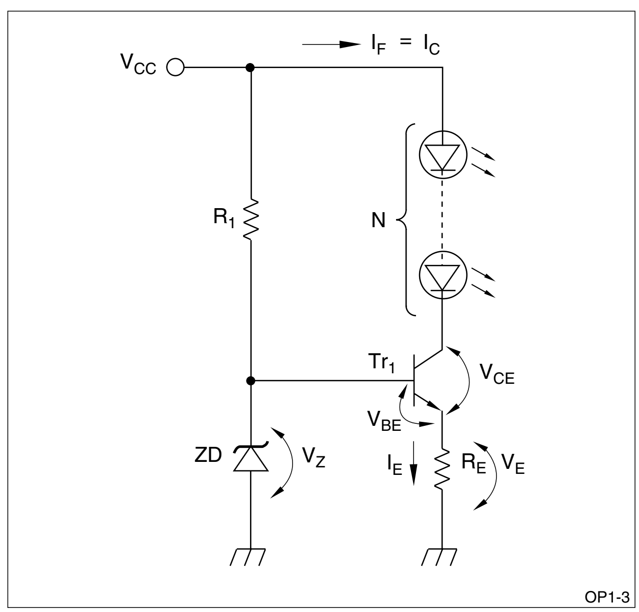

Figure 3. Constant Current Driving Circuit (1)

The transistor (Tr_1) is biased by a constant voltage supplied by a zener diode (ZD) so that the voltage across the emitter follower loaded by resistor R_E is constant, thereby making the collector current ($I_C = I_F$) constant. The I_C is given as $I_C = I_E = (V_Z = V_{BE})/R_E$. If too many LEDs are connected, the transistor enters the saturation region and does not operate as a constant current circuit. The number of LEDs (N) which can be connected in series is calculated by the following equations.

$V_{CC} - N \times V_F - V_E > V_{CE}$ (sat)

$V_E = V_Z - V_{BE}$

These equations give:

$N < (V_{CC} - V_Z + V_{BE} - V_{CE}(sat))/V_F$

Figures 4 and 5 show other constant current driving circuits that use diodes or transistors, instead of zener diodes.

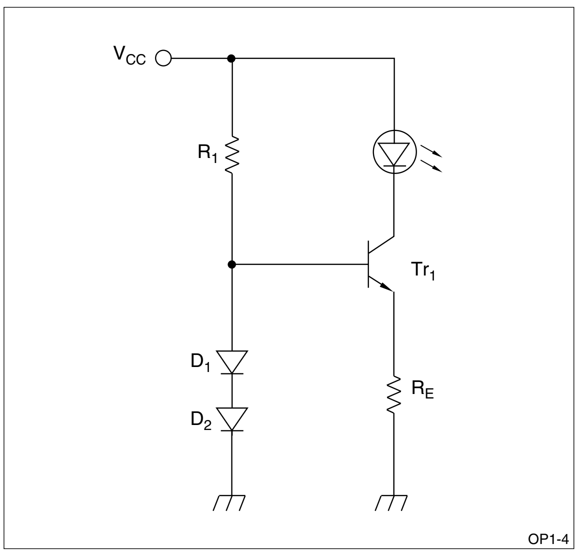

Figure 4. Constant Current Driving Circuit (2)

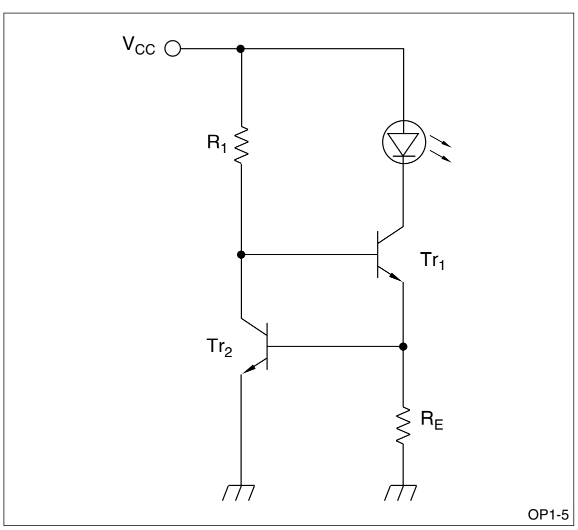

Figure 5. Constant Current Driving Circuit (3)

DRIVING CIRCUIT ACTIVATED BY A LOGIC IC

Figures 6 and 7 show LED driving circuits that operate in response to digital signals provided by TTL or CMOS circuits.

Figure 8 shows a driving circuit connected with a high level logic circuit.

In Figure 6, a high input signal V_{IN} from a TTL circuit makes the NPN transistor (Tr_1) conductive so that the forward current (I_F) flows through the LED. Accordingly, this circuit operates in the positive logic mode, in which a high input activates the LED.

In Figure 7, a low input signal V_{IN} from a TTL circuit makes the PNP transistor (Tr_1) conductive so that the forward current flows through the LED. This circuit operates in the negative logic mode, in which a low input activates the LED.

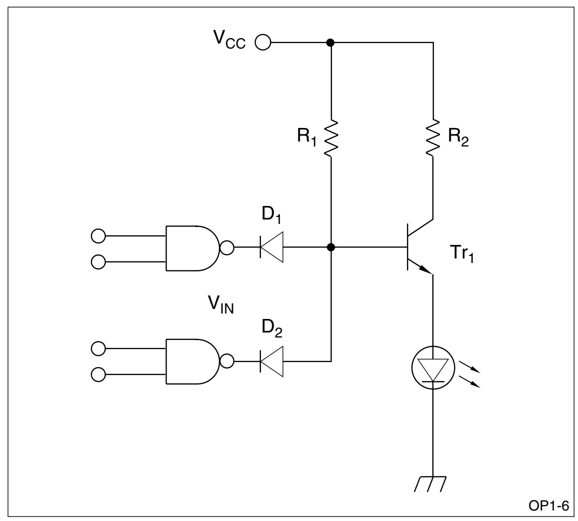

Figure 6. Connection with the TTL Logic Circuit (2)

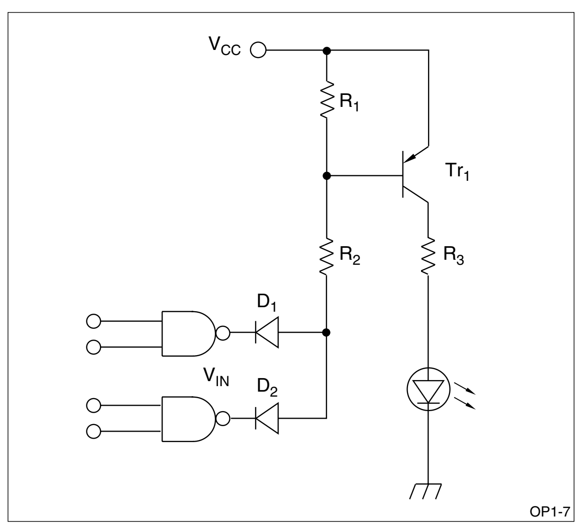

Figure 7. Connection with the TTL Logic Circuit (2)

In Figure 8, the circuit operates in the positive logic mode, and current I_F is stabilized by constant current driving so that the radiant flux of LED is stabilized against variations in the supply voltage (V_{CC}).

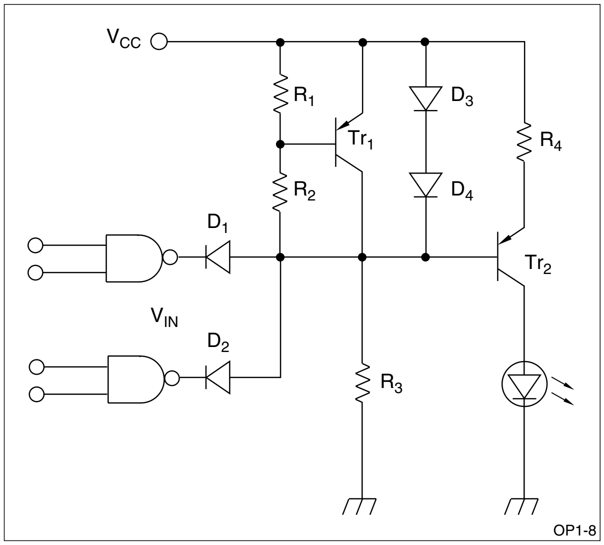

Figure 8. Connection with the TTL Logic Circuit (3)

DRIVING CIRCUIT WITH AN AC SIGNAL

Figure 9 (A) shows a circuit in which an AC power source supplies the forward current (I_{F1}) to an LED. A diode (D_1) in inverse parallel connection with the LED protects the LED against reverse voltage, suppressing the reverse voltage applied to the LED lower than V_{F2} by using a reverse voltage protection diode of an LED. The LED provides a radiant flux proportional to the applied AC current, (emitting only in half wave).

Figure 9 (B) shows the driving waveform of the AC power source.

Figure 10 (A) shows a driving circuit which modulates the radiant flux of LED in response to a sine wave or modulation signal. Figure 10 (B) shows modulation operation.

If an LED and light detector are used together in an environment of high intensity disturbing light, it is difficult for the light detector to detect the optical signal. In this case, modulating the LED drive signal alleviates the influence of disturbing light and facilitates signal detection.

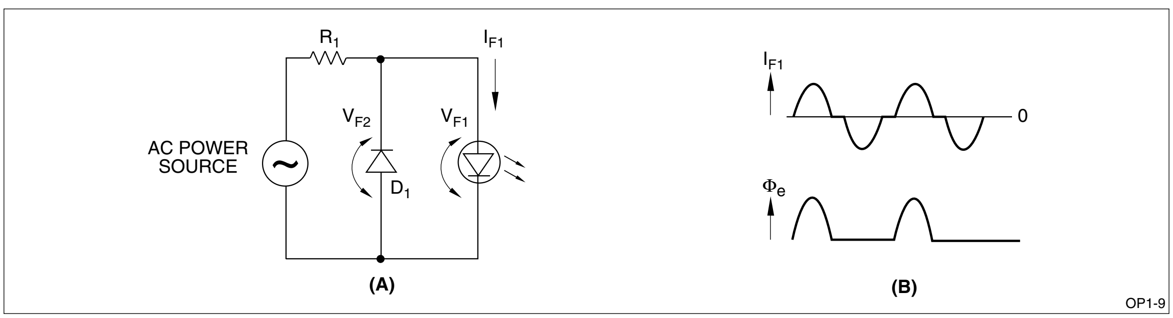

Figure 9. Driving Circuit with AC Power Source (A) and Driving Waveform (B)

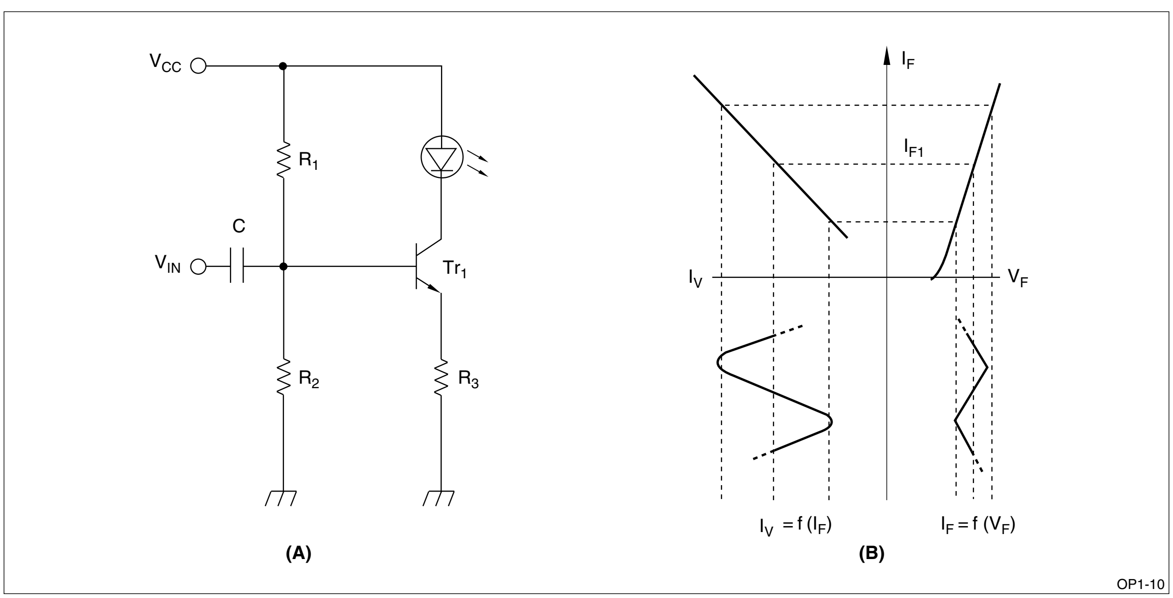

Figure 10. Modulation Driving Circuit (A) and Modulation Operation (B)

To drive an LED with a continuous modulation signal, it is necessary to operate the LED in the linear region of the light-emitting characteristics. In the arrangement of Figure 10, a fixed bias (I_{F1}) is applied to the LED using R_1 and R_2 so that the maximum amplitude of the modulation signal voltage (V_{IN}) lies within the linear portion of the LED characteristics. Moreover, to stabilize the radiant flux of the LED, it is driven by a constant current by the constant current driving circuit shown in Figure 3. The capacitor (C) used in Figure 10 (A) is a DC signal blocking capacitor.

PULSE DRIVING

LED driving systems fall into three categories: DC driving system, AC driving system (including modulation systems), and pulse driving system.

Features of the Pulse Driving System

- Large radiant flux
- Less influence of disturbing light
- Information transmission

The radiant flux of the LED is proportional to its forward current (I_F), but in reality a large I_F heats up the LED by itself, causing the light-emitting efficiency to fall and thus saturating the radiant flux. In this circumstance, a relatively large I_F can be used with no risk of heating through the pulse drive of the LED. Consequently, a large radiant flux can be obtained.

When an LED is used in the outdoors where disturbing light is intense, the DC driving system or AC driving system which superimposes an AC signal on a fixed bias current provides low radiant flux, making it difficult to distinguish the signal (irradiation of LED) from disturbing light. In other words, the S/N ratio is small enough to reliably detect the signal. The pulse driving system provides high radiant flux and allows the detection of signal variations at the rising and falling edges of pulses, thereby enabling the use of LED-light detector where disturbing light is intense.

Transmission of information is possible by variations in pulse width or counting of the number of pulse used to encode the LED emission.

Figures 11 through 14 show typical pulse driving circuits. Figure 15 shows the pulse driving circuit used in the optical remote control. The circuit shown in Figure 11 uses an N-gate thyristor with voltage between the anode and cathode oscillated at a certain interval determined by the time constant of C × R so that the LED emits light pulse. To turn off the N-gate thyristor, resistor R_3 must be used so that the anode current is smaller than the holding current (I_H), i.e., $I_H > V_{CC}/R_3$. Therefore, R_3 has a large value, resulting in a large time constant ($\tau \pm C \times R_3$) and the circuit operates for a relatively long period to provide short pulse widths. The circuit shown in Figure 12 uses a type 555 timer IC to form an astable multi-vibrator to produce light pulses on the LED. The off-period (t_1) and the on-period (t_2) of the LED are calculated by the following equations.

$$t_1 = 1n2 \times (R_1 + R_2) \times C_1$$

$$t_2 = 1n2 \times R_2 \times C_1$$

The value of R1 is determined so that the rating of I_{IN} of a 555 timer IC is not exceeded, i.e. $S_1 > V_{CC}/I_{IN}$.

This pulse driving circuit uses a 555 timer IC to provide wide variable range in the oscillation period and light-on time. It is used extensively.

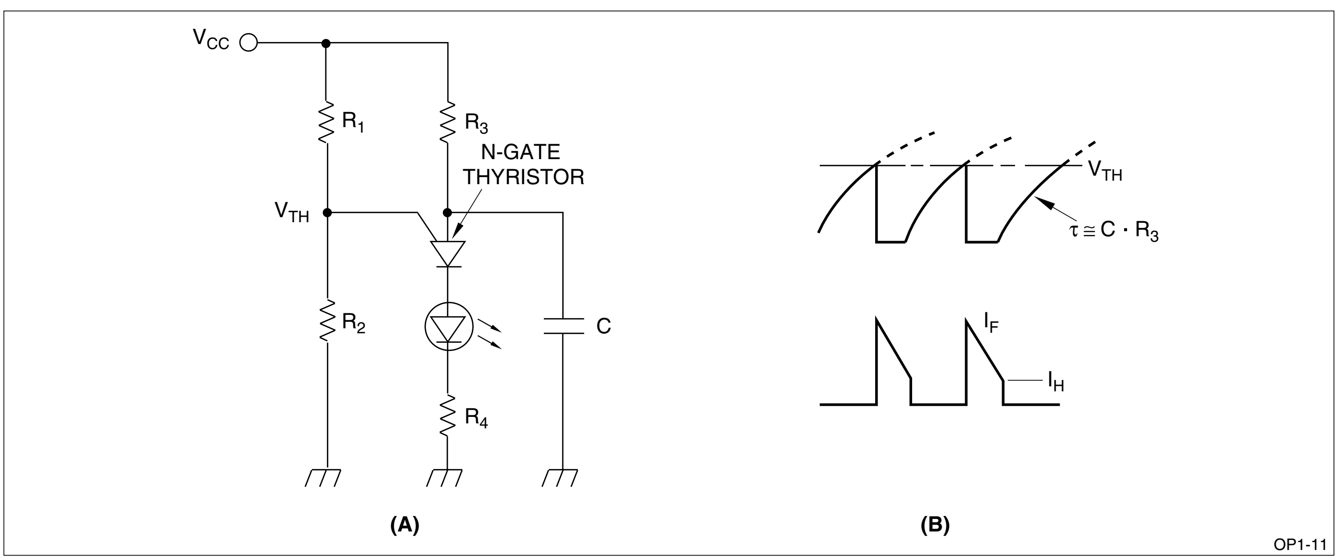

Figure 11. Pulse Driving Circuit using N-Gate Thyristor (A) and Operating Waveform (B)

The circuit shown in Figure 13 uses transistors to form an astable multi-vibrator for pulse driving an LED. The off-period (t_1) of the LED is given by $C_1 \times R_1$, while its on-period (t_2) is given by $C_2 \times R_2$. For oscillation of this circuit, resistors must be chosen so that the R_1/R_3 and R_2/R_5 ratios are large.

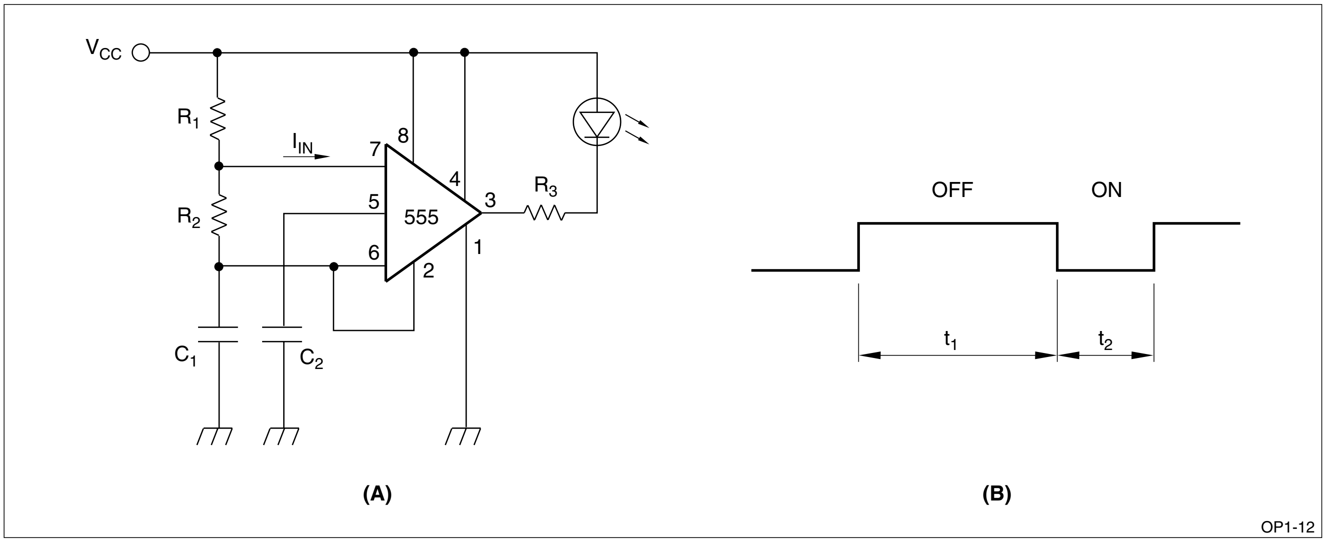

Figure 12. Pulse Driving using a 555 Timer IC (A) and Output Waveform (B)

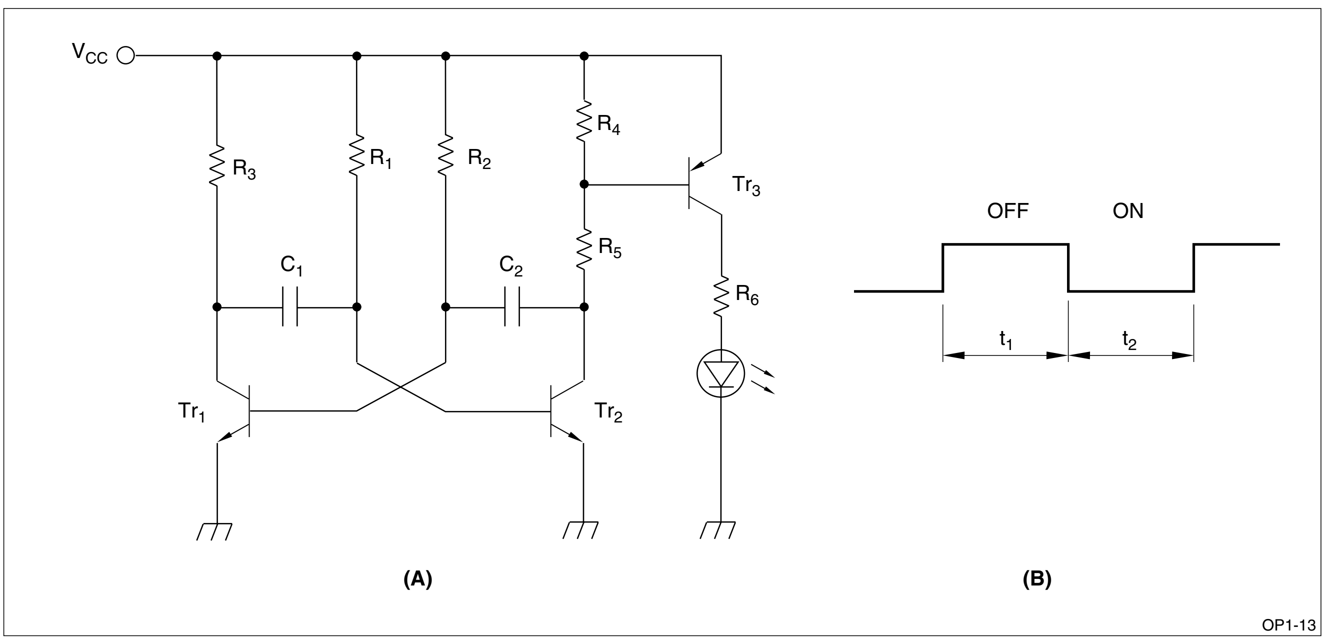

Figure 13. Pulse Driving Circuit using Astable Multi-vibrator (A) and Output Waveform (B)

The circuit shown in Figure 14 uses a CMOS logic IC (inverter) to form an oscillation circuit for pulse driving an LED. The pulse driving circuit using a logic IC provides a relatively short oscillation period with a 50% duty cycle.

Figure 15 (A) shows an LED pulse driving circuit used for the light projector of the optical remote control and optoelectronic switch. The circuit is arranged by combining two different oscillation circuits i.e., a long period oscillation (f_1) superimposed with a short period oscillation (f_2) as shown in Figure 15 (B). Frequencies f_1 and f_2 can be set independently.

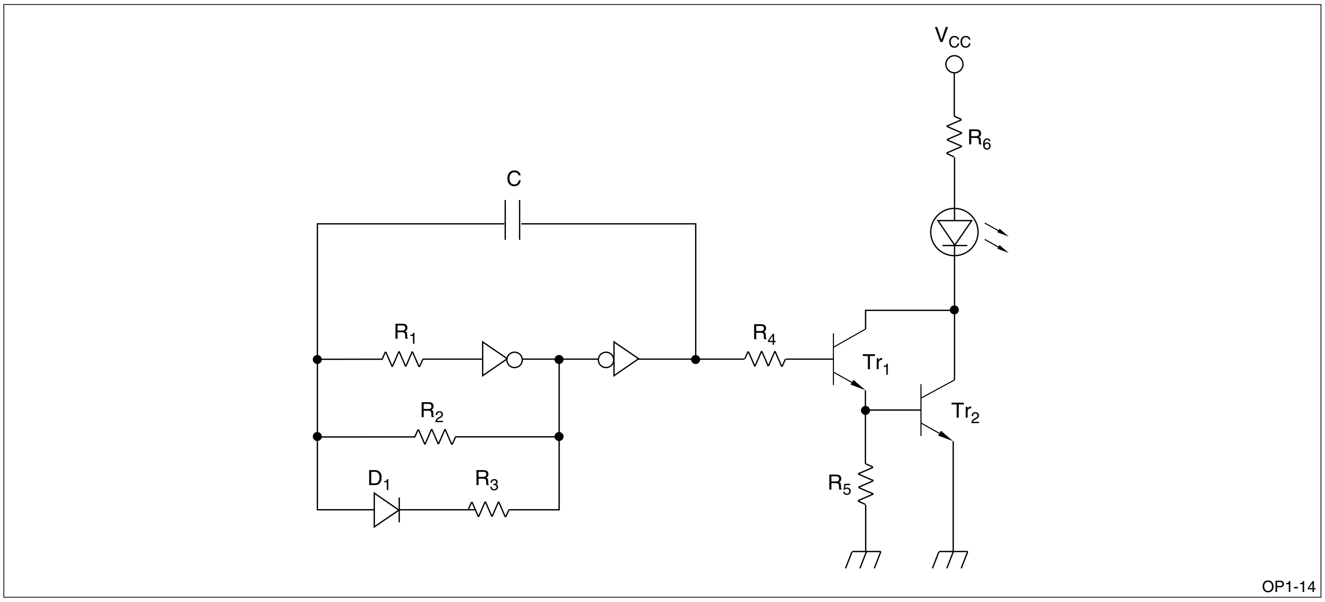

Figure 14. Pulse Driving Circuit using CMOS Logic IC

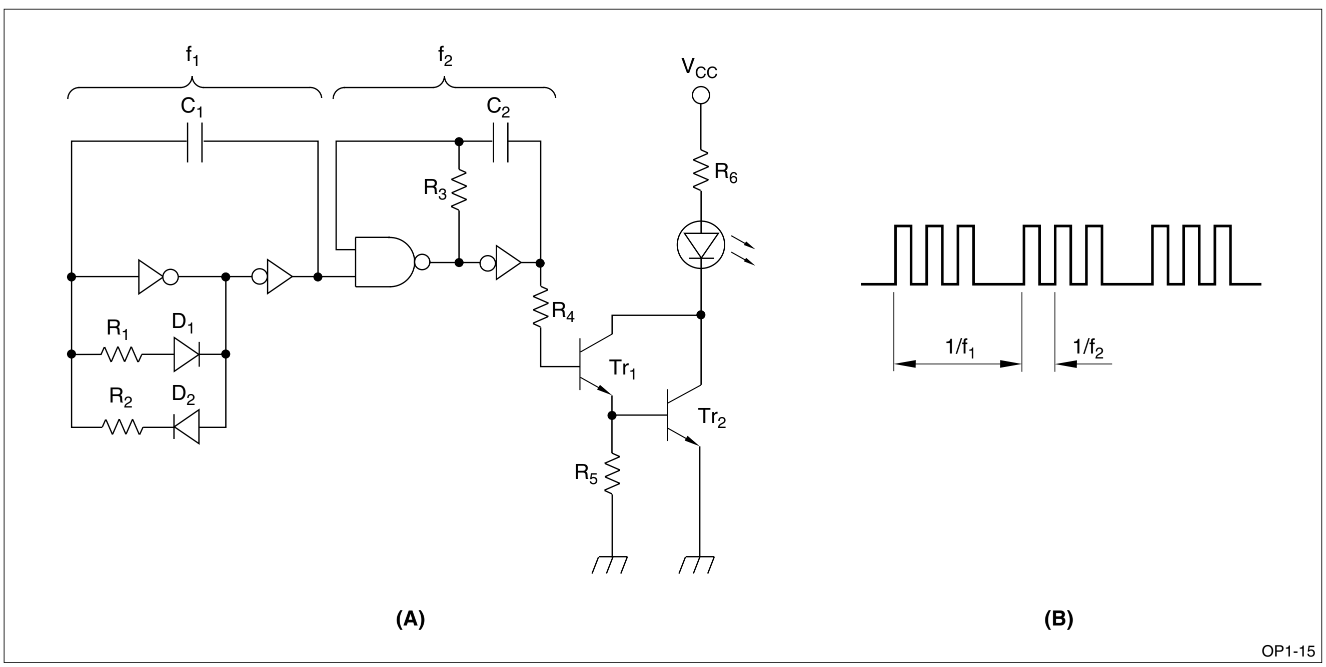

Figure 15. Pulse Driving Circuit (A) and Output Waveform (B)

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