EEE 411

DIGITAL ELECTRONICS

EXPERIMENT 2

TRANSISTOR (BJT) SWITCHING TIMES

2.1 OBJECTIVE

To demonstrate the $\mathbf{t_{on}}$ and $\mathbf{t_{off}}$ times of switching transistor

2.2 THEORY

A BJT can be made to approximate an ideal switch. One most important characteristics of a switching transistor is the speed with which it can be switched ON and OFF. When the transistor is OFF, a small collector-base leakage current flows through the load. When it is ON, there is a small collector-emitter saturation voltage across the device. A BJT will not switch ON or OFF instantaneously. The BJT suffers from the effects of junction capacitances and storage time which affect its switching speed. Turn-ON (t_{on}) and turn-OFF (t_{off}) times depend upon the device and the circuit conditions. Here only saturated transistor switching circuit will be discussed since they are the most widely used and are easier to design. Unsaturated transistor switching circuits are rarely used and are, in fact, practically nonexistent in integrated circuits.

Transistor Switching Times: When input current I_B is applied, the transistor does not switch ON immediately. t_{on} for the transistor is the sum of delay time (t_d) and rise time (t_r). Similarly, a transistor cannot be switched OFF instantaneously. t_{off} is composed of a storage time (t_s) and a fall time (t_f). The transistor's switching times will be a significant factor in the circuit operation especially in high frequency, fast rise time applications.

Delay time $\mathbf{t_d}$ is defined as the time required for I_C to reach 10% of its final level, after I_B has commenced.

Rise time $\mathbf{t_r}$ is defined as the time it takes for I_C to go from 10% to 90% of its maximum level.

Storage time $\mathbf{t_s}$ is defined as the time between I_B switched OFF and I_C falling to 90% of its maximum level.

Fall time $\mathbf{t_f}$ is the time required for I_C to fall from 90% to 10% of its maximum.

Pulse width $\mathbf{t_p}$ is the time interval between the end of rise time and the beginning of fall time.

To improve the switching times speed-up capacitors are used.The upper limit of speed-up capacitor depends on the maximum signal frequency.

$$C_S \leq \frac{t_{re}}{2.3R_B} j$$

Recovery time (tre) is the time between switch-off and switch on.

2.3 PRELIMINARY

Assume β=100, V_γ=0.7 V and $V_{CE(SAT)}$=0 V

P1. If V_i=10 $V_{p\text{-}p}$ square wave at 50 KHz for given circuit in Fig. 1, draw the V_o and V_i on the same scale.

P2. Calculate t_d, t_r, t_s, t_f, and t_p of output waveform.

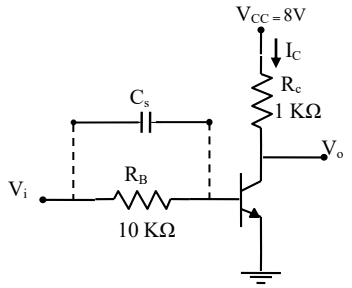


Fig. 1 BJT switching circuit

2.4 EXPERIMENTAL PROCEDURE

Set up the circuit in Fig. 1 without C_s and apply V_i=10 $V_{p\text{-}p}$ square wave at 50 KHz.

E1. Draw V_o and V_i on the same scale. Measure t_d, t_r, t_s, t_f, and t_p of output waveform.

E2. Repeat E2 if frequency is chosen at 1 KHz and 10 KHz.

E3. Increase the positive portion of input voltage at 50 KHz and repeat E1.

E4. Increase the negative portion of input voltage (more negative) at 50 KHz and repeat E1.

E5. Connect a parallel capacitor C_s=330 pF across the R_B resistance and repeat E1 (V_i=10 $V_{p\text{-}p}$ square wave at 50 KHz).

E6. Take C_s=560 pF and repeat E1 (V_i=10 $V_{p\text{-}p}$ square wave at 50 KHz).

2.5 CONCLUSIONS

C1. Compare the theoretical and experimental results obtained in the experiment. Explain any differences if exist.

C2. What is the function of C_s.

EQUIPMENT LIST

Resistor (1 KΩ, 10 KΩ)

Capacitor (330 pF, 560 pF)

BJT (BC237-npn)

Standard set equipment