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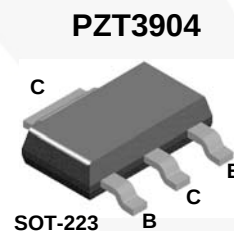
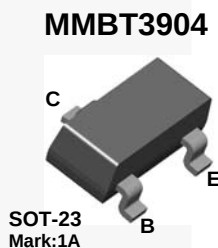
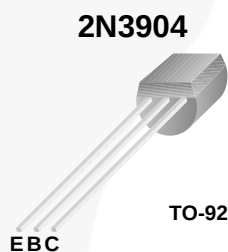


October 2014

## 2N3904 / MMBT3904 / PZT3904 NPN General-Purpose Amplifier

### Description

This device is designed as a general-purpose amplifier and switch. The useful dynamic range extends to 100 mA as a switch and to 100 MHz as an amplifier.



### Ordering Information

| Part Number | Marking | Package    | Packing Method | Pack Quantity |
|-------------|---------|------------|----------------|---------------|
| 2N3904BU    | 2N3904  | TO-92 3L   | Bulk           | 10000         |
| 2N3904TA    | 2N3904  | TO-92 3L   | Ammo           | 2000          |
| 2N3904TAR   | 2N3904  | TO-92 3L   | Ammo           | 2000          |
| 2N3904TF    | 2N3904  | TO-92 3L   | Tape and Reel  | 2000          |
| 2N3904TFR   | 2N3904  | TO-92 3L   | Tape and Reel  | 2000          |
| MMBT3904    | 1A      | SOT-23 3L  | Tape and Reel  | 3000          |
| PZT3904     | 3904    | SOT-223 4L | Tape and Reel  | 2500          |

2N3904 / MMBT3904 / PZT3904 — NPN General-Purpose Amplifier

## Absolute Maximum Ratings<sup>(1), (2)</sup>

Stresses exceeding the absolute maximum ratings may damage the device. The device may not function or be operable above the recommended operating conditions and stressing the parts to these levels is not recommended. In addition, extended exposure to stresses above the recommended operating conditions may affect device reliability. The absolute maximum ratings are stress ratings only. Values are at  $T_A = 25^\circ\text{C}$  unless otherwise noted.

| Symbol         | Parameter                                        | Value      | Unit             |
|----------------|--------------------------------------------------|------------|------------------|
| $V_{CEO}$      | Collector-Emitter Voltage                        | 40         | V                |
| $V_{CBO}$      | Collector-Base Voltage                           | 60         | V                |
| $V_{EBO}$      | Emitter-Base Voltage                             | 6.0        | V                |
| $I_C$          | Collector Current - Continuous                   | 200        | mA               |
| $T_J, T_{STG}$ | Operating and Storage Junction Temperature Range | -55 to 150 | $^\circ\text{C}$ |

### Notes:

- These ratings are based on a maximum junction temperature of  $150^\circ\text{C}$ .
- These are steady-state limits. Fairchild Semiconductor should be consulted on applications involving pulsed or low-duty cycle operations.

## Thermal Characteristics

Values are at  $T_A = 25^\circ\text{C}$  unless otherwise noted.

| Symbol          | Parameter                               | Maximum |                         |                        | Unit                 |
|-----------------|-----------------------------------------|---------|-------------------------|------------------------|----------------------|
|                 |                                         | 2N3904  | MMBT3904 <sup>(3)</sup> | PZT3904 <sup>(4)</sup> |                      |
| $P_D$           | Total Device Dissipation                | 625     | 350                     | 1,000                  | mW                   |
|                 | Derate Above $25^\circ\text{C}$         | 5.0     | 2.8                     | 8.0                    | mW/ $^\circ\text{C}$ |
| $R_{\theta JC}$ | Thermal Resistance, Junction to Case    | 83.3    |                         |                        | $^\circ\text{C/W}$   |
| $R_{\theta JA}$ | Thermal Resistance, Junction to Ambient | 200     | 357                     | 125                    | $^\circ\text{C/W}$   |

### Notes:

- Device is mounted on FR-4 PCB 1.6 inch X 1.6 inch X 0.06 inch.
- Device is mounted on FR-4 PCB 36 mm X 18 mm X 1.5 mm, mounting pad for the collector lead minimum  $6\text{ cm}^2$ .

## Electrical Characteristics

Values are at  $T_A = 25^\circ\text{C}$  unless otherwise noted.

| Symbol                            | Parameter                            | Conditions                                                                                       | Min. | Max. | Unit |
|-----------------------------------|--------------------------------------|--------------------------------------------------------------------------------------------------|------|------|------|
| OFF CHARACTERISTICS               |                                      |                                                                                                  |      |      |      |
| V <sub>(BR)CEO</sub>              | Collector-Emitter Breakdown Voltage  | I <sub>C</sub> = 1.0 mA, I <sub>B</sub> = 0                                                      | 40   |      | V    |
| V <sub>(BR)CBO</sub>              | Collector-Base Breakdown Voltage     | I <sub>C</sub> = 10 μA, I <sub>E</sub> = 0                                                       | 60   |      | V    |
| V <sub>(BR)EBO</sub>              | Emitter-Base Breakdown Voltage       | I <sub>E</sub> = 10 μA, I <sub>C</sub> = 0                                                       | 6.0  |      | V    |
| I <sub>BL</sub>                   | Base Cut-Off Current                 | V <sub>CE</sub> = 30 V, V <sub>EB</sub> = 3 V                                                    |      | 50   | nA   |
| I <sub>CEX</sub>                  | Collector Cut-Off Current            | V <sub>CE</sub> = 30 V, V <sub>EB</sub> = 3 V                                                    |      | 50   | nA   |
| ON CHARACTERISTICS <sup>(5)</sup> |                                      |                                                                                                  |      |      |      |
| h <sub>FE</sub>                   | DC Current Gain                      | I <sub>C</sub> = 0.1 mA, V <sub>CE</sub> = 1.0 V                                                 | 40   |      |      |
|                                   |                                      | I <sub>C</sub> = 1.0 mA, V <sub>CE</sub> = 1.0 V                                                 | 70   |      |      |
|                                   |                                      | I <sub>C</sub> = 10 mA, V <sub>CE</sub> = 1.0 V                                                  | 100  | 300  |      |
|                                   |                                      | I <sub>C</sub> = 50 mA, V <sub>CE</sub> = 1.0 V                                                  | 60   |      |      |
|                                   |                                      | I <sub>C</sub> =100 mA, V <sub>CE</sub> = 1.0V                                                   | 30   |      |      |
| V <sub>CE</sub> (sat)             | Collector-Emitter Saturation Voltage | I <sub>C</sub> = 10 mA, I <sub>B</sub> = 1.0 mA                                                  |      | 0.2  | V    |
|                                   |                                      | I <sub>C</sub> = 50 mA, I <sub>B</sub> = 5.0 mA                                                  |      | 0.3  |      |
| V <sub>BE</sub> (sat)             | Base-Emitter Saturation Voltage      | I <sub>C</sub> = 10 mA, I <sub>B</sub> = 1.0 mA                                                  | 0.65 | 0.85 | V    |
|                                   |                                      | I <sub>C</sub> = 50 mA, I <sub>B</sub> = 5.0 mA                                                  |      | 0.95 |      |
| SMALL SIGNAL CHARACTERISTICS      |                                      |                                                                                                  |      |      |      |
| f <sub>T</sub>                    | Current Gain - Bandwidth Product     | I <sub>C</sub> = 10 mA, V <sub>CE</sub> = 20 V, f = 100 MHz                                      | 300  |      | MHz  |
| C <sub>obo</sub>                  | Output Capacitance                   | V <sub>CB</sub> = 5.0 V, I <sub>E</sub> = 0, f = 100 kHz                                         |      | 4.0  | pF   |
| C <sub>ibo</sub>                  | Input Capacitance                    | V <sub>EB</sub> = 0.5 V, I <sub>C</sub> = 0, f = 100 kHz                                         |      | 8.0  | pF   |
| NF                                | Noise Figure                         | I <sub>C</sub> = 100 μA, V <sub>CE</sub> = 5.0 V, R <sub>S</sub> = 1.0 kΩ, f = 10 Hz to 15.7 kHz |      | 5.0  | dB   |
| SWITCHING CHARACTERISTICS         |                                      |                                                                                                  |      |      |      |
| t <sub>d</sub>                    | Delay Time                           | V <sub>CC</sub> = 3.0 V, V <sub>BE</sub> = 0.5 V                                                 |      | 35   | ns   |
| t <sub>r</sub>                    | Rise Time                            | I <sub>C</sub> = 10 mA, I <sub>B1</sub> = 1.0 mA                                                 |      | 35   | ns   |
| t <sub>s</sub>                    | Storage Time                         | V <sub>CC</sub> = 3.0 V, I <sub>C</sub> = 10 mA,                                                 |      | 200  | ns   |
| t <sub>f</sub>                    | Fall Time                            | I <sub>B1</sub> = I <sub>B2</sub> = 1.0 mA                                                       |      | 50   | ns   |

### Note:

5. Pulse test: pulse width  $\leq 300\text{ }\mu\text{s}$ , duty cycle  $\leq 2.0\%$ .

## Typical Performance Characteristics

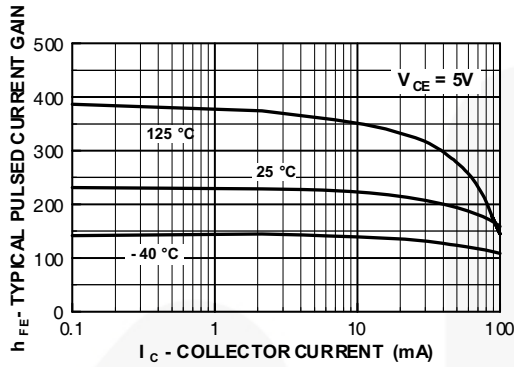


Figure 1. Typical Pulsed Current Gain vs. Collector Current

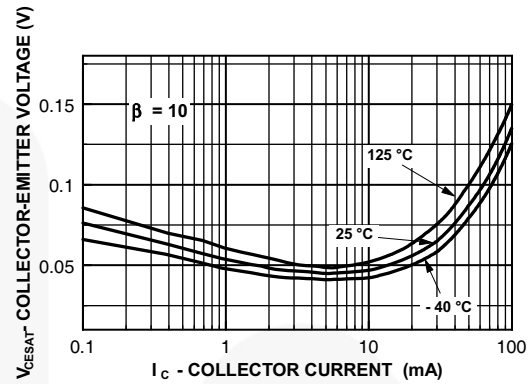


Figure 2. Collector-Emitter Saturation Voltage vs. Collector Current

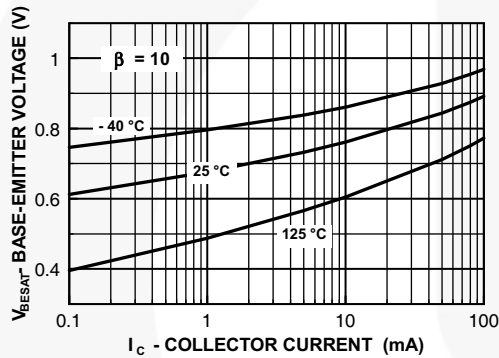


Figure 3. Base-Emitter Saturation Voltage vs. Collector Current

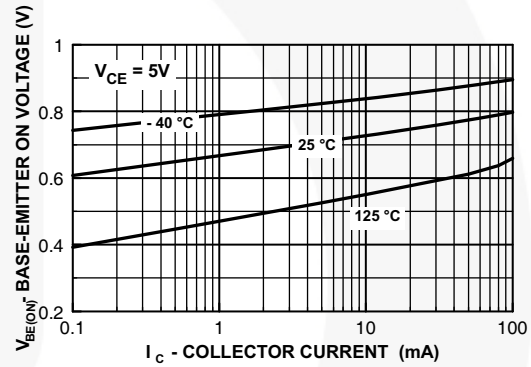


Figure 4. Base-Emitter On Voltage vs. Collector Current

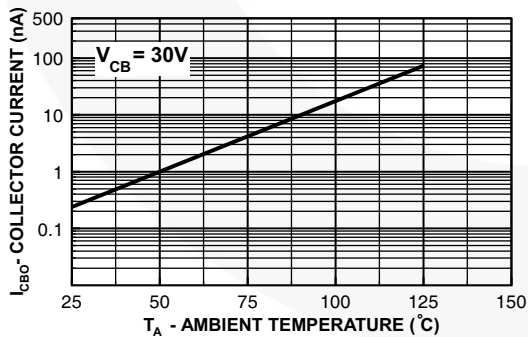


Figure 5. Collector Cut-Off Current vs. Ambient Temperature

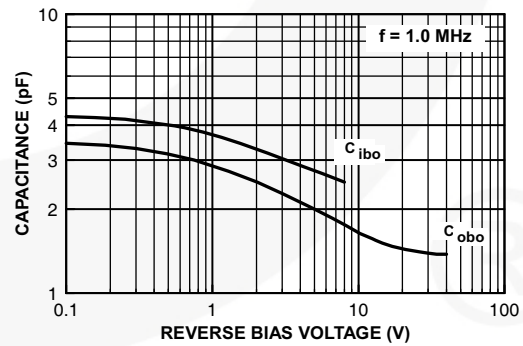


Figure 6. Capacitance vs. Reverse Bias Voltage

## Typical Performance Characteristics (Continued)

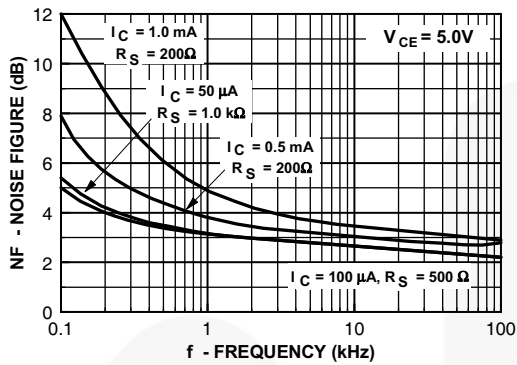


Figure 7. Noise Figure vs. Frequency

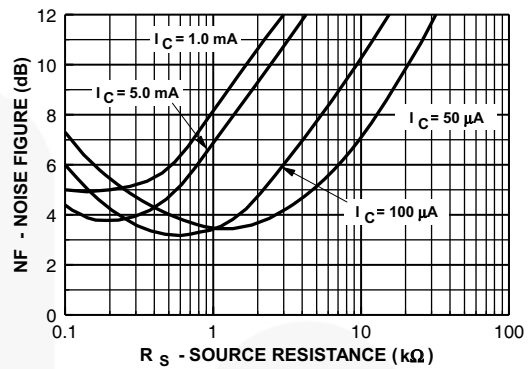


Figure 8. Noise Figure vs. Source Resistance

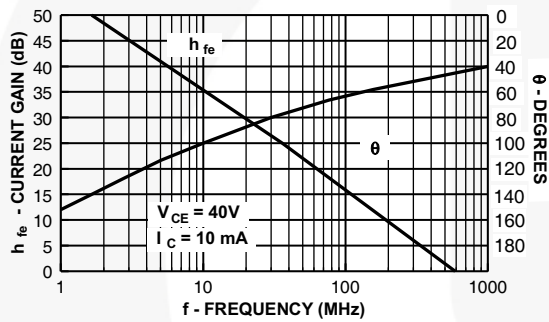


Figure 9. Current Gain and Phase Angle vs. Frequency

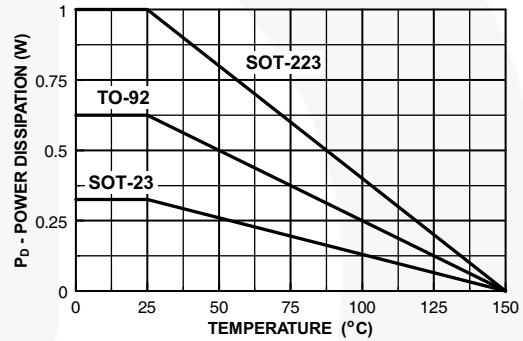


Figure 10. Power Dissipation vs. Ambient Temperature

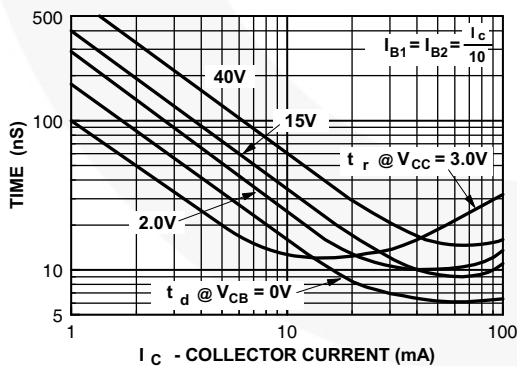


Figure 11. Turn-On Time vs. Collector Current

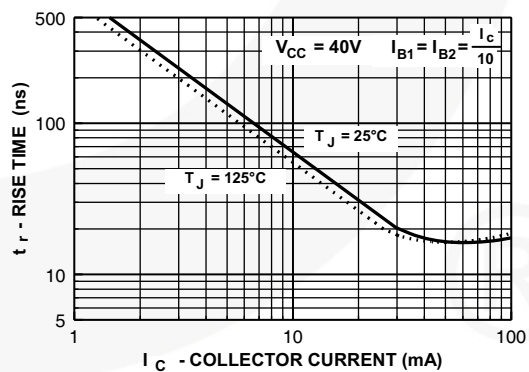


Figure 12. Rise Time vs. Collector Current

# Typical Performance Characteristics (Continued)

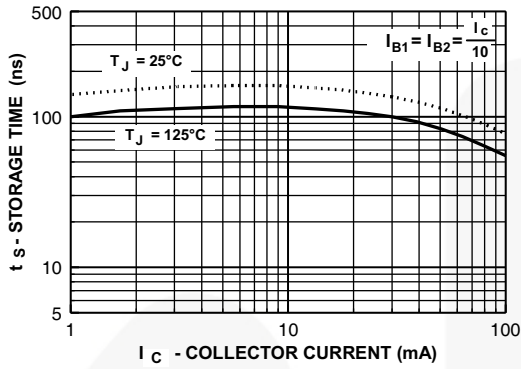


Figure 13. Storage Time vs. Collector Current

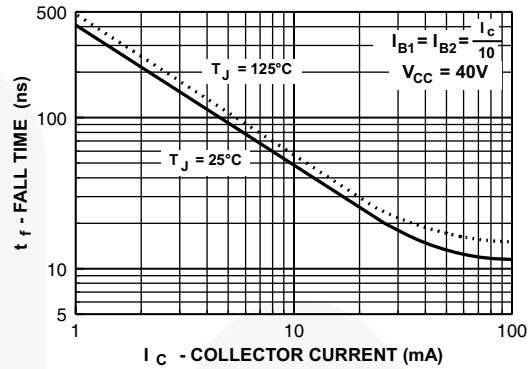


Figure 14. Fall Time vs. Collector Current

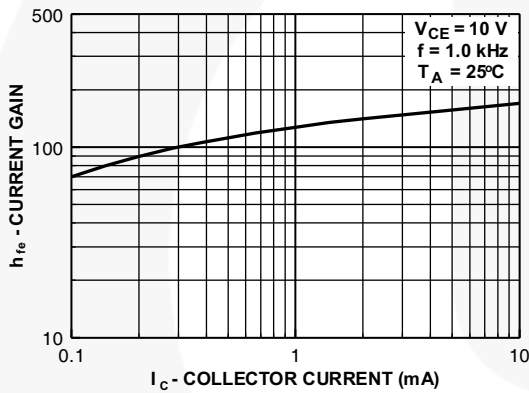


Figure 15. Current Gain

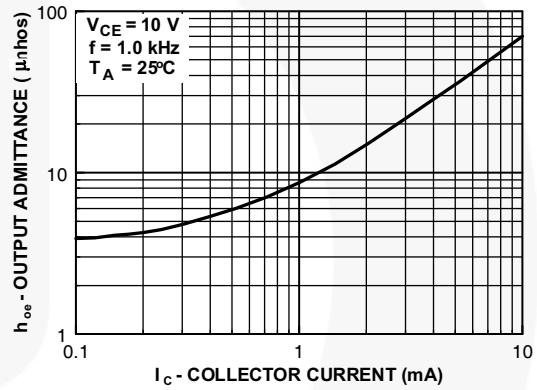


Figure 16. Output Admittance

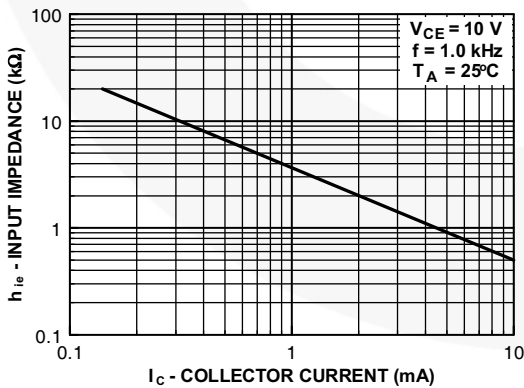


Figure 17. Input Impedance

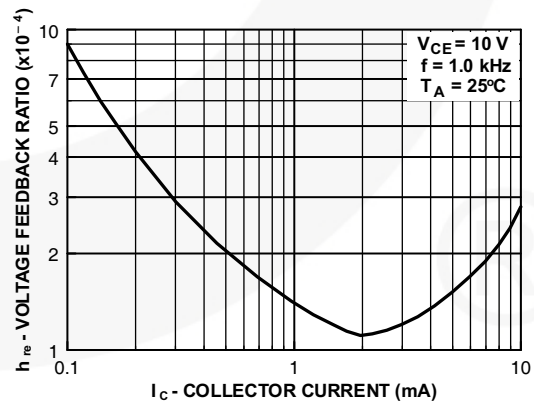


Figure 18. Voltage Feedback Ratio

## Test Circuits

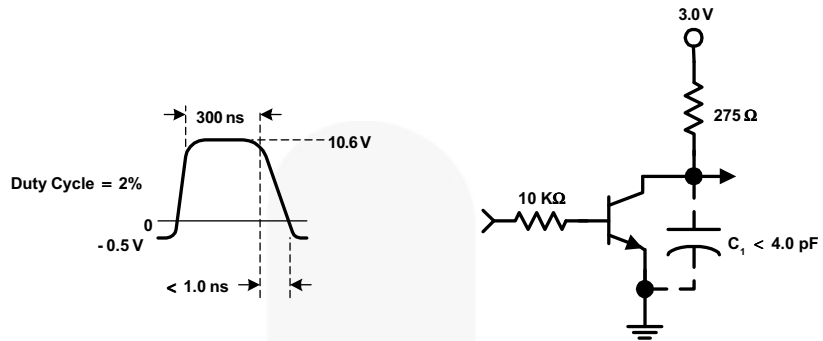


Figure 19. Delay and Rise Time Equivalent Test Circuit

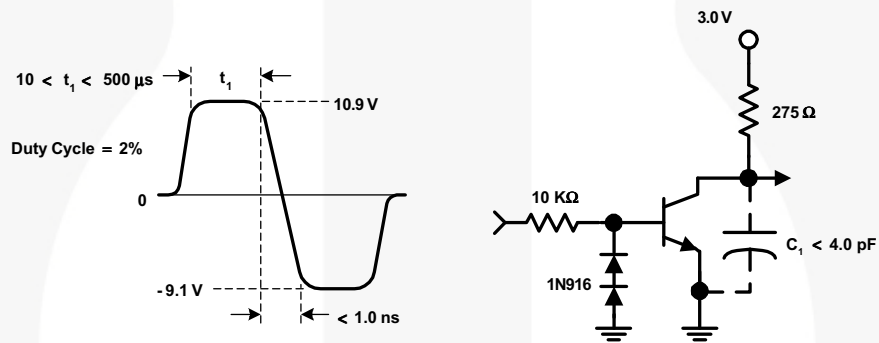
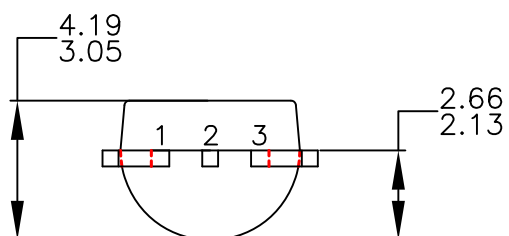
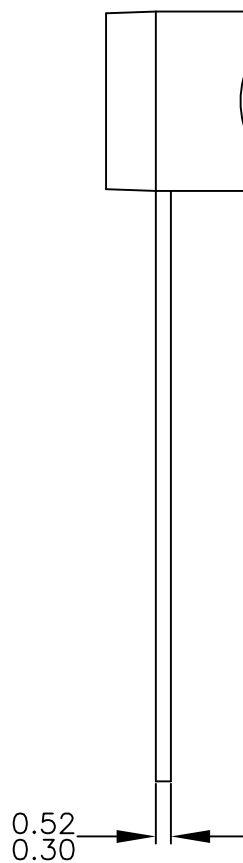
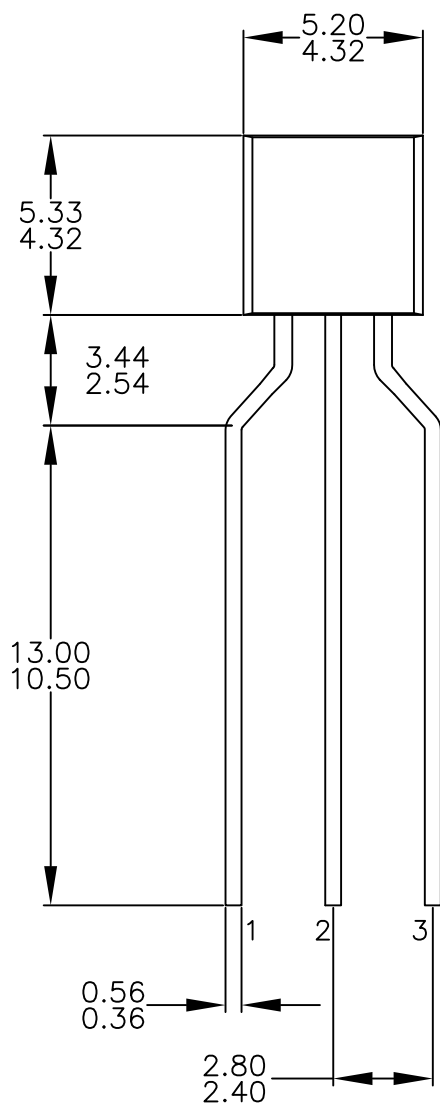


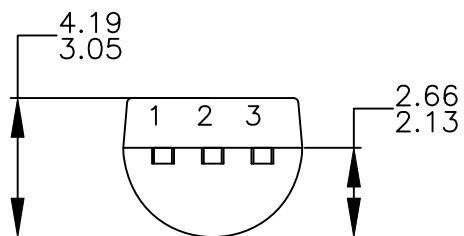
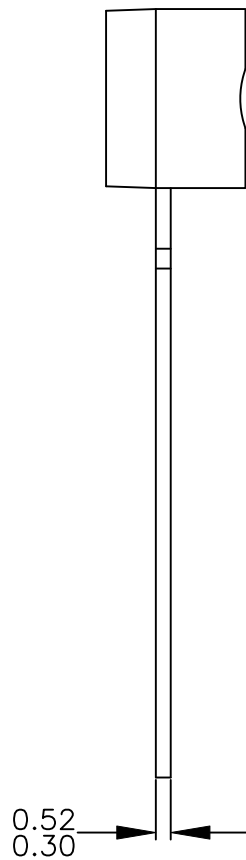
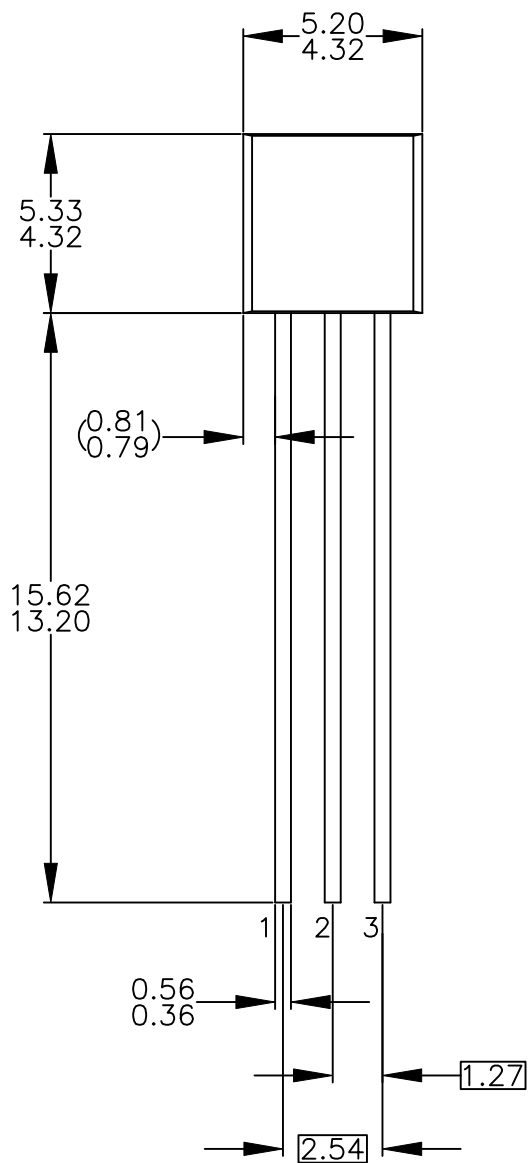
Figure 20. Storage and Fall Time Equivalent Test Circuit



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