

# NPN General - Purpose Amplifier

## 2N3904

### 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.

### MAXIMUM RATINGS

(Values are at  $T_A = 25^\circ\text{C}$  unless otherwise noted.) (Note 1, Note 2)

| 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 | $^\circ\text{C}$ |

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. These ratings are based on a maximum junction temperature of  $150^\circ\text{C}$ .
2. These are steady-state limits. ON 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                               | Max  | Unit                      |
|-----------------|---|------|---------------------------|
| $P_D$           | Total Device Dissipation                | 625  | mW                        |
|                 | Derate Above $25^\circ\text{C}$         | 5.0  | mW/ $^\circ\text{C}$      |
| $R_{\theta JC}$ | Thermal Resistance, Junction to Case    | 83.3 | $^\circ\text{C}/\text{W}$ |
| $R_{\theta JA}$ | Thermal Resistance, Junction to Ambient | 200  | $^\circ\text{C}/\text{W}$ |



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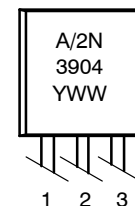


TO-92 3  
CASE 135AN



TO-92 3  
LEADFORMED  
CASE 135AR

### MARKING DIAGRAM



- 1: Emitter
- 2: Base
- 3: Collector

A = Assembly Code  
2N3904 = Device Code  
YWW = Date Code

### ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 6 of this data sheet.

## 2N3904

### ELECTRICAL CHARACTERISTICS (Values are at $T_A = 25^\circ\text{C}$ unless otherwise noted.)

| Symbol                     | Parametr                              | Conditions                                  | Min | Max | Unit |
|----------------------------|---------------------------------------|---|-----|-----|------|
| <b>OFF CHARACTERISTICS</b> |                                       |   |     |     |      |
| $V_{(BR)CEO}$              | Collector – Emitter Breakdown Voltage | $I_C = 1.0\text{ mA}, I_B = 0$              | 40  | –   | V    |
| $V_{(BR)CBO}$              | Collector – Base Breakdown Voltage    | $I_C = 10\ \mu\text{A}, I_E = 0$            | 60  | –   | V    |
| $V_{(BR)EBO}$              | Emitter – Base Breakdown Voltage      | $I_E = 10\ \mu\text{A}, I_C = 0$            | 6.0 | –   | V    |
| $I_{BL}$                   | Base Cutoff Current                   | $V_{CE} = 30\text{ V}, V_{EB} = 3\text{ V}$ | –   | 50  | nA   |
| $I_{CEX}$                  | Collector Cut-Off Current             | $V_{CE} = 30\text{ V}, V_{EB} = 3\text{ V}$ | –   | 50  | nA   |

### ON CHARACTERISTICS (Note 3)

|               |  |  |      |      |   |
|---------------|--|--|------|------|---|
| $h_{FE}$      | DC Current Gain                        | $I_C = 0.1\text{ mA}, V_{CE} = 1.0\text{ V}$ | 40   | –    | – |
|               |  | $I_C = 1.0\text{ mA}, V_{CE} = 1.0\text{ V}$ | 70   | –    |   |
|               |  | $I_C = 10\text{ mA}, V_{CE} = 1.0\text{ V}$  | 100  | 300  |   |
|               |  | $I_C = 50\text{ mA}, V_{CE} = 1.0\text{ V}$  | 60   | –    |   |
|               |  | $I_C = 100\text{ mA}, V_{CE} = 1.0\text{ V}$ | 30   | –    |   |
| $V_{CE(sat)}$ | Collector – Emitter Saturation Voltage | $I_C = 10\text{ mA}, I_B = 1.0\text{ mA}$    | –    | 0.2  | V |
|               |  | $I_C = 50.0\text{ mA}, I_B = 5.0\text{ mA}$  | –    | 0.3  |   |
| $V_{BE(sat)}$ | Base – Emitter Saturation Voltage      | $I_C = 10.0\text{ mA}, I_B = 1.0\text{ mA}$  | 0.65 | 0.85 | V |
|               |  | $I_C = 50.0\text{ mA}, I_B = 5.0\text{ mA}$  | –    | 0.95 |   |

### SMALL-SIGNAL CHARACTERISTICS

|           |                                    |  |     |     |     |
|-----------|------------------------------------|--|-----|-----|-----|
| $f_T$     | Current – Gain – Bandwidth Product | $I_C = 10\text{ mA}, V_{CE} = 20\text{ V}, f = 100\text{ MHz}$   | 300 | –   | MHz |
| $C_{obo}$ | Output Capacitance                 | $V_{CB} = 5.0\text{ V}, I_E = 0, f = 100\text{ kHz}$   | –   | 4.0 | pF  |
| $C_{ibo}$ | Input Capacitance                  | $V_{EB} = 0.5\text{ V}, I_C = 0, f = 100\text{ kHz}$   | –   | 8.0 | pF  |
| NF        | Noise Figure                       | $I_C = 100\ \mu\text{A}, V_{CE} = 5.0\text{ V}, R_S = 1.0\text{ k}\Omega, f = 10\text{ Hz to }15.7\text{ kHz}$ | –   | 5.0 | dB  |

### SWITCHING CHARACTERISTICS

|       |              |  |   |     |    |
|-------|--------------|--|---|-----|----|
| $t_d$ | Delay Time   | $V_{CC} = 3.0\text{ V}, V_{BE} = 0.5\text{ V}, I_C = 10\text{ mA}, I_{B1} = 1.0\text{ mA}$ | – | 35  | ns |
| $t_r$ | Rise Time    |  | – | 35  | ns |
| $t_s$ | Storage Time | $V_{CC} = 3.0\text{ V}, I_C = 10\text{ mA}, I_{B1} = I_{B2} = 1.0\text{ mA}$               | – | 200 | ns |
| $t_f$ | Fall Time    |  | – | 50  | ns |

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

3. Pulse Test: Pulse Width  $\leq 300\ \mu\text{s}$ ; Duty Cycle  $\leq 2\%$ .

TYPICAL PERFORMANCE CHARACTERISTICS

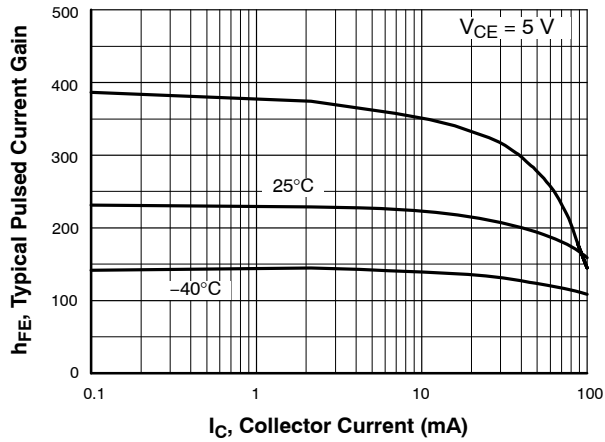


Figure 1. Typical Pulsed Current Gain vs. Collector Current

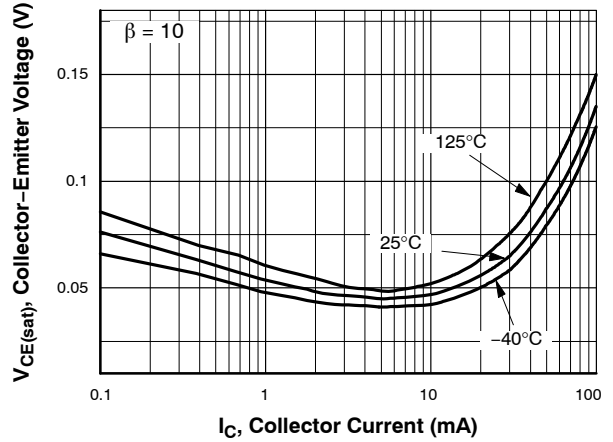


Figure 2. Collector-Emitter Saturation Voltage vs. Collector Current

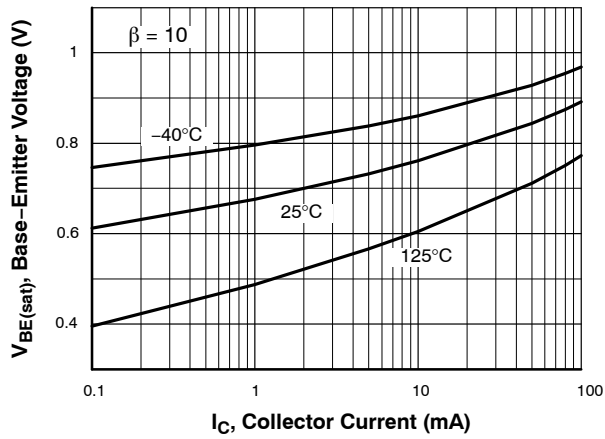


Figure 3. Base-Emitter Saturation Voltage vs. Collector Current

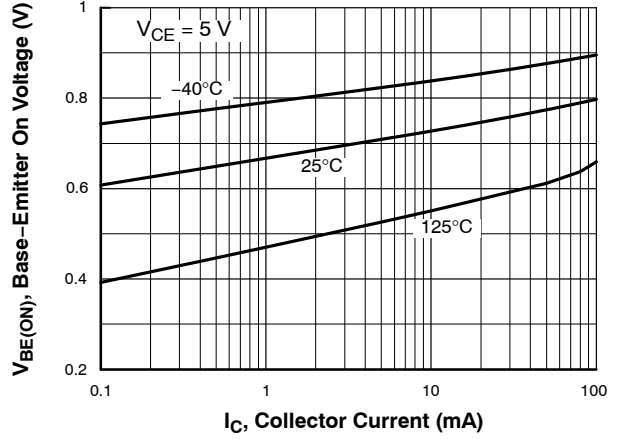


Figure 4. Base-Emitter On Voltage vs. Collector Current

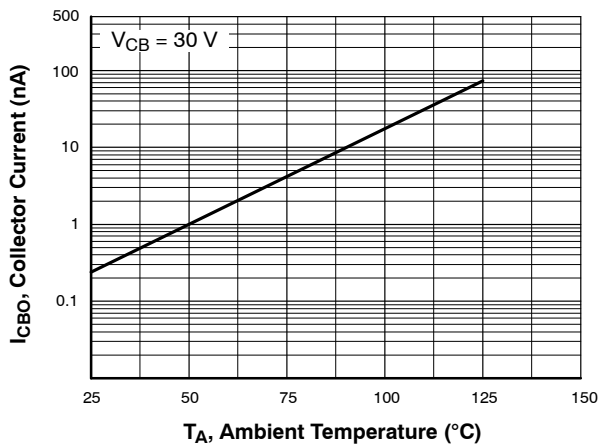


Figure 5. Collector Cut-Off Current vs. Ambient Temperature

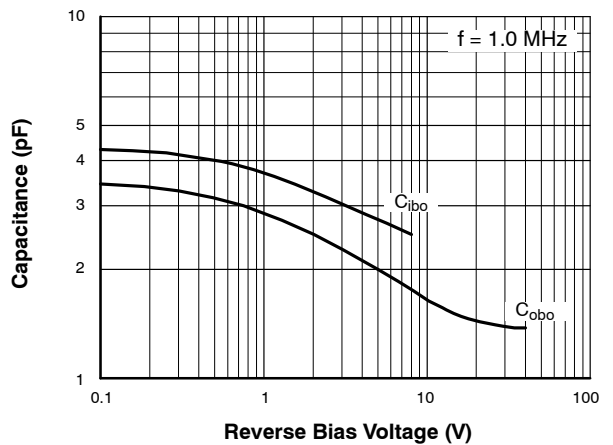


Figure 6. Capacitance vs. Reverse Bias Voltage

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

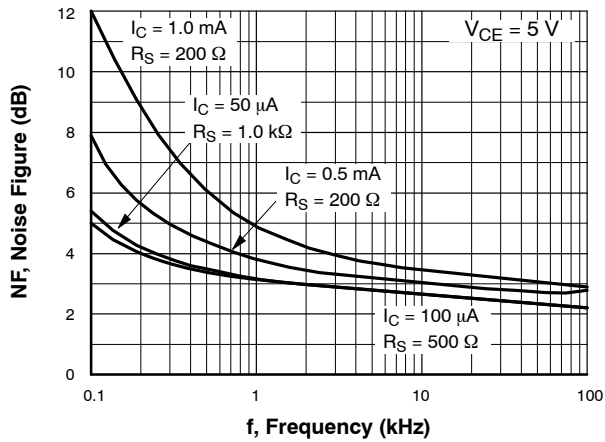


Figure 7. Noise Figure vs. Frequency

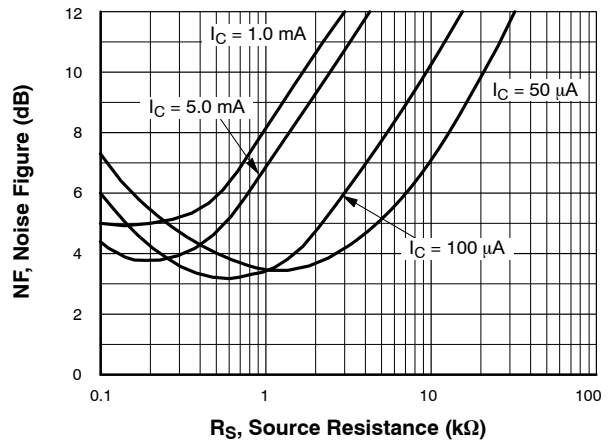


Figure 8. Noise Figure vs. Source Resistance

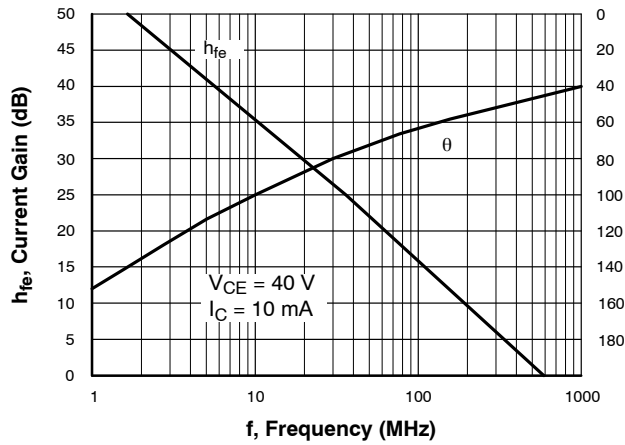


Figure 9. Current Gain and Phase Angle vs. Frequency

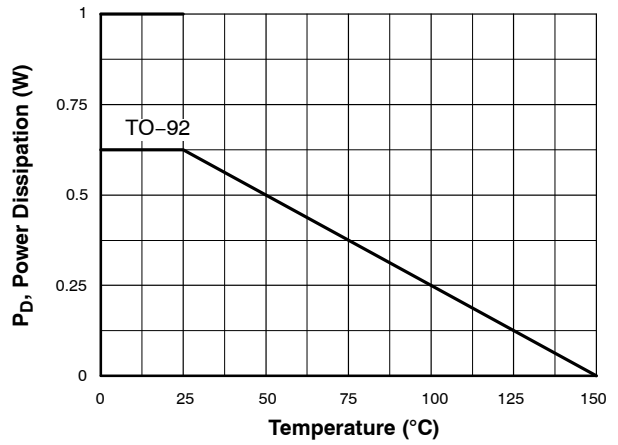


Figure 10. Power Dissipation vs. Ambient Temperature

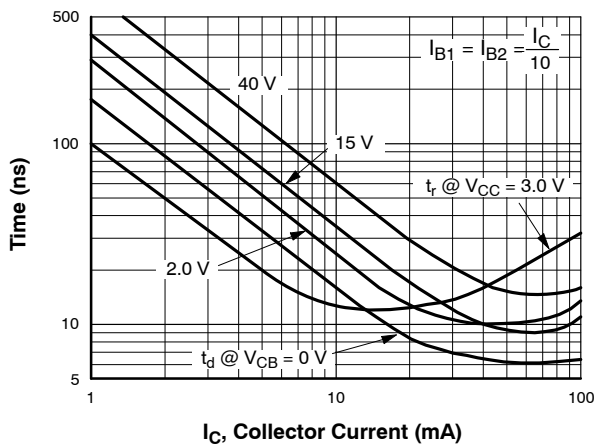


Figure 11. Turn-On Time vs. Collector Current

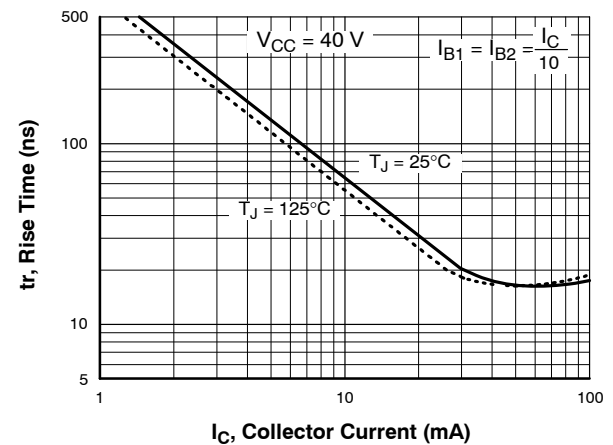


Figure 12. Rise Time vs. Collector Current

TYPICAL PERFORMANCE CHARACTERISTICS (Continued)

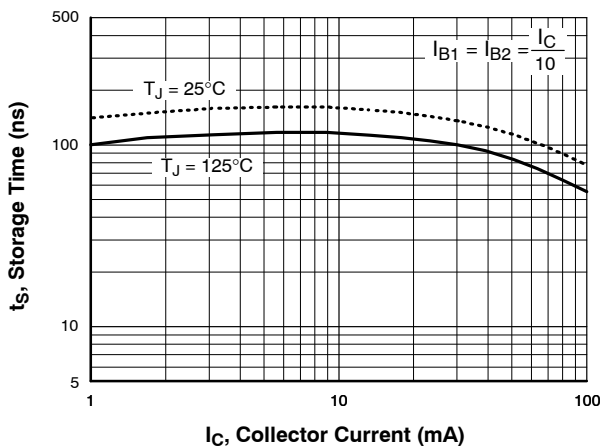


Figure 13. Storage Time vs. Collector Current

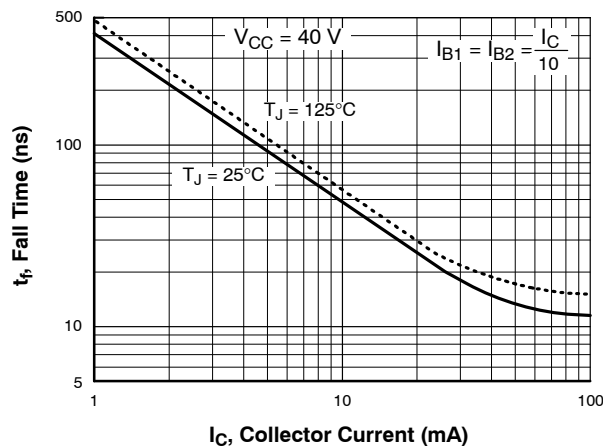


Figure 14. Fall Time vs. Collector Current

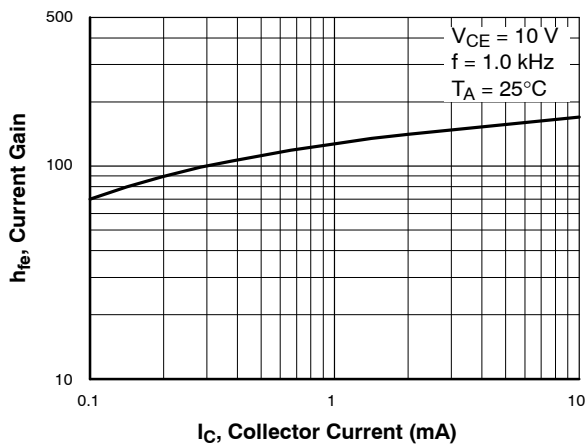


Figure 15. Current Gain

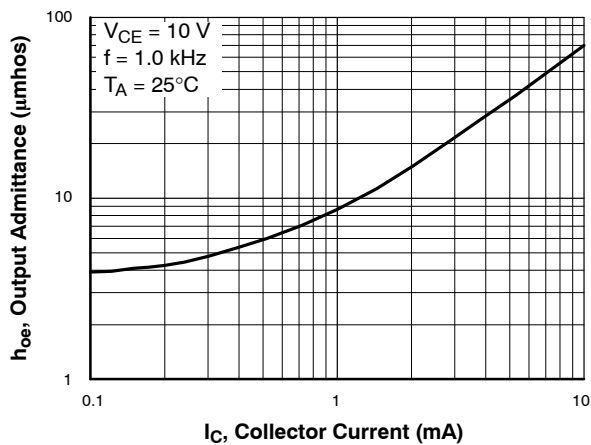


Figure 16. Output Admittance

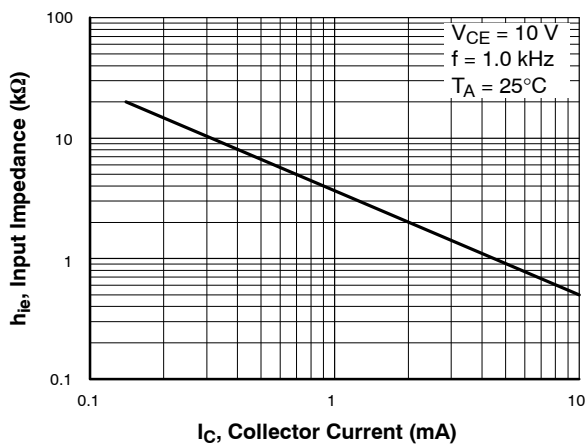


Figure 17. Input Impedance

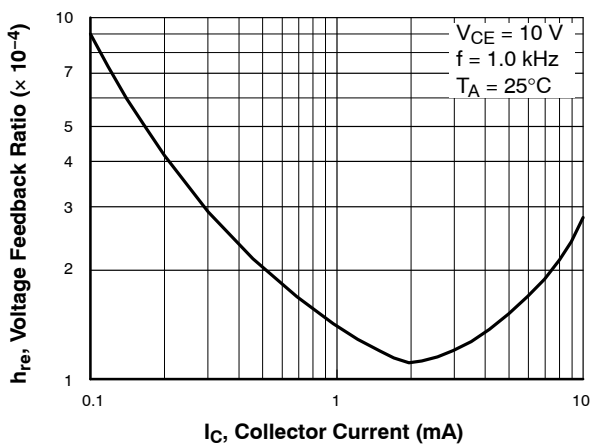


Figure 18. Voltage Feedback Ratio

# 2N3904

## TEST CIRCUITS

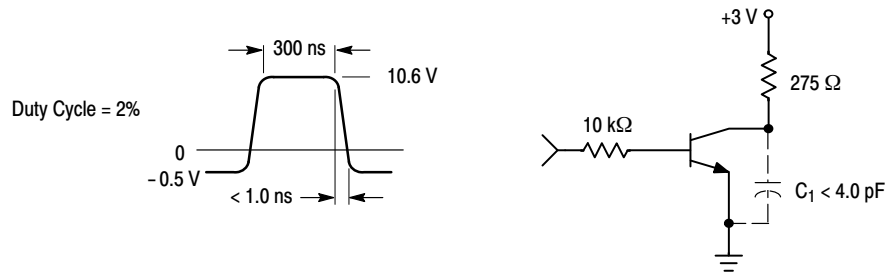


Figure 19. Delay and Rise Time Equivalent Test Circuit

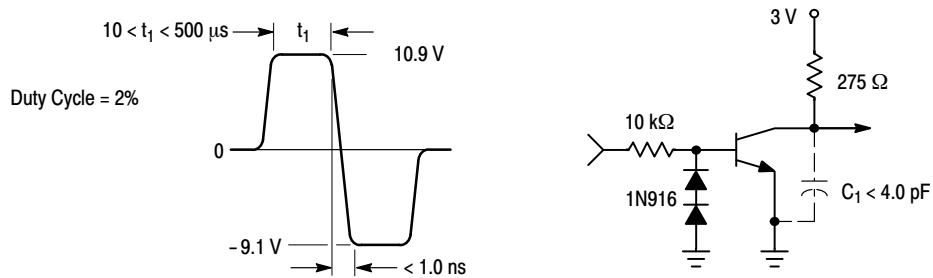


Figure 20. Storage and Fall Time Equivalent Test Circuit

### ORDERING INFORMATION

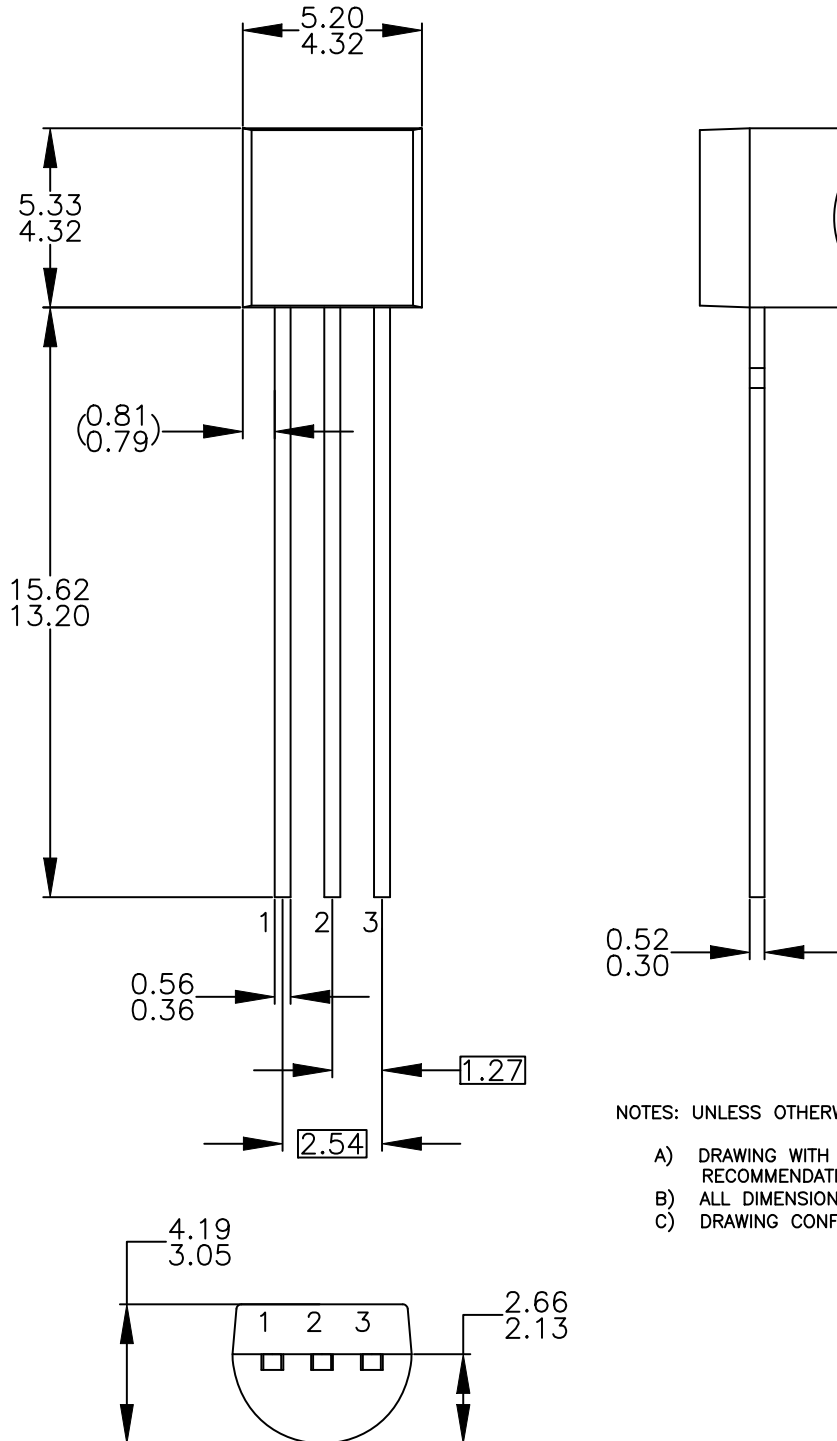
| Device    | Package                 | Shipping <sup>†</sup>    |
|-----------|-------------------------|--------------------------|
| 2N3904BU  | TO-92-3 LF<br>(Pb-Free) | 10000 Units / Bulk Bag   |
| 2N3904TA  | TO-92-3 LF<br>(Pb-Free) | 2000 Units / Fan-Fold    |
| 2N3904TAR | TO-92-3 LF<br>(Pb-Free) | 2000 Units / Fan-Fold    |
| 2N3904TF  | TO-92-3 LF<br>(Pb-Free) | 2000 Units / Tape & Reel |
| 2N3904TFR | TO-92-3 LF<br>(Pb-Free) | 2000 Units / Tape & Reel |

<sup>†</sup>For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

**MECHANICAL CASE OUTLINE**  
**PACKAGE DIMENSIONS**

TO-92 3 4.825x4.76  
CASE 135AN  
ISSUE O

DATE 31 JUL 2016



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- A) DRAWING WITH REFERENCE TO JEDEC TO-92 RECOMMENDATIONS.
- B) ALL DIMENSIONS ARE IN MILLIMETERS.
- C) DRAWING CONFORMS TO ASME Y14.5M-2009.

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**TO-92 3 4.83x4.76 LEADFORMED**  
**CASE 135AR**  
**ISSUE O**


DATE 30 SEP 2016



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