# Fall-2020 UM-SJTU JI Ve311 Lab #2

Instructor: Dr. Chang-Ching Tu

Due: 11:59 am, October 30, 2020 (Friday)

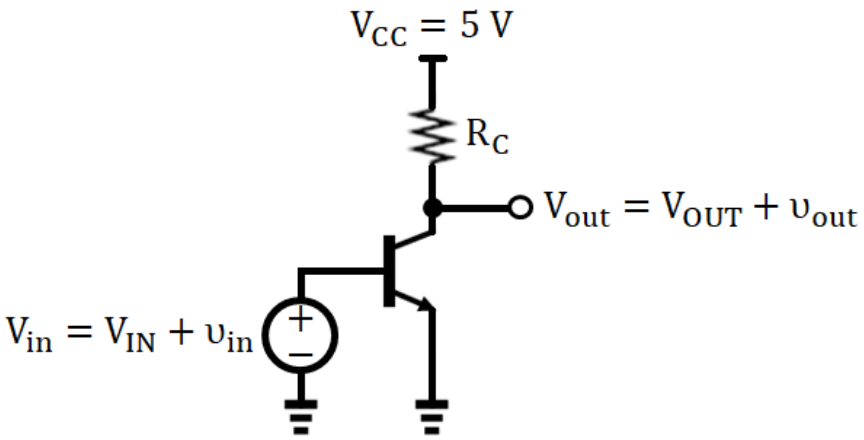
Note:

(1) Please use A4 size papers.

(2) The lab report should be submitted online individually.

(3) Use Proteus 8.10 for simulation before the lab session. In the Proteus library, you should be able to find all the components used in the schematics. **The lab report must include both the simulation and measurement results.**

1. [Common-Emitter Amplifier]
   (a) [40%] Design and build a common-emitter amplifier in Proteus and on the breadboard which has a voltage gain $A_\upsilon > 10$, using **npn BJT 2N3904**. Plot $V_{OUT}$ vs $V_{IN}$. (Hint: First choose an appropriate $R_C$. Second, perform DC sweep to find out a $V_{IN}$ at which the magnitude of slope is more than 10. At the same time, make sure the BJT is in the forward-active region. If not working, change for another $R_C$ and repeat the DC analysis again.)
   (b) [30%] For $V_{in} = V_{IN} + 0.01\sin(2\pi 10^2 \cdot \text{time})$, plot $V_{out} = V_{OUT} + \upsilon_{out}$ vs time. Confirm that the amplitude of $\upsilon_{out}$ is equal to $0.01 \times A_\upsilon$.
   (c) [30%] For $V_{in} = V_{IN} + 0.01\sin(2\pi 10^7 \cdot \text{time})$, plot $V_{out} = V_{OUT} + \upsilon_{out}$ vs time. Is the amplitude of $\upsilon_{out}$ still equal to $0.01 \times A_\upsilon$? If not, explain the possible reasons.


$V_{CC} = 5\ V$
$R_C$
$V_{out} = V_{OUT} + \upsilon_{out}$
$V_{in} = V_{IN} + \upsilon_{in}$
+
−

# 2N3903, 2N3904

# General Purpose Transistors

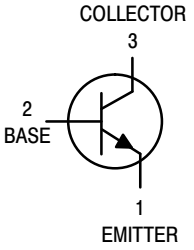
## NPN Silicon

**Features**

- Pb−Free Packages are Available*

**ON Semiconductor®**

**http://onsemi.com**




**MAXIMUM RATINGS**

| Rating | Symbol | Value | Unit |
|---|---|---|---|
| Collector − Emitter Voltage | $V_{CEO}$ | 40 | Vdc |
| Collector − Base Voltage | $V_{CBO}$ | 60 | Vdc |
| Emitter − Base Voltage | $V_{EBO}$ | 6.0 | Vdc |
| Collector Current − Continuous | $I_C$ | 200 | mAdc |
| Total Device Dissipation<br>@ $T_A$ = 25°C<br>Derate above 25°C | $P_D$ | <br>625<br>5.0 | <br>mW<br>mW/°C |
| Total Device Dissipation<br>@ $T_C$ = 25°C<br>Derate above 25°C | $P_D$ | <br>1.5<br>12 | <br>W<br>mW/°C |
| Operating and Storage Junction Temperature Range | $T_J$, $T_{stg}$ | −55 to +150 | °C |

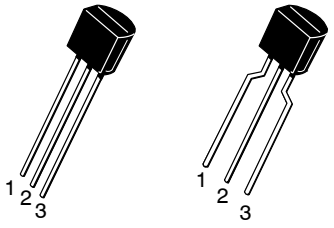
**THERMAL CHARACTERISTICS** (Note 1)

| Characteristic | Symbol | Max | Unit |
|---|---|---|---|
| Thermal Resistance, Junction−to−Ambient | $R_{\theta JA}$ | 200 | °C/W |
| Thermal Resistance, Junction−to−Case | $R_{\theta JC}$ | 83.3 | °C/W |

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

1. Indicates Data in addition to JEDEC Requirements.

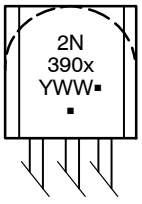
**TO−92**
**CASE 29**
**STYLE 1**




STRAIGHT LEAD
BULK PACK

BENT LEAD
TAPE & REEL
AMMO PACK

**MARKING DIAGRAMS**




x = 3 or 4
Y = Year
WW = Work Week
▪ = Pb−Free Package
(Note: Microdot may be in either location)

**ORDERING INFORMATION**

See detailed ordering and shipping information in the package dimensions section on page 3 of this data sheet.

*For additional information on our Pb−Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

**ELECTRICAL CHARACTERISTICS** ($T_A$ = 25°C unless otherwise noted)

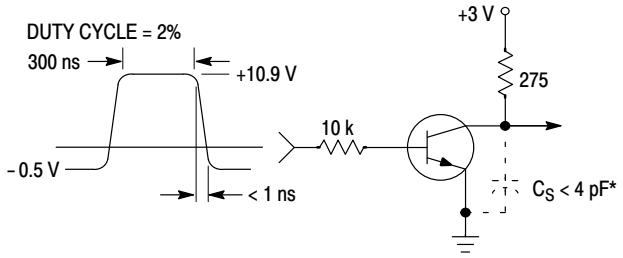
| Characteristic | | Symbol | Min | Max | Unit |
|---|---|---|---|---|---|
| **OFF CHARACTERISTICS** | | | | | |
| Collector – Emitter Breakdown Voltage (Note 2) ($I_C$ = 1.0 mAdc, $I_B$ = 0) | | $V_{(BR)CEO}$ | 40 | – | Vdc |
| Collector – Base Breakdown Voltage ($I_C$ = 10 μAdc, $I_E$ = 0) | | $V_{(BR)CBO}$ | 60 | – | Vdc |
| Emitter – Base Breakdown Voltage ($I_E$ = 10 μAdc, $I_C$ = 0) | | $V_{(BR)EBO}$ | 6.0 | – | Vdc |
| Base Cutoff Current ($V_{CE}$ = 30 Vdc, $V_{EB}$ = 3.0 Vdc) | | $I_{BL}$ | – | 50 | nAdc |
| Collector Cutoff Current ($V_{CE}$ = 30 Vdc, $V_{EB}$ = 3.0 Vdc) | | $I_{CEX}$ | – | 50 | nAdc |
| **ON CHARACTERISTICS** | | | | | |
| DC Current Gain (Note 2) | | $h_{FE}$ | | | – |
| ($I_C$ = 0.1 mAdc, $V_{CE}$ = 1.0 Vdc) | 2N3903 | | 20 | – | |
| | 2N3904 | | 40 | – | |
| ($I_C$ = 1.0 mAdc, $V_{CE}$ = 1.0 Vdc) | 2N3903 | | 35 | – | |
| | 2N3904 | | 70 | – | |
| ($I_C$ = 10 mAdc, $V_{CE}$ = 1.0 Vdc) | 2N3903 | | 50 | 150 | |
| | 2N3904 | | 100 | 300 | |
| ($I_C$ = 50 mAdc, $V_{CE}$ = 1.0 Vdc) | 2N3903 | | 30 | – | |
| | 2N3904 | | 60 | – | |
| ($I_C$ = 100 mAdc, $V_{CE}$ = 1.0 Vdc) | 2N3903 | | 15 | – | |
| | 2N3904 | | 30 | – | |
| Collector – Emitter Saturation Voltage (Note 2) | | $V_{CE(sat)}$ | | | Vdc |
| ($I_C$ = 10 mAdc, $I_B$ = 1.0 mAdc) | | | – | 0.2 | |
| ($I_C$ = 50 mAdc, $I_B$ = 5.0 mAdc | | | – | 0.3 | |
| Base – Emitter Saturation Voltage (Note 2) | | $V_{BE(sat)}$ | | | Vdc |
| ($I_C$ = 10 mAdc, $I_B$ = 1.0 mAdc) | | | 0.65 | 0.85 | |
| ($I_C$ = 50 mAdc, $I_B$ = 5.0 mAdc) | | | – | 0.95 | |
| **SMALL–SIGNAL CHARACTERISTICS** | | | | | |
| Current – Gain – Bandwidth Product | | $f_T$ | | | MHz |
| ($I_C$ = 10 mAdc, $V_{CE}$ = 20 Vdc, f = 100 MHz) | 2N3903 | | 250 | – | |
| | 2N3904 | | 300 | – | |
| Output Capacitance ($V_{CB}$ = 5.0 Vdc, $I_E$ = 0, f = 1.0 MHz) | | $C_{obo}$ | – | 4.0 | pF |
| Input Capacitance ($V_{EB}$ = 0.5 Vdc, $I_C$ = 0, f = 1.0 MHz) | | $C_{ibo}$ | – | 8.0 | pF |
| Input Impedance | | $h_{ie}$ | | | k Ω |
| ($I_C$ = 1.0 mAdc, $V_{CE}$ = 10 Vdc, f = 1.0 kHz) | 2N3903 | | 1.0 | 8.0 | |
| | 2N3904 | | 1.0 | 10 | |
| Voltage Feedback Ratio | | $h_{re}$ | | | X $10^{-4}$ |
| ($I_C$ = 1.0 mAdc, $V_{CE}$ = 10 Vdc, f = 1.0 kHz) | 2N3903 | | 0.1 | 5.0 | |
| | 2N3904 | | 0.5 | 8.0 | |
| Small–Signal Current Gain | | $h_{fe}$ | | | – |
| ($I_C$ = 1.0 mAdc, $V_{CE}$ = 10 Vdc, f = 1.0 kHz) | 2N3903 | | 50 | 200 | |
| | 2N3904 | | 100 | 400 | |
| Output Admittance ($I_C$ = 1.0 mAdc, $V_{CE}$ = 10 Vdc, f = 1.0 kHz) | | $h_{oe}$ | 1.0 | 40 | μmhos |
| Noise Figure | | NF | | | dB |
| ($I_C$ = 100 μAdc, $V_{CE}$ = 5.0 Vdc, $R_S$ = 1.0 k Ω, f = 1.0 kHz) | 2N3903 | | – | 6.0 | |
| | 2N3904 | | – | 5.0 | |
| **SWITCHING CHARACTERISTICS** | | | | | |
| Delay Time | ($V_{CC}$ = 3.0 Vdc, $V_{BE}$ = 0.5 Vdc, $I_C$ = 10 mAdc, $I_{B1}$ = 1.0 mAdc) | $t_d$ | – | 35 | ns |
| Rise Time | | $t_r$ | – | 35 | ns |
| Storage Time | ($V_{CC}$ = 3.0 Vdc, $I_C$ = 10 mAdc, $I_{B1}$ = $I_{B2}$ = 1.0 mAdc) 2N3903 | $t_s$ | – | 175 | ns |
| | 2N3904 | | – | 200 | |
| Fall Time | | $t_f$ | – | 50 | ns |

2. Pulse Test: Pulse Width ≤ 300 μs; Duty Cycle ≤ 2%.

**ORDERING INFORMATION**

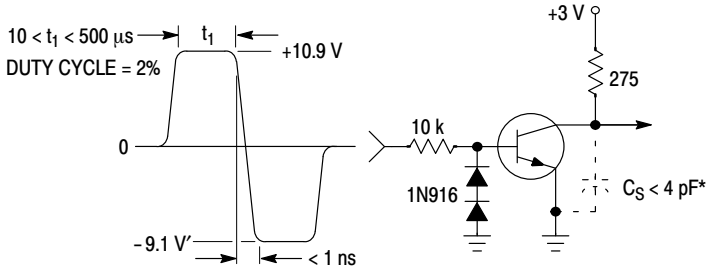
| Device | Package | Shipping† |
|---|---|---|
| 2N3903RLRM | TO−92 | 2000 / Ammo Pack |
| 2N3904 | TO−92 | 5000 Units / Bulk |
| 2N3904G | TO−92 (Pb−Free) | 5000 Units / Bulk |
| 2N3904RLRA | TO−92 | 2000 / Tape & Reel |
| 2N3904RLRAG | TO−92 (Pb−Free) | 2000 / Tape & Reel |
| 2N3904RLRM | TO−92 | 2000 / Ammo Pack |
| 2N3904RLRMG | TO−92 (Pb−Free) | 2000 / Ammo Pack |
| 2N3904RLRP | TO−92 | 2000 / Ammo Pack |
| 2N3904RLRPG | TO−92 (Pb−Free) | 2000 / Ammo Pack |
| 2N3904RL1G | TO−92 (Pb−Free) | 2000 / Tape & Reel |
| 2N3904ZL1 | TO−92 | 2000 / Ammo Pack |
| 2N3904ZL1G | TO−92 (Pb−Free) | 2000 / Ammo Pack |

†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.




* Total shunt capacitance of test jig and connectors

**Figure 1. Delay and Rise Time Equivalent Test Circuit**




* Total shunt capacitance of test jig and connectors

**Figure 2. Storage and Fall Time Equivalent Test Circuit**

## TYPICAL TRANSIENT CHARACTERISTICS

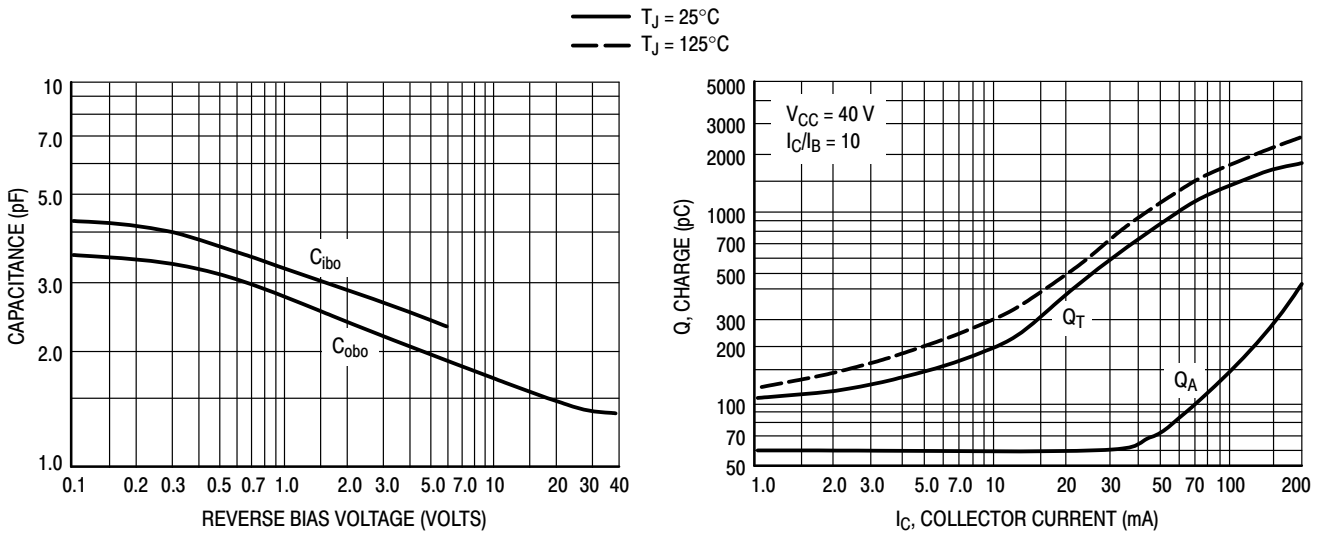



**Figure 3. Capacitance**

**Figure 4. Charge Data**

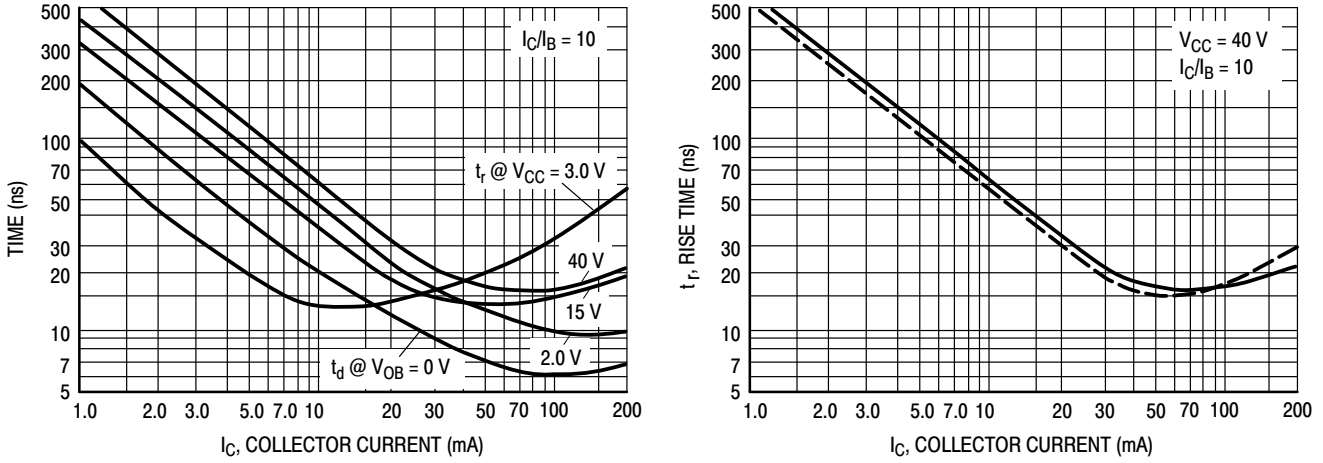



**Figure 5. Turn – On Time**

**Figure 6. Rise Time**

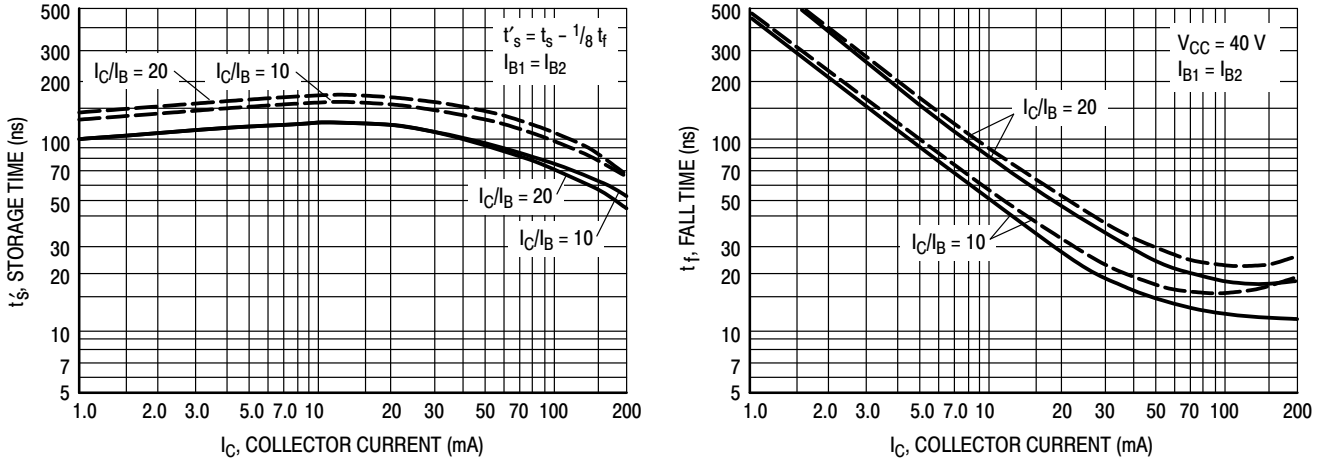



**Figure 7. Storage Time**

**Figure 8. Fall Time**

## TYPICAL AUDIO SMALL−SIGNAL CHARACTERISTICS
## NOISE FIGURE VARIATIONS

($V_{CE}$ = 5.0 Vdc, $T_A$ = 25°C, Bandwidth = 1.0 Hz)

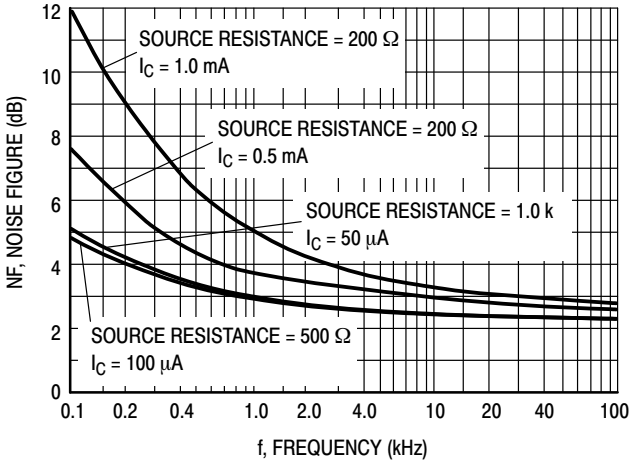



**Figure 9.**

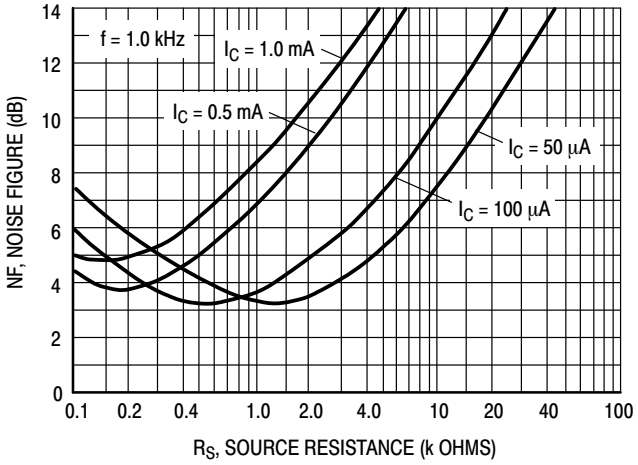



**Figure 10.**

## h PARAMETERS

($V_{CE}$ = 10 Vdc, f = 1.0 kHz, $T_A$ = 25°C)

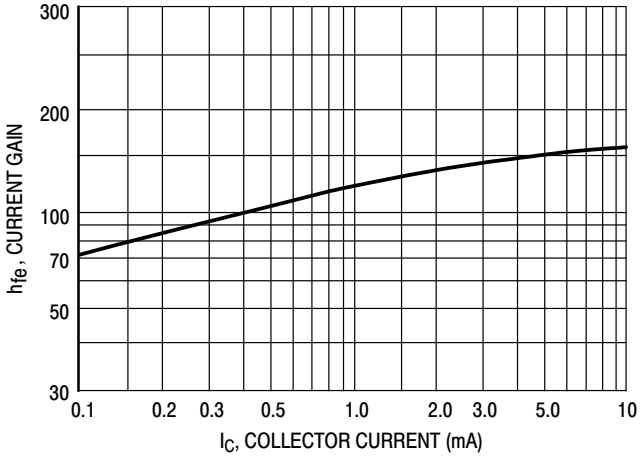



**Figure 11. Current Gain**

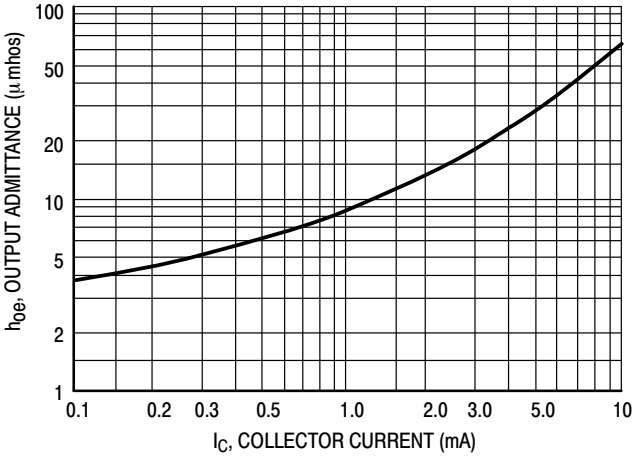



**Figure 12. Output Admittance**

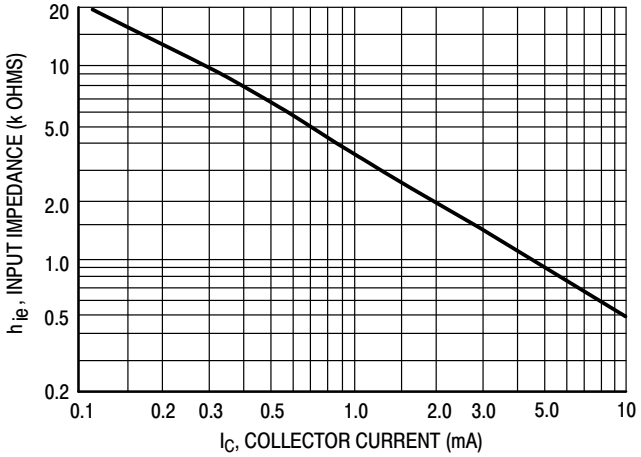



**Figure 13. Input Impedance**

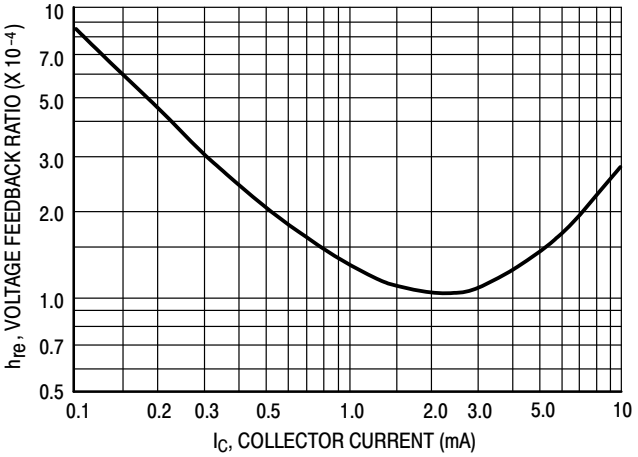



**Figure 14. Voltage Feedback Ratio**

## TYPICAL STATIC CHARACTERISTICS

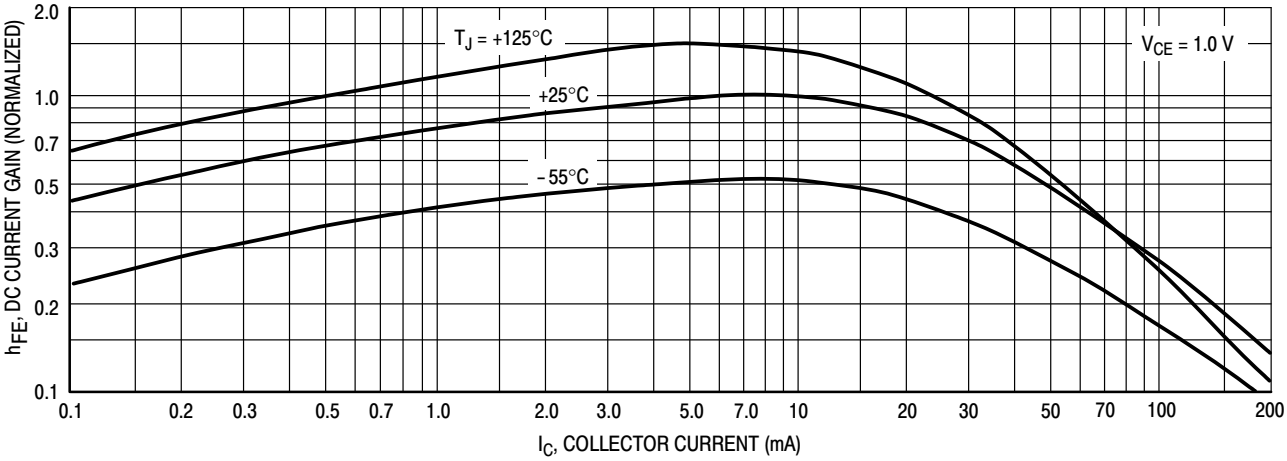



**Figure 15. DC Current Gain**

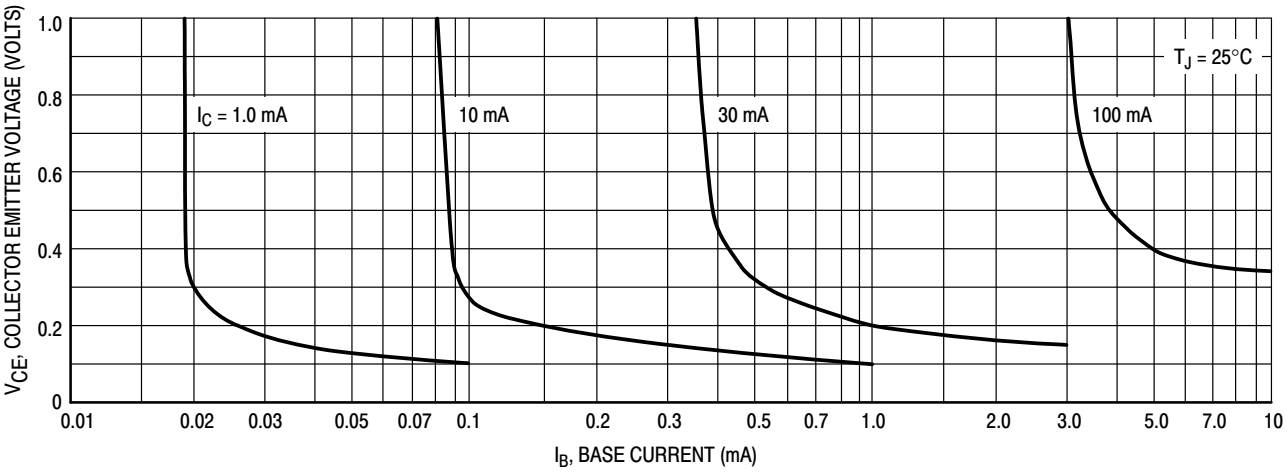



**Figure 16. Collector Saturation Region**

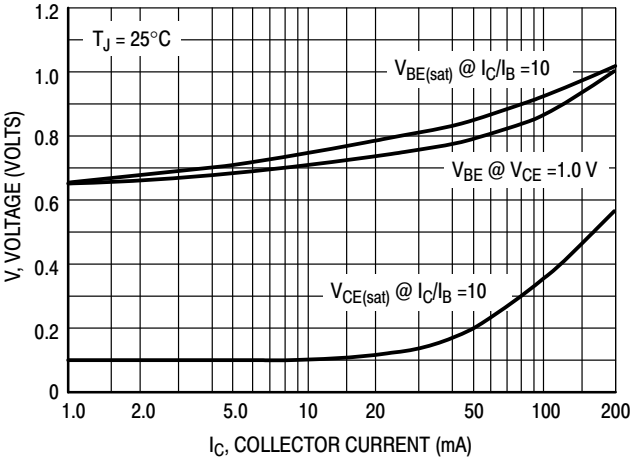



**Figure 17. “ON” Voltages**

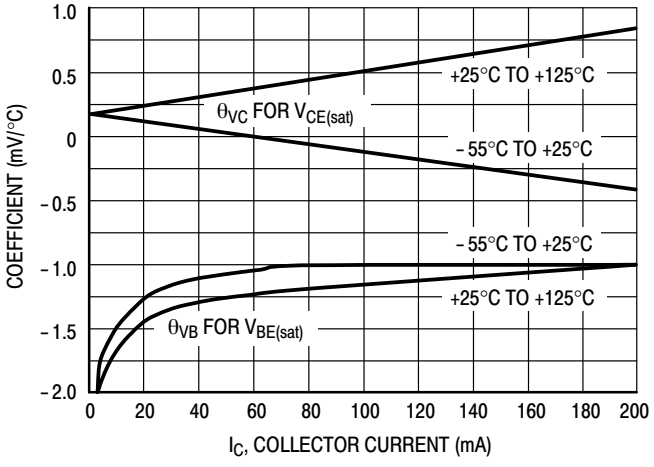



**Figure 18. Temperature Coefficients**

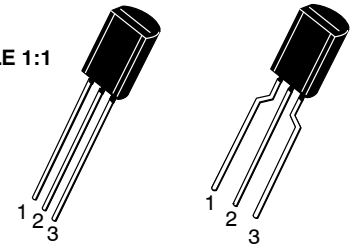
# MECHANICAL CASE OUTLINE
## PACKAGE DIMENSIONS

ON Semiconductor®

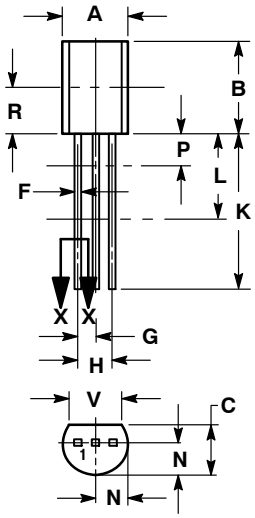
**TO−92 (TO−226) 1 WATT**
CASE 29−10
ISSUE A

DATE 08 MAY 2012

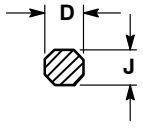
SCALE 1:1




STRAIGHT LEAD BENT LEAD



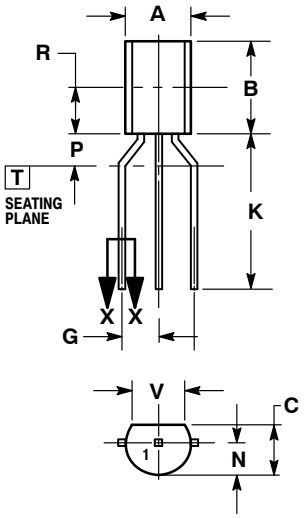

STRAIGHT LEAD



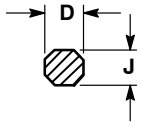

SECTION X−X

NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1994.
2. CONTROLLING DIMENSION: INCHES.
3. CONTOUR OF PACKAGE BEYOND DIMENSION R IS UNCONTROLLED.
4. DIMENSION F APPLIES BETWEEN DIMENSIONS P AND L. DIMENSIONS D AND J APPLY BETWEEN DIMENSIONS L AND K MINIMUM. THE LEAD DIMENSIONS ARE UNCONTROLLED IN DIMENSION P AND BEYOND DIMENSION K MINIMUM.

| | INCHES | | MILLIMETERS | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | 0.175 | 0.205 | 4.44 | 5.21 |
| B | 0.290 | 0.310 | 7.37 | 7.87 |
| C | 0.125 | 0.165 | 3.18 | 4.19 |
| D | 0.018 | 0.021 | 0.46 | 0.53 |
| F | 0.016 | 0.019 | 0.41 | 0.48 |
| G | 0.045 | 0.055 | 1.15 | 1.39 |
| H | 0.095 | 0.105 | 2.42 | 2.66 |
| J | 0.018 | 0.024 | 0.46 | 0.61 |
| K | 0.500 | --- | 12.70 | --- |
| L | 0.250 | --- | 6.35 | --- |
| N | 0.080 | 0.105 | 2.04 | 2.66 |
| P | --- | 0.100 | --- | 2.54 |
| R | 0.135 | --- | 3.43 | --- |
| V | 0.135 | --- | 3.43 | --- |




BENT LEAD




SECTION X−X

NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: INCHES.
3. CONTOUR OF PACKAGE BEYOND DIMENSION R IS UNCONTROLLED.
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| | INCHES | | MILLIMETERS | |
|---|---|---|---|---|
| DIM | MIN | MAX | MIN | MAX |
| A | 0.175 | 0.205 | 4.44 | 5.21 |
| B | 0.290 | 0.310 | 7.37 | 7.87 |
| C | 0.125 | 0.165 | 3.18 | 4.19 |
| D | 0.018 | 0.021 | 0.46 | 0.53 |
| G | 0.094 | 0.102 | 2.40 | 2.80 |
| J | 0.018 | 0.024 | 0.46 | 0.61 |
| K | 0.500 | --- | 12.70 | --- |
| N | 0.080 | 0.105 | 2.04 | 2.66 |
| P | --- | 0.100 | --- | 2.54 |
| R | 0.135 | --- | 3.43 | --- |
| V | 0.135 | --- | 3.43 | --- |

**STYLES ON PAGE 2**

| | | |
|---|---|---|
| **DOCUMENT NUMBER:** | **98AON52857E** | Electronic versions are uncontrolled except when accessed directly from the Document Repository. Printed versions are uncontrolled except when stamped "CONTROLLED COPY" in red. |
| **DESCRIPTION:** | **TO−92 (TO−226) 1 WATT** | **PAGE 1 OF 2** |

**TO−92 (TO−226) 1 WATT**
CASE 29−10
ISSUE A

DATE 08 MAY 2012

STYLE 1:
PIN 1. EMITTER
2. BASE
3. COLLECTOR

STYLE 2:
PIN 1. BASE
2. EMITTER
3. COLLECTOR

STYLE 3:
PIN 1. ANODE
2. ANODE
3. CATHODE

STYLE 4:
PIN 1. CATHODE
2. CATHODE
3. ANODE

STYLE 5:
PIN 1. DRAIN
2. SOURCE
3. GATE

STYLE 6:
PIN 1. GATE
2. SOURCE & SUBSTRATE
3. DRAIN

STYLE 7:
PIN 1. SOURCE
2. DRAIN
3. GATE

STYLE 8:
PIN 1. DRAIN
2. GATE
3. SOURCE & SUBSTRATE

STYLE 9:
PIN 1. BASE 1
2. EMITTER
3. BASE 2

STYLE 10:
PIN 1. CATHODE
2. GATE
3. ANODE

STYLE 11:
PIN 1. ANODE
2. CATHODE & ANODE
3. CATHODE

STYLE 12:
PIN 1. MAIN TERMINAL 1
2. GATE
3. MAIN TERMINAL 2

STYLE 13:
PIN 1. ANODE 1
2. GATE
3. CATHODE 2

STYLE 14:
PIN 1. EMITTER
2. COLLECTOR
3. BASE

STYLE 15:
PIN 1. ANODE 1
2. CATHODE
3. ANODE 2

STYLE 16:
PIN 1. ANODE
2. GATE
3. CATHODE

STYLE 17:
PIN 1. COLLECTOR
2. BASE
3. EMITTER

STYLE 18:
PIN 1. ANODE
2. CATHODE
3. NOT CONNECTED

STYLE 19:
PIN 1. GATE
2. ANODE
3. CATHODE

STYLE 20:
PIN 1. NOT CONNECTED
2. CATHODE
3. ANODE

STYLE 21:
PIN 1. COLLECTOR
2. EMITTER
3. BASE

STYLE 22:
PIN 1. SOURCE
2. GATE
3. DRAIN

STYLE 23:
PIN 1. GATE
2. SOURCE
3. DRAIN

STYLE 24:
PIN 1. EMITTER
2. COLLECTOR/ANODE
3. CATHODE

STYLE 25:
PIN 1. MT 1
2. GATE
3. MT 2

STYLE 26:
PIN 1. $V_{CC}$
2. GROUND 2
3. OUTPUT

STYLE 27:
PIN 1. MT
2. SUBSTRATE
3. MT

STYLE 28:
PIN 1. CATHODE
2. ANODE
3. GATE

STYLE 29:
PIN 1. NOT CONNECTED
2. ANODE
3. CATHODE

STYLE 30:
PIN 1. DRAIN
2. GATE
3. SOURCE

STYLE 31:
PIN 1. GATE
2. DRAIN
3. SOURCE

STYLE 32:
PIN 1. BASE
2. COLLECTOR
3. EMITTER

STYLE 33:
PIN 1. RETURN
2. INPUT
3. OUTPUT

STYLE 34:
PIN 1. INPUT
2. GROUND
3. LOGIC

STYLE 35:
PIN 1. GATE
2. COLLECTOR
3. EMITTER

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