

## PNP SILICON ANNULAR HERMETIC TRANSISTORS

... designed for high-speed switching circuits, DC to VHF amplifier applications and complementary circuitry.

- High DC Current Gain Specified — 0.1 to 500 mAdc
- High Current-Gain — Bandwidth Product —  
 $f_T = 200 \text{ MHz (Min)}$  ( $\alpha I_C = 50 \text{ mAdc}$ )
- Low Collector-Emitter Saturation Voltage —  
 $V_{CE(sat)} = 0.4 \text{ Vdc (Max)}$  ( $\alpha I_C = 150 \text{ mAdc}$ )
- 2N2904, A thru 2N2907, A Complement to NPN 2N2218, A, 2N2219, A, 2N2221, A, 2N2222, A

### MAXIMUM RATINGS

Rating	Symbol	Non-A Suffix	A-Suffix	Unit
Collector-Emitter Voltage	$V_{CEQ}$	- 40	- 60	Vdc
Collector-Base Voltage	$V_{CBQ}$	- 60	-	Vdc
Emitter-Base Voltage	$V_{EBQ}$	- 5.0	-	Vdc
Collector Current — Continuous	$I_C$	- 600	-	mAdc
		<b>2N2904,A 2N2905,A</b>	<b>2N2906,A 2N2907,A</b>	
Total Device Dissipation ( $T_A = 25^\circ\text{C}$ Derate above $25^\circ\text{C}$ )	$P_D$	600 3.43	400 2.28	mW mW/°C
Total Device Dissipation ( $T_C = 25^\circ\text{C}$ Derate above $25^\circ\text{C}$ )	$P_D$	3.0 17.2	1.2 6.85	Watts mW/°C
Operating and Storage Junction Temperature Range	$T_J, T_{stg}$	- 65 to + 200		°C

### THERMAL CHARACTERISTICS

Characteristic	Symbol	Max		Unit
		2N2904,A; 2N2905,A	2N2906,A; 2N2907,A	
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	292	438	°C/W
Thermal Resistance, Junction to Case	$R_{\theta JC}$	58	146	°C/W

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

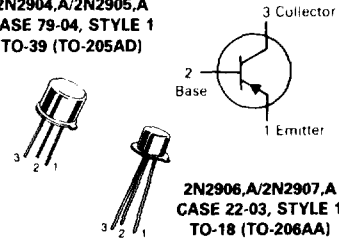
Characteristic	Symbol	Min	Typ	Max	Unit
<b>OFF CHARACTERISTICS</b>					
Collector-Emitter Breakdown Voltage(1) ( $I_C = -10 \text{ mAdc}, I_B = 0$ )	$V_{(BR)CEO}$	- 40 - 60	—	—	Vdc
Collector-Base Breakdown Voltage ( $I_C = -10 \mu\text{Adc}, I_E = 0$ )	$V_{(BR)CBO}$	- 60	—	—	Vdc
Emitter-Base Breakdown Voltage ( $I_E = -10 \mu\text{Adc}, I_C = 0$ )	$V_{(BR)EBO}$	- 5.0	—	—	Vdc
Collector Cutoff Current ( $V_{CE} = -30 \text{ Vdc}, V_{EB} = -0.5 \text{ Vdc}$ )	$I_{CEX}$	—	—	- 50	nAdc
Collector Cutoff Current ( $V_{CB} = -50 \text{ Vdc}, I_E = 0$ )	$I_{CBO}$	—	—	- 0.02 - 0.01	$\mu\text{Adc}$
( $V_{CB} = -50 \text{ Vdc}, I_E = 0, T_A = 150^\circ\text{C}$ )		—	—	- 20 - 10	
Base Current ( $V_{CE} = -30 \text{ Vdc}, V_{EB} = -0.5 \text{ Vdc}$ )	$I_B$	—	—	- 50	nAdc
<b>ON CHARACTERISTICS</b>					
DC Current Gain ( $I_C = -0.1 \text{ mAdc}, V_{CE} = -10 \text{ Vdc}$ )	$h_{FE}$	20 35 40 75	—	—	—

(1) Pulse Test: Pulse Width  $\leq 300 \mu\text{s}$ , Duty Cycle  $\leq 2.0\%$ .

(continued)

## 2N2904,A★ thru 2N2907,A★

2N2904,A/2N2905,A  
CASE 79-04, STYLE 1  
TO-39 (TO-205AD)



2N2906,A/2N2907,A  
CASE 22-03, STYLE 1  
TO-18 (TO-206AA)

### GENERAL PURPOSE TRANSISTORS

PNP SILICON

★2N2905A and 2N2907A  
are Motorola designated  
preferred devices.

## 2N2904, A THRU 2N2907, A

**ELECTRICAL CHARACTERISTICS** (continued) ( $T_A = 25^\circ\text{C}$  unless otherwise noted.)

Characteristic	Symbol	Min	Typ	Max	Unit	
<b>ON CHARACTERISTICS</b> (continued)						
DC Current Gain ( $I_C = -1.0\text{ mAdc}$ , $V_{CE} = -10\text{ Vdc}$ )	2N2904, 2N2906 2N2905, 2N2907 2N2904A, 2N2906A 2N2905A, 2N2907A	25 50 40 100	— — — —	— — — —		
( $I_C = -10\text{ mAdc}$ , $V_{CE} = -10\text{ Vdc}$ )	2N2904, 2N2906 2N2905, 2N2907 2N2904A, 2N2906A 2N2905A, 2N2907A	35 75 40 100	— — — —	— — — —		
( $I_C = -150\text{ mAdc}$ , $V_{CE} = -10\text{ Vdc}$ )(1)	2N2904,A, 2N2906,A 2N2905,A, 2N2907,A	40 100	— —	120 300		
( $I_C = -500\text{ mAdc}$ , $V_{CE} = -10\text{ Vdc}$ )(1)	2N2904, 2N2906 2N2905, 2N2907 2N2904A, 2N2906A 2N2905A, 2N2907A	20 30 40 50	— — — —	— — — —		
Collector-Emitter Saturation Voltage(1) ( $I_C = -150\text{ mAdc}$ , $I_B = -15\text{ mAdc}$ ) ( $I_C = -500\text{ mAdc}$ , $I_B = -50\text{ mAdc}$ )	$V_{CE(sat)}$	— —	— —	-0.4 -1.6	Vdc	
Base-Emitter Saturation Voltage ( $I_C = -150\text{ mAdc}$ , $I_B = -15\text{ mAdc}$ )(1) ( $I_C = -500\text{ mAdc}$ , $I_B = -50\text{ mAdc}$ )(1)	$V_{BE(sat)}$	— —	— —	-1.3 -2.6	Vdc	
<b>DYNAMIC CHARACTERISTICS</b>						
Current-Gain — Bandwidth Product(2) ( $I_C = -50\text{ mAdc}$ , $V_{CE} = -20\text{ Vdc}$ , $f = 100\text{ MHz}$ )	$f_T$	200	—	—	MHz	
Output Capacitance ( $V_{CB} = -10\text{ Vdc}$ , $I_E = 0$ , $f = 1.0\text{ MHz}$ )	$C_{ob}$	—	—	8.0	pF	
Input Capacitance ( $V_{EB} = -2.0\text{ Vdc}$ , $I_C = 0$ , $f = 1.0\text{ MHz}$ )	$C_{ib}$	—	—	30	pF	
<b>SWITCHING CHARACTERISTICS</b>						
Turn-On Time	$(V_{CC} = -30\text{ Vdc}$ , $I_C = -150\text{ mAdc}$ , $I_{B1} = -15\text{ mAdc}$ ) (Figure 15a)	$t_{on}$	—	26	45	ns
Delay Time		$t_d$	—	6.0	10	
Rise Time		$t_r$	—	20	40	
Turn-Off Time	$(V_{CC} = -6.0\text{ Vdc}$ , $I_C = 150\text{ mAdc}$ , $I_{B1} = I_{B2} = -15\text{ mAdc}$ ) (Figure 15b)	$t_{off}$	—	70	100	ns
Storage Time		$t_s$	—	50	80	
Fall Time		$t_f$	—	20	30	

(1) Pulse Test: Pulse Width  $\leq 300\ \mu\text{s}$ , Duty Cycle  $\leq 2.0\%$ .

(2)  $f_T$  is defined as the frequency at which  $|h_{fe}|$  extrapolates to unity.

FIGURE 1 — NORMALIZED DC CURRENT GAIN

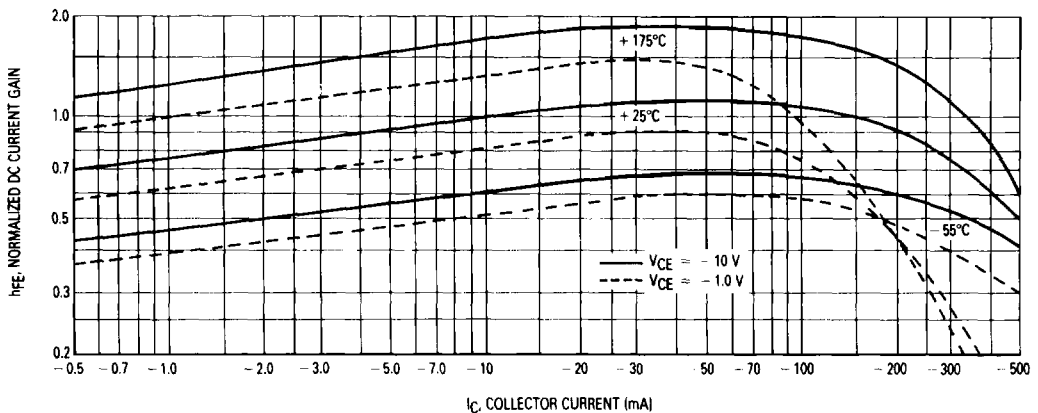
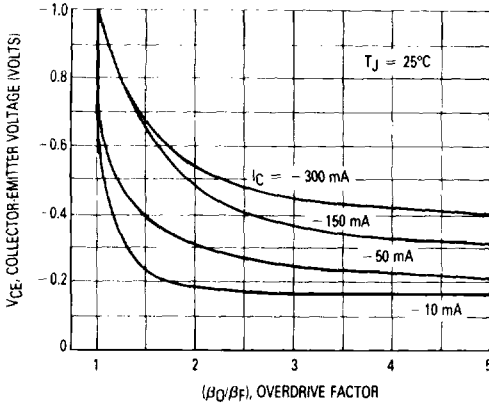


FIGURE 2 - NORMALIZED COLLECTOR SATURATION REGION



This graph shows the effect of base current on collector current.  $\beta_0$  (current gain at edge of saturation) is the current gain of the transistor at 1 volt, and  $\beta_f$  (forced gain) is the ratio of  $I_C/I_{BF}$  in a circuit.

EXAMPLE: For type 2N2905, estimate a base current ( $I_{BF}$ ) to insure saturation at a temperature of 25°C and a collector current of 150 mA.

Observe that at  $I_C = 150$  mA an overdrive factor of at least 3 is required to drive the transistor well into the saturation region. From Figure 1, it is seen that  $h_{FE}$  @ 1 volt is approximately 0.60 of  $h_{FE}$  @ 10 volts. Using the guaranteed minimum of 100 @ 150 mA and 10 V,  $\beta_0 = 60$  and substituting values in the overdrive equation, we find:

$$\frac{\beta_0}{\beta_f} = \frac{h_{FE} @ 1 V}{I_C/I_{BF}} \quad 3 = \frac{60}{150/I_{BF}} \quad I_{BF} \approx 7.5 \text{ mA}$$

FIGURE 3 - "ON" VOLTAGES

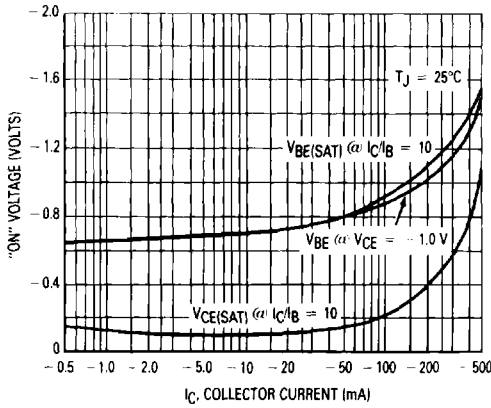
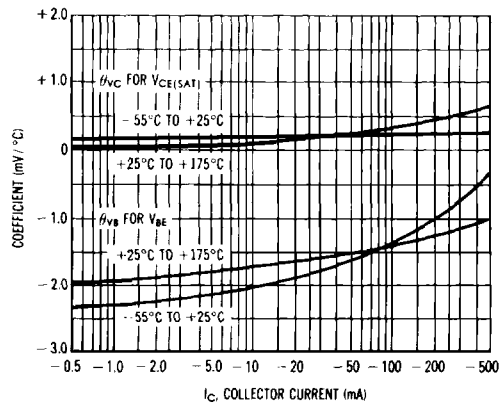


FIGURE 4 - TEMPERATURE COEFFICIENTS



SMALL-SIGNAL CHARACTERISTICS  
NOISE FIGURE

V<sub>CE</sub> = 10 V, T<sub>A</sub> = 25°C

FIGURE 5 - FREQUENCY EFFECTS

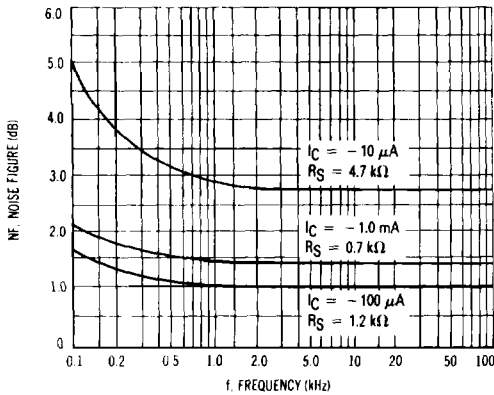
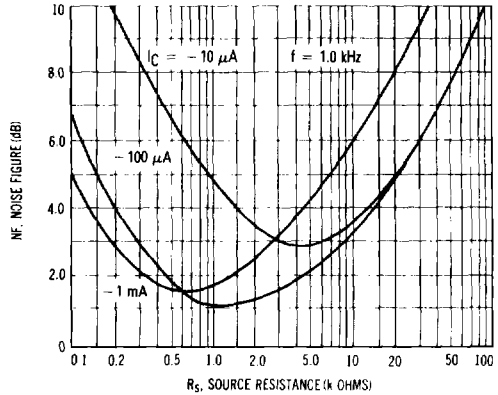


FIGURE 6 - SOURCE RESISTANCE EFFECTS



# 2N2904, A THRU 2N2907, A

## h PARAMETERS

$V_{CE} = 10 \text{ Vdc}$ ,  $f = 1.0 \text{ kHz}$ ,  $T_A = 25^\circ\text{C}$

This group of graphs illustrates the relationship between  $h_{fe}$  and other "h" parameters for this series of transistors. To obtain these curves, a high-gain and a low-gain unit were selected and the same units were used to develop the correspondingly numbered curves on each graph.

FIGURE 7 - INPUT IMPEDANCE

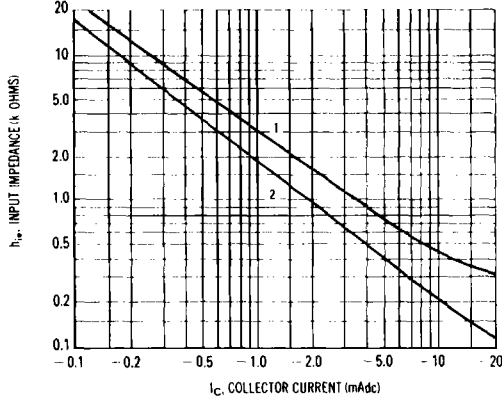


FIGURE 8 - VOLTAGE FEEDBACK RATIO

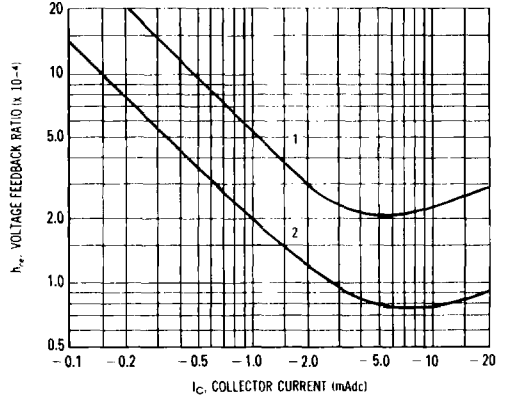


FIGURE 9 - CURRENT GAIN

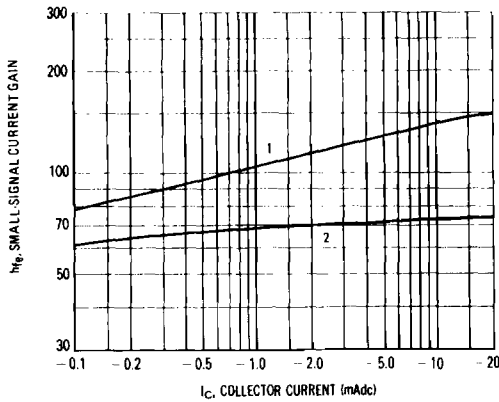


FIGURE 10 - OUTPUT ADMITTANCE

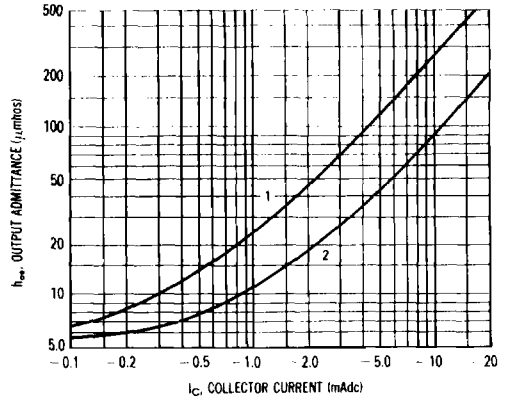


FIGURE 11 - TURN ON TIME

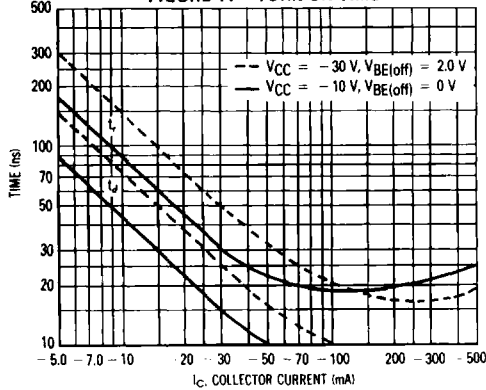


FIGURE 12 - CHARGE DATA

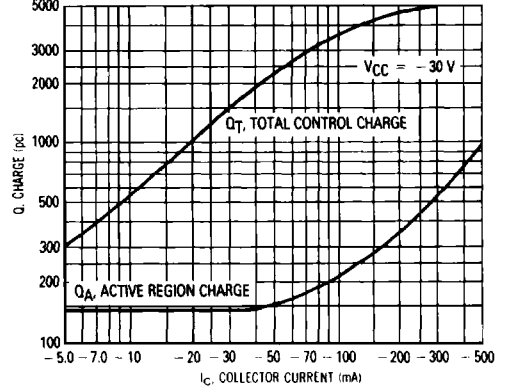


FIGURE 13 - STORAGE TIME

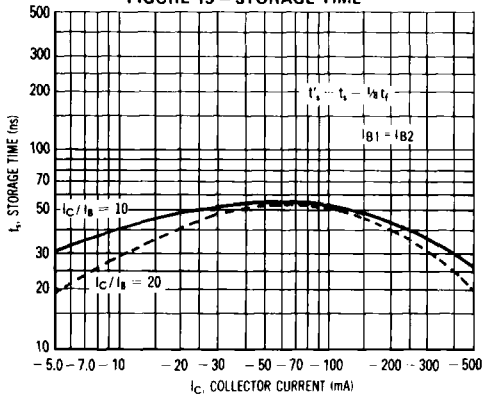


FIGURE 14 - FALL TIME

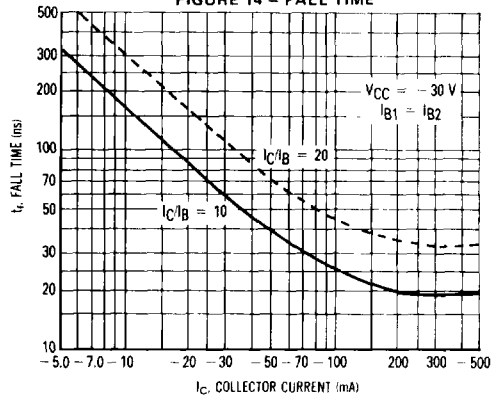


FIGURE 15a - DELAY AND RISE TIME TEST CIRCUIT

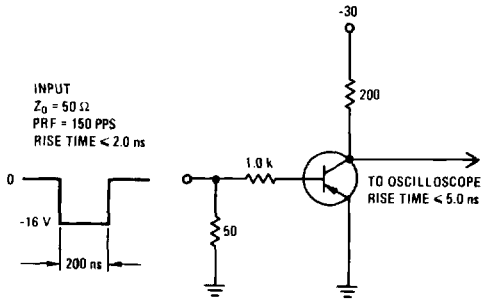


FIGURE 15b - STORAGE AND FALL TIME TEST CIRCUIT

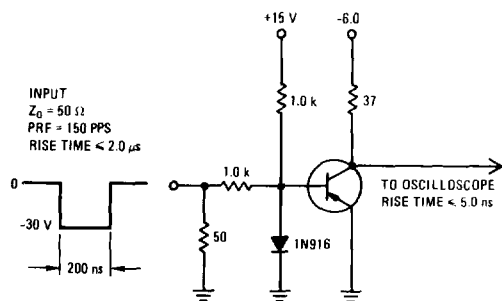


FIGURE 16 - CURRENT-GAIN-BANDWIDTH PRODUCT

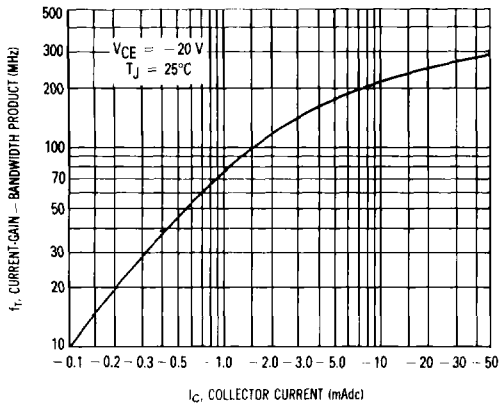
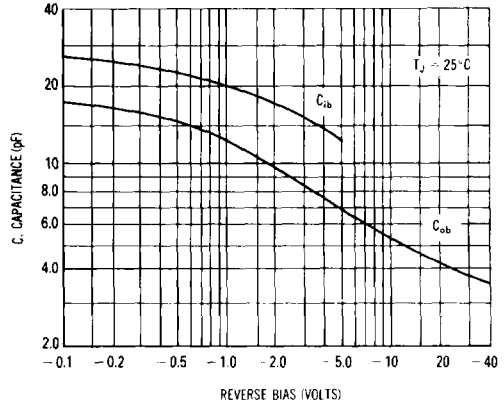
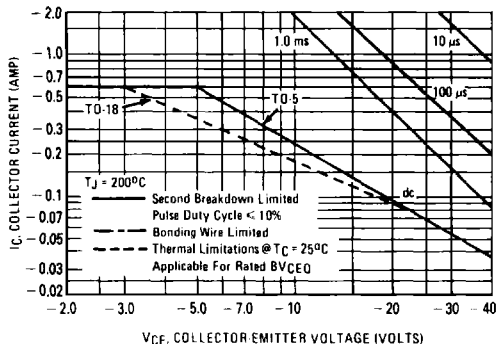


FIGURE 17 - CAPACITANCES



**2N2904, A THRU 2N2907, A**

**FIGURE 18 – ACTIVE REGION SAFE OPERATING AREAS**



This graph shows the maximum  $I_C$ - $V_{CE}$  limits of the device both from the standpoint of thermal dissipation (at  $25^\circ\text{C}$  case temperature), and secondary breakdown. For case temperatures other than  $25^\circ\text{C}$ , the thermal dissipation curve must be modified in accordance with the derating factor in the Maximum Ratings table.

To avoid possible device failure, the collector load line must fall below the limits indicated by the applicable curve. Thus, for certain operating conditions the device is thermally limited, and for others it is limited by secondary breakdown.

For pulse applications, the maximum  $I_C$ - $V_{CE}$  product indicated by the dc thermal limits can be exceeded. Pulse thermal limits may be calculated by using the transient thermal resistance curve of Figure 19.

**FIGURE 19 – THERMAL RESISTANCE**

