RCA SILICON CONTROLLED-RECTIFIERS

ALL-DIFFUSED SCR's FOR LOW-COST POWER-CONTROL AND POWER-SWITCHING APPLICATIONS

2N3228
2N3525
2N4101
2N3528
2N3529
2N4102

RCA 2N3228*, 2N3525*, 2N4101*, and 2N3528●, 2N3529●, and 2N4102● are all-diffused, three-junction, silicon controlled-rectifiers (SCR's▲) intended for use in power-control and power-switching applications.

Types 2N3228, 2N3525, and 2N4101 use the JEDEC TO-66 package and have a blocking voltage capability of up to 600 volts and a forward current rating of 5 amperes (rms value) at a case temperature of 75°C.

Types 2N3528, 2N3529, and 2N4102 use the JEDEC TO-8 package and have a blocking voltage capability of up to 600 volts and a forward current rating of 2 amperes (rms value) at an ambient temperature of 25°C.

* Formerly Dev. Types TA1222, TA1225, and TA2773, respectively.

● Formerly Dev. Types TA2597, TA2617, and TA2774, respectively.

▲ The silicon controlled-rectifier is also known as a reverse-blocking triode thyristor.

JEDEC No. TO-66

2N3228
2N3525
2N4101

JEDEC No. TO-8

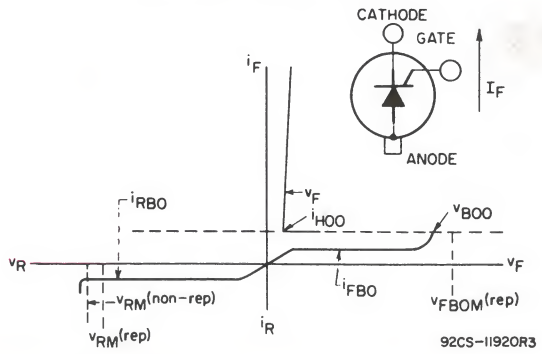
2N3528
2N3529
2N4102

Current → / Voltage ↓	Average Forward Amperes 3.2	Average Forward Amperes 1.3
For 120–Volt Line Operation	2N3228	2N3528
For 240–Volt Line Operation	2N3525	2N3529
For High–Voltage Power Supplies	2N4101	2N4102

FEATURES

- Designed especially for high-volume systems
- Readily adaptable for printed-circuit boards and metal heat sinks
- Low switching losses
- High di/dt and dv/dt capabilities
- Integral-resistance construction
- Forward and reverse gate dissipation ratings
- All-diffused construction – assures exceptional uniformity and stability of characteristics
- Direct-soldered internal construction – assures exceptional resistance to fatigue
- Symmetrical gate-cathode construction – provides uniform current density, rapid electrical conduction, and efficient heat dissipation
- All-welded construction and hermetic sealing
- Low leakage currents, both forward and reverse
- Low forward voltage drop at high current levels
- Low thermal resistance

TYPICAL E-I CHARACTERISTIC OF SILICON CONTROLLED-RECTIFIER



RADIO CORPORATION OF AMERICA
Electronic Components and Devices Harrison, N. J.

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Marca(s) Registrada(s)

2N3228 2-66
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Printed in U.S.A.

Absolute-Maximum Ratings, for Operation with Sinusoidal AC Supply Voltage at a Frequency between 50 and 400 Hz, and with Resistive or Inductive Load

RATINGS	CONTROLLED-RECTIFIER TYPES						UNITS
	2N3228	2N3525	2N4101	2N3528	2N3529	2N4102	
Transient Peak Reverse Voltage (Non-Repetitive), $v_{RM(non\text{-}rep)}$[a]	330	660	700	330	660	700	volts
Peak Reverse Voltage (Repetitive), $v_{RM(rep)}$[b]	200	400	600	200	400	600	volts
Peak Forward Blocking Voltage (Repetitive), $v_{FBOM(rep)}$[c]	600	600	700	600	600	700	volts
Forward Current:							
For case temperature (T_C) of + 75°C, and unit mounted on heat sink–							
Average DC value at a conduction angle of 180°, I_{FAV}[d]	3.2	3.2	3.2	—	—	—	amperes
RMS value, I_{FRMS}[e]	5.0	5.0	5.0	—	—	—	amperes
For other conditions, See Fig. 8							
For free-air temperature (T_{FA}) of 25°C, and with no heat sink employed–							
Average DC value at a conduction angle of 180°, I_{FAV}[d]	—	—	—	1.3	1.3	1.3	amperes
RMS value, I_{FRMS}[e]	—	—	—	2.0	2.0	2.0	amperes
For other conditions, See Fig. 9.							
Peak Surge Current, $i_{FM(surge)}$[f]:							
For one cycle of applied voltage	60			60			amperes
For more than one cycle of applied voltage.	See Fig. 13			See Fig. 13			
Sub-Cycle Surge (Non-Repetitive) I^2t[g]							
For a period of 1 ms to 8.3 ms	15			15			$ampere^2$ second
Rate of Change of Forward Current, di/dt[h]	200			200			amperes/ microsecond
V_{FB} = v_{BOO} (min. value) I_{GT} = 200 mA, 0.5 μs rise time (See waveshapes of Fig. 1)							
Gate Power*:							
Peak, Forward or Reverse, for 10 μs duration, P_{GM}[i] (See Figs. 5 and 6)	13			13			watts
Average, P_{GAV}[k]	0.5			0.5			watt
Temperature:							
Storage, T_{stg}	−40 to +125			−40 to +125			°C
Operating (Case), T_C	−40 to +100			−40 to +100			°C

*Any values of peak gate current or peak gate voltage to give the maximum gate power is permissible.

WAVESHAPE OF di/dt RATING TEST

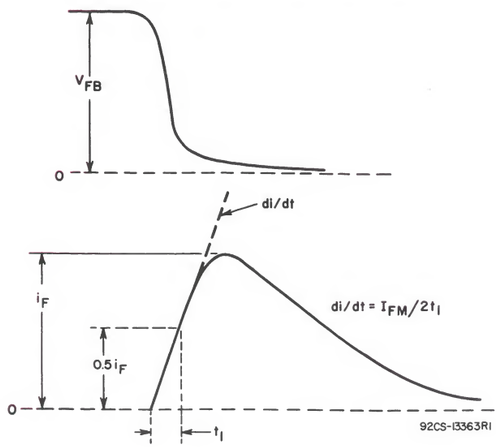


Fig. 1

WAVESHAPE OF CRITICAL dv/dt RATING TEST

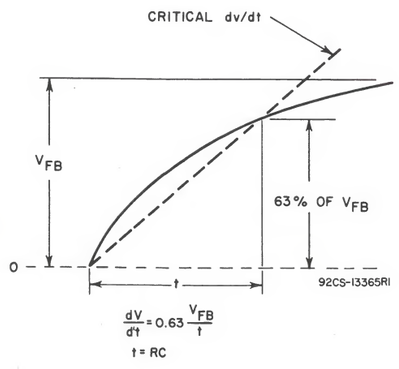


Fig. 2

Characteristics at Maximum Ratings (unless otherwise specified), and at Indicated Case Temperature (T_C)

CHARACTERISTICS	2N3228, 2N3528			2N3525, 2N3529			2N4101, 2N4102			UNITS
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.	
Forward Breakover Voltage, v_{BOO}[m]: At T_C = +100°C	200	—	—	400	—	—	600	—	—	volts
Peak Blocking Current, at T_C = +100°C:										
Forward, I_{FBOM}[n]	—	0.10	1.5	—	0.20	3.0	—	0.40	4.0	mA
V_{FBO}[p] = v_{BOO} (min. value)										
Reverse, I_{RBOM}[q]	—	0.05	0.75	—	0.10	1.5	—	0.20	2.0	mA
V_{RBO}[p] = $v_{RM(rep)}$ value										
Forward Voltage Drop, v_{Fr} At a Forward Current of 30 amperes and a T_C = +25°C (See Fig. 11)	—	2.15	2.8	—	2.15	2.8	—	2.15	2.8	volts
DC Gate-Trigger Current, I_{GT}[s]										
At T_C = +25°C (See Fig. 5)	—	8	15	—	8	15	—	8	15	mA(dc)
Gate-Trigger Voltage, V_{GT}[t]										
At T_C = +25°C (See Fig. 5)	—	1.2	2.0	—	1.2	2.0	—	1.2	2.0	volts(dc)
Holding Current, i_{HOO}[u] At T_C = +25°C	—	10	20	—	10	20	—	10	20	mA
Critical Rate of Applied Forward Voltage, Critical dv/dt[v]	10	200	—	10	200	—	10	200	—	volts/ microsecond
V_{FB} = v_{BOO} (min. value), exponential rise, T_C = +100°C (See waveshape of Fig. 2)										
Turn-On Time, t_{on}[w], (Delay Time + Rise Time)	0.75	1.5	—	0.75	1.5	—	0.75	1.5	—	microseconds
V_{FB} = v_{BOO} (min. value), i_F = 4.5 amperes, I_{GT} = 200 mA, 0.1 μs rise time, T_C = +25°C (See waveshapes of Fig. 3)										
Turn-Off Time, t_{off}[x], (Reverse Recovery Time + Gate Recovery Time)	—	15	50	—	15	50	—	15	50	microseconds
i_F = 2 amperes, 50 μs pulse width, dv_{FB}/dt = 20 v/μs, di_r/dt = 30 A/μs, I_{GT} = 200 mA, T_C = +75°C (See waveshapes of Fig. 4)										

	2N3228, 2N3525, 2N4101			2N3528, 2N3529, 2N4102			
	Min.	Typ.	Max.	Min.	Typ.	Max.	
Thermal Resistance:							
Junction-to-case	—	—	4	—	—	—	°C/W
Junction-to-ambient	—	—	—	—	—	40	°C/W

WAVESHAPE OF t_{on} RATING TEST

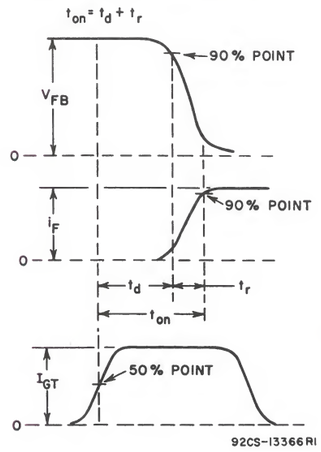


Fig. 3

WAVESHAPE OF t_{off} RATING TEST

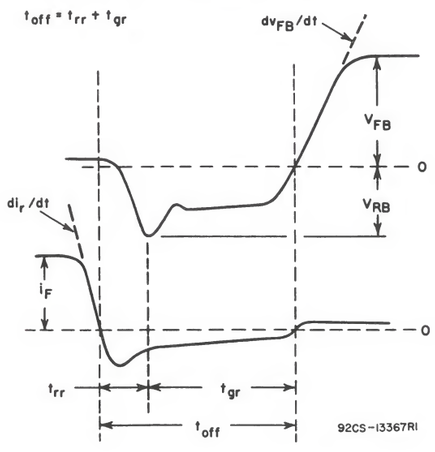


Fig. 4

FORWARD GATE CHARACTERISTICS

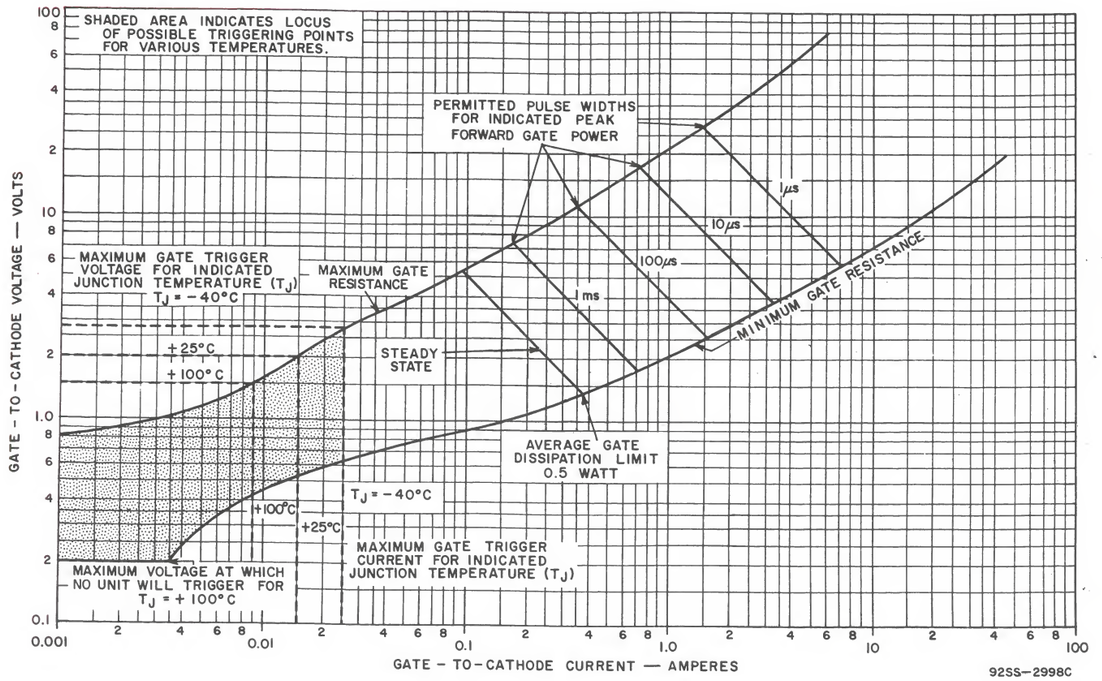


Fig. 5

REVERSE GATE CHARACTERISTICS

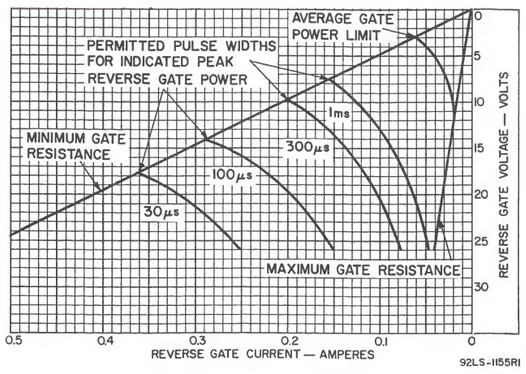


Fig. 6

TRIGGERING CONSIDERATIONS

The construction of the gate-cathode junction used in these devices provides a large periphery center gate. These devices also employ integral-resistance construction which removes restrictions on both forward and reverse peak gate voltage and peak gate current. Limiting values of volt-ampere products for different gate pulse widths are shown in Fig. 5. These limits should be adhered to when designing pulse trigger circuits for maximum trigger pulse widths and peak power dissipation. The volt-ampere products in the reverse direction shown in Fig. 6 should be used to determine limitations for reverse gate transients or reverse gate pulses if present. In all cases, total average gate dissipation, both forward and reverse, should not exceed the average gate dissipation rating (P_{GAV}) of 0.5 watt.

Turn-on times for different gate currents are shown in Fig. 7. These curves may be used to determine the required width of the gate trigger pulses. It is only necessary to maintain the gate trigger pulse until the magnitude of the forward anode current has reached the latching current value. However, conservative design requires that the gate trigger pulse width be at least equal to or somewhat greater than the device turn-on time. Some applications may require wider gate pulse widths for proper circuit operation. Additional information on gate characteristics and triggering requirements for use in pulse applications are contained in RCA Application Note, SMA-39, "Gate Parameters of RCA SCR's for Trigger Circuit Design".

TURN-ON TIME CHARACTERISTICS

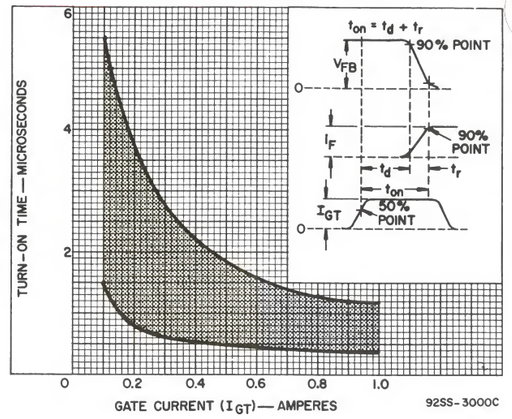


Fig. 7

RATING CHART (CASE TEMPERATURE) FOR TYPES 2N3228, 2N3525, AND 2N4101

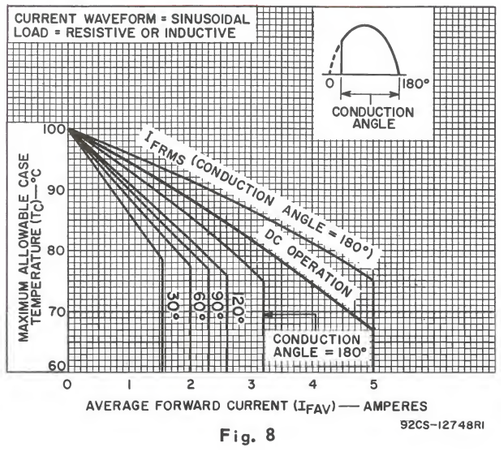


Fig. 8

RATING CHART (FREE-AIR TEMPERATURE) FOR TYPES 2N3528, 2N3529, AND 2N4102

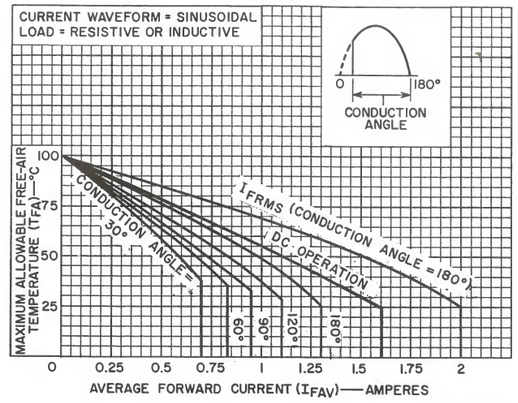


Fig. 9

POWER DISSIPATION CHART FOR ALL TYPES

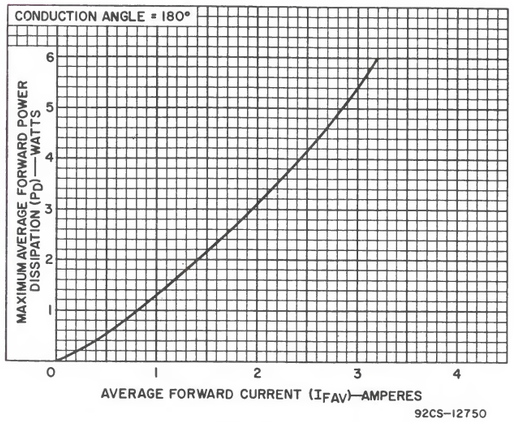


Fig. 10

FORWARD CHARACTERISTICS FOR ALL TYPES

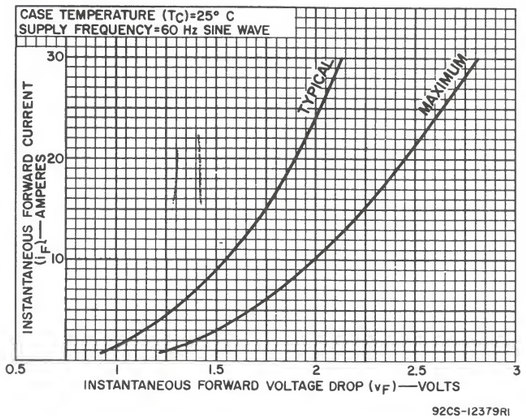


Fig. 11

OPERATION GUIDANCE CHART FOR TYPES 2N3228, 2N3525, AND 2N4101

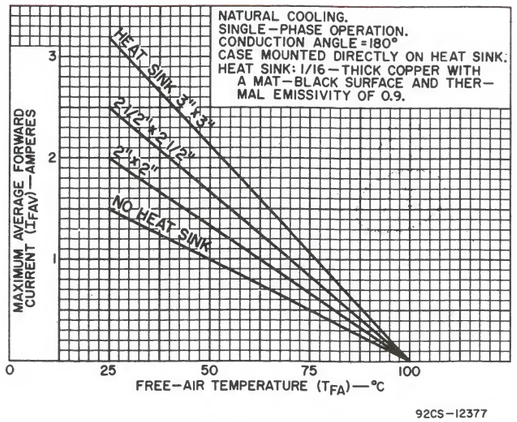


Fig. 12

SURGE CURRENT RATING CHART

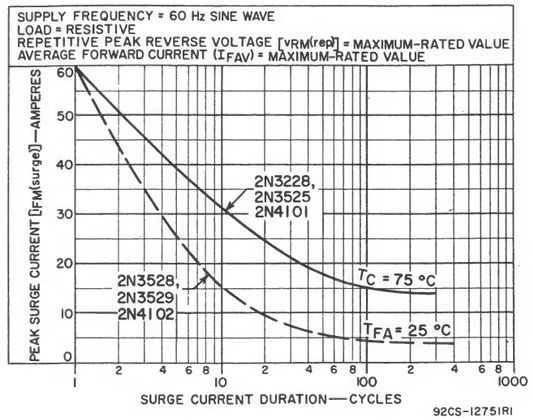


Fig. 13

CONTROLLED-RECTIFIER TERMS, SYMBOLS, AND DEFINITIONS

a **Transient Peak Reverse Voltage (Non-repetitive)** - v_{RM} (non-rep) - The maximum value of negative (reverse-blocking) voltage which may be applied between the anode and cathode for not more than 5 milliseconds when the gate is open (gate voltage is zero or negative with respect to cathode).

b **Peak Reverse Voltage (Repetitive)** - $v_{RM(rep)}$ - The maximum instantaneous value of negative (reverse-blocking) voltage which may be applied repetitively between the anode and cathode when the gate is open.

c **Peak Forward Blocking Voltage (Repetitive)** - $v_{FBOM(rep)}$ - The maximum instantaneous value of positive (forward-blocking) voltage which may be applied repetitively between the anode and cathode when the gate is open.

d **Average Forward Current** - I_{FAV} - The average (dc) value of the current flowing from anode to cathode in the device.

e **RMS Forward Current** - I_{FRMS} - The RMS value of the current flowing from anode to cathode in the device.

f **Peak Surge Current** - $i_{FM(surge)}$ - The maximum total instantaneous value of forward current which may be imposed during one forward half-cycle with the device operating within its specified maximum voltage, average-forward-current, gate-power, and temperature ratings in a single-phase circuit with 60-Hz supply and resistive load. The peak surge current may be repeated after sufficient time has elapsed for the device to return to pre-surge thermal equilibrium conditions.

g **Sub-Cycle Surge (Non-Repetitive)** I^2t - The non-recurrent surge capability of the device for sub-cycle pulses where I is RMS amperes and t is pulse duration in seconds.

h **Rate of Change of Forward Current** - di/dt - The maximum rate of change of current which may be imposed on the device immediately after turn on by the gate from a forward blocking condition.

i **Peak Forward and Reverse Gate Power** - P_{GM} - The maximum instantaneous power dissipated between gate and cathode for a specified time duration.

k **Average Forward Gate Power** - P_{GAV} - The average power dissipated between gate and cathode.

m **Forward Breakover Voltage** - v_{BOO} - The value of positive anode voltage at which a controlled rectifier may switch into the conducting state when the gate is open.

n **Peak Forward Blocking Current** - I_{FBOM} - The maximum value of the forward blocking current of a controlled rectifier with gate open.

p **Forward and Reverse Blocking Voltage** - V_{FBO}, V_{RBO} - The value of voltage applied between anode and cathode with the gate open.

q **Peak Reverse Blocking Current** - I_{RBOM} - The maximum value of the reverse blocking current of a controlled rectifier with gate open.

r **Forward Voltage Drop** - v_F - The instantaneous voltage drop across a controlled rectifier at a given instantaneous forward current i_F and under steady-state conditions.

s **Gate-Trigger Current** - I_{GT} - The gate current required to trigger a controlled rectifier operating at a specified temperature when the anode is at a potential of +6 volts with respect to the cathode.

t **Gate-Trigger Voltage** - V_{GT} - The gate-to-cathode voltage required to trigger a controlled rectifier operating at a specified temperature when the anode is at a potential of +6 volts with respect to the cathode.

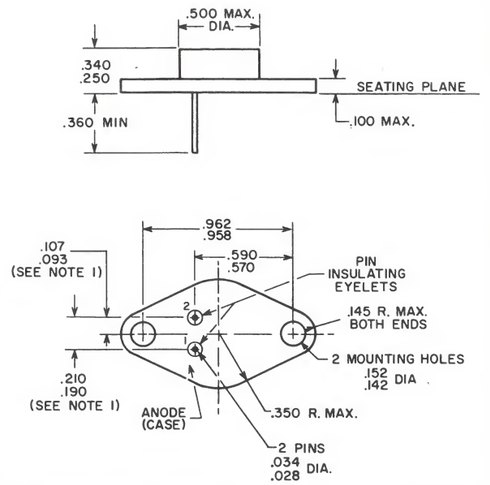
u **Holding Current** - i_{HOO} - The instantaneous value of forward current i_F below which a controlled rectifier with its gate open returns to its forward blocking state.

v **Critical Rate of Applied Forward Voltage** - Critical dv/dt - The critical rate of applied forward voltage is the minimum value of the rate of applied forward voltage which will cause switching from the off-state to the on-state under stated conditions.

w **Turn-On Time** - t_{on} - Turn-on time is the time interval between the initiation of the gate signal and the time when the resulting forward current reaches 90 per cent of its maximum value during switching from the off-state to the on-state under stated conditions.

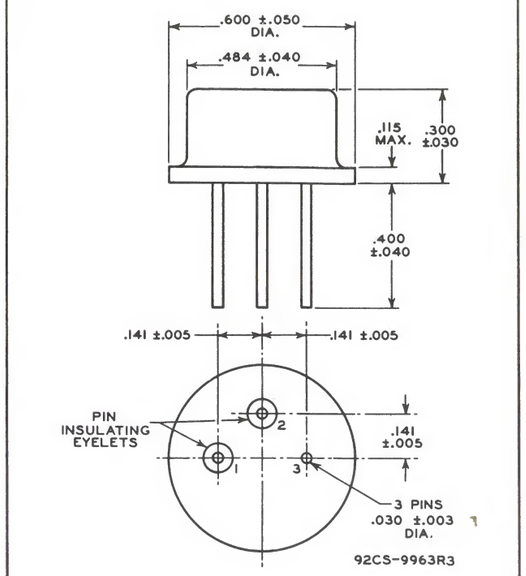
x **Turn-Off Time** - t_{off} - Turn-off time is the time interval between the time when the forward current decreases to zero and the time when the device anode voltage reaches zero and is rising to a stated value of forward blocking voltage at a stated rate of rise without turning on during switching in the external anode circuit from the on-state to the off-state under stated conditions.

DIMENSIONAL OUTLINE FOR TYPES 2N3228, 2N3525, AND 2N4101 JEDEC No. TO-66

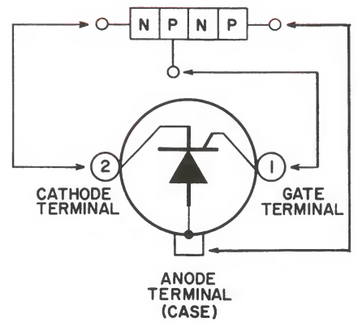


NOTE 1: THESE DIMENSIONS SHOULD BE MEASURED AT POINTS .050 TO .055 BELOW SEATING PLANE. WHEN GAUGE IS NOT USED, MEASUREMENT MENT WILL BE MADE AT SEATING PLANE.

DIMENSIONAL OUTLINE FOR TYPES 2N3528, 2N3529, AND 2N4102 JEDEC No. TO-8

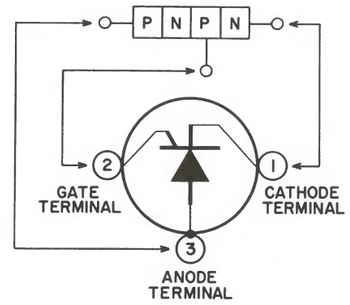


TERMINAL DIAGRAM FOR TYPES 2N3228, 2N3525, AND 2N4101



PIN 1: GATE
PIN 2: CATHODE
CASE: ANODE

TERMINAL DIAGRAM FOR TYPES 2N3528, 2N3529, AND 2N4102



PIN 1: CATHODE
PIN 2: GATE
PIN 3: ANODE (CONNECTED TO CASE)


RCA