3N128, 3N143

Silicon MOS Transistors N-Channel Depletion Types

For Amplifier, Mixer, & Oscillator Applications in Military & Industrial VHF Communications Equipment Operating up to 250 MHz

RCA-3N128 and 3N143 are N-channel depletion-type silicon insulated-gate field-effect transistors utilizing the MOS* construction. The 3N128 is intended primarily for VHF amplifier service in military and industrial applications. It also is extremely well suited for use in dc and low-frequency amplifier applications requiring a transistor having high power gain, very high input impedance, and low gate leakage.

The 3N143 is designed for use as a VHF mixer and oscillator. Because of their improved transfer characteristic and increased dynamic range the 3N128 and 3N143 provide substantially better cross-modulation performance in linear amplifier applications than conventional (bipolar) transistors and are free from diode-current loading common to junction type FET's. These transistors are hermetically sealed in JEDEC TO-72 metal packages.

Maximum Ratings, *Absolute-Maximum Values at T_A = 25° C:*

*DRAIN-TO-SOURCE VOLTAGE, V_{DS}	+20	V
*DRAIN-TO-GATE VOLTAGE, V_{DG}	+20	V
*GATE-TO-SOURCE VOLTAGE, V_{GS}:		
Continuous dc	+1, -8	V
Peak ac	±15	V
*DRAIN CURRENT, I_D	50	mA
*TRANSISTOR DISSIPATION, P_T:		
At Ambient up to 25°C	330	mW
Temperatures above 25°	Derate 2.2	mW/°C
*AMBIENT TEMPERATURE RANGE:		
Storage and Operating	-65 to +175	°C
*LEAD TEMPERATURE (During soldering):		
At distances not closer than 1/32 inch to seating surface for 10 seconds maximum	265	°C

*In accordance with Jedec Registration Data Format JS9-RDF11B.

Performance Features

- Large dynamic range
- Greatly reduces spurious responses in rceiver front ends
- Permits use of vacuum-tube biasing techniques
- Excellent thermal stability
- Superior crossmodulation capability

Device Features

- Low noise figure (3N128) – 3.5 dB typ. at 200 MHz
- High VHF amplifier gain (3N128) – 16 dB typ. at 200 MHz
- Low input capacitance – 5.5 pF typ.
- High transconductance – 7500 μmho typ.
- High input resistance – 10^{14} Ω typ.
- High conversion gain (3N143, mixer) – 13.5 dB typ. at 200 MHz

Applications

- VHF amplifiers, mixers, converters and if-amplifiers in communication receivers.
- High-impedance timing circuits
- Detectors, oscillators, frequency multipliers, phase splitters, pulse stretchers and current limiters
- Electrometer amplifiers
- Voltage-controlled attenuators
- High impedance differential amplifiers

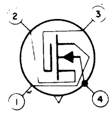
ELECTRICAL CHARACTERISTICS: *(At T_A = 25° C)*

Measured with Substrate Connected to Source Unless Otherwise Specified.

	CHARACTERISTIC	SYMBOL	CONDITIONS	3N128 MIN.	3N128 TYP.	3N128 MAX.	3N143 MIN.	3N143 TYP.	3N143 MAX.	UNITS
*	Gate Leakage Current	I_{GSS}	V_{DS} = 0, V_{GS} = -8 V T_A = 25°C	–	0.1	50	–	0.1	1000	pA
			V_{DS} = 0, V_{GS} = -8 V T_A = 125°C	–	–	5	–	–	200	nA
*	Zero-Bias Drain Current	I_{DSS}	V_{DS} = 15 V, V_{GS} = 0	5	15	25	5	15	30	mA
*	Drain-to-Source Cutoff Current	$I_{D(off)}$	V_{DS} = 20 V, V_{GS} = -8 V	–	–	50	–	–	50	μA
*	Gate-to-Source Cutoff Voltage	$V_{GS(off)}$	V_{DS} = 15 V, I_D = 50 μA	-0.5	-3	-8	-0.5	-3	-8	V
*	Forward Transconductance	g_{fs}	V_{DS} = 15 V, I_D = 5 mA, f = 1 kHz	5,000	7,500	12,000	5,000	7,500	12,000	μmho
*	Drain-to-Source Channel Resistance	$r_{DS(on)}$	V_{DS} = 0, V_{GS} = 0, f = 1 kHz	–	200	–	–	200	–	Ω
*	Small-Signal Short-Circuit Reverse Transfer Capacitance▲	C_{rss}	V_{DS} = 15 V, I_D = 5 mA, f = 0.1 to 1 MHz	0.15	0.25	0.35	0.12	0.25	0.38	pF
*	Small-Signal Short-Circuit Input Capacitance	C_{iss}	V_{DS} = 15 V, I_D = 5 mA, f = 0.1 to 1 MHz	–	5.5	7	–	5.5	7	pF
			Common-Source Configuration							
*	Input Admittance	Y_{is}	f = 200 MHz	–	0.4 + J7.3	–	–	–	–	mmho
*	Forward Transfer Admittance	Y_{ss}	V_{os} = 15 Volts	–	7 – J2	–	–	–	–	mmho
*	Output Admittance	Y_{os}	I_D = 5 mA	–	0.28 + J1.8	–	–	–	–	mmho
*	Maximum Available Power Gain	MAG	V_{DS} = 15 V, I_D = 5 mA, f = 200 MHz		21	–	–	–	–	dB
*	Insertion Power Gain (Fixed Neutralization) See Fig. 1	G_{PS}		13.5	16	–	–	–	–	dB
	Power Gain (Conversion (See Fig. 3)	$G_{PS(c)}$	V_{DS} = 15 V, I_D = 1 mA, f_{in} = 200 MHz f_{out} = 30 MHz	–	–	–	10	13.5	–	dB
	Noise Figure (See Fig. 1 & 2)	NF	V_{DS} = 15 V, I_D = 5 mA, f = 200 MHz	–	3.5	5	–	–	–	–

*In accordance with JEDEC Registration Data Format JS9-RDF-11B.
▲Three-Terminal Measurement: Source Returned to Guard Terminal.

TERMINAL DIAGRAM



1 · Drain
2 · Source
3 · Insulated Gate
4 · Bulk (Substrate) and Case

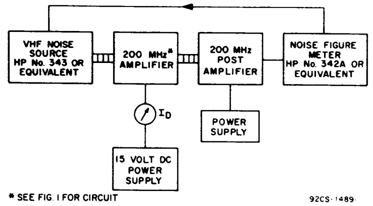
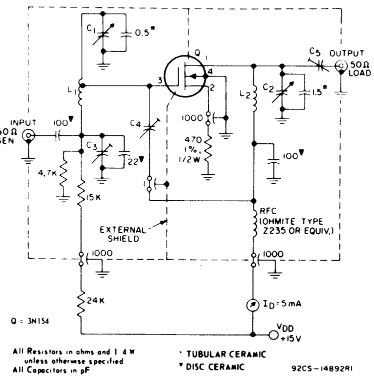


Fig. 2 - Noise figure measurement setup for 3N128



C_1, C_2: 1.5-5 pF variable air capacitor: E. F. Johnson Type 160-102 or equivalent

C_3: 1-10 pF piston-type variable air capacitor: JFD Type VAM-010, Johanson Type 4335, or equivalent

C_4, C_5: 0.3-3 pF piston-type variable air capacitor: Roanwell Type MH-13 or equivalent

L_1: 5 turns silver-plated 0.02" thick, 0.07"-0.08" wide copper ribbon. Internal diameter of winding = 0.25"; winding length approx. 0.65". Tapped at 1-1/2 turns from C_1 end of winding

L_2: Same as L_1 except winding length approx. 0.7"; no tap.

Fig. 1 - Test circuit used to measure 200-MHz maximum usable power gain and noise figure for 3N128

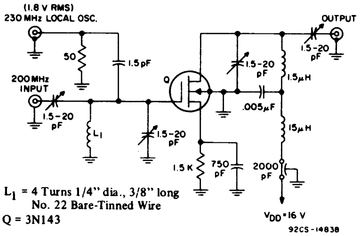


Fig. 3 - Conversion power gain test circuit for 3N143

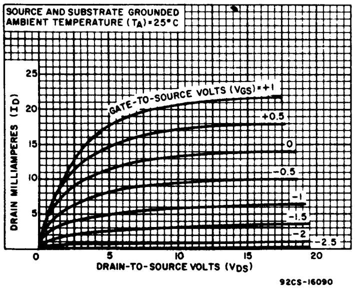


Fig. 4 - Drain current vs. drain-to-source voltage

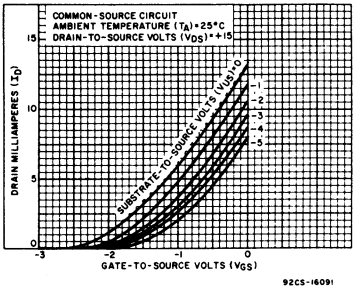


Fig. 5 - Drain current vs. gate-to-source voltage (V_{GS})

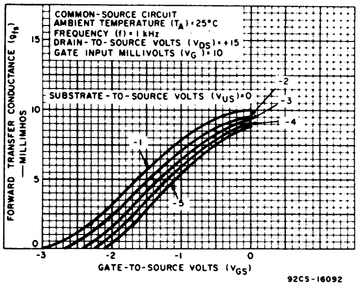


Fig. 6 - Forward transconductance vs. gate bias voltage

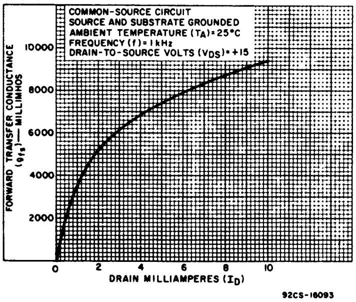


Fig. 7 - Forward transconductance vs. drain current

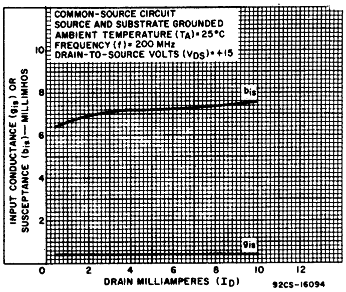


Fig. 8 - Input admittance vs. drain current

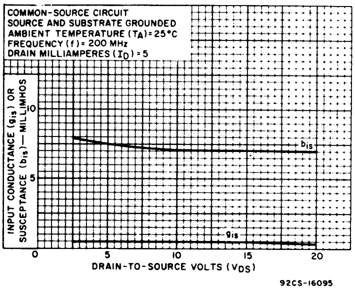


Fig. 9 - Input admittance vs. drain-to-source voltage

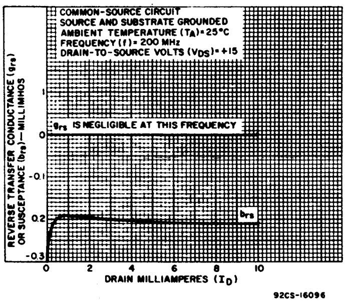


Fig. 10 - Reverse transadmittance vs. drain current

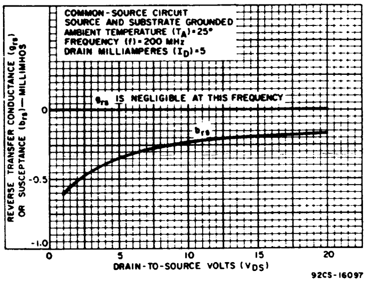


Fig. 11 - Reverse transadmittance vs. drain-to-source voltage

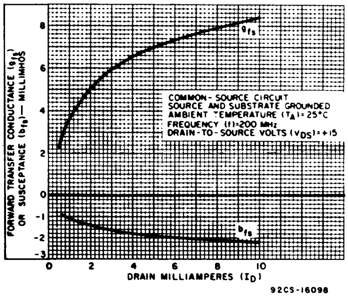


Fig. 12 - Forward transadmittance vs. drain current

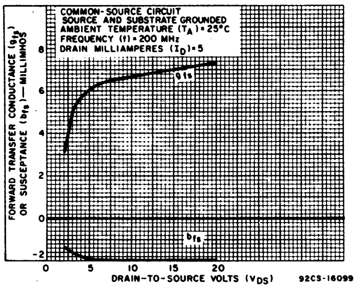


Fig. 13 - Forward transadmittance vs. drain-to-source voltage

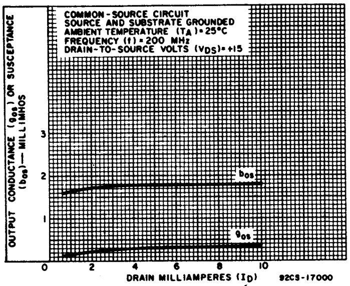


Fig. 14 - Output admittance vs. drain current

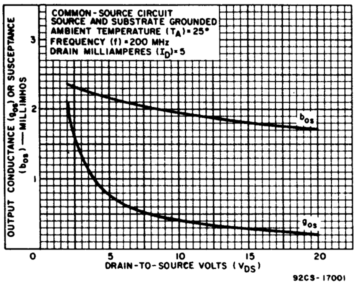


Fig. 15 - Output admittance vs. drain-to-source voltage

3N140, 3N141

SILICON DUAL INSULATED-GATE FIELD-EFFECT TRANSISTORS

N-Channel Depletion Types

For Amplifier and Mixer Applications Up to 300 MHz

RCA-3N140 and 3N141* are n-channel silicon, depletion type, dual insulated-gate, field-effect transistors utilizing the MOS** construction. They have exceptional characteristics for rf-amplifier and mixer applications at frequencies up to 300 MHz. These transistors feature a series arrangement of two separate channels, each channel having an independent control gate.

The 3N140, used in a common-source configuration in which gate No.2 is ac grounded, reduces oscillator feed-through to the antenna thereby minimizing oscillator radiation. The 3N141 provides excellent isolation between the oscillator and rf signals because each of the two signal frequencies being mixed has its own control element.

The mixing function performed by the 3N141 is unique in that the signal applied to gate No.2 is used to modulate the input-gate (gate No.1) transfer characteristic. This technique is superior to conventional "square law" mixing, which can only be accomplished in the non-linear region of the device transfer characteristic.

The use of the 3N141 as described provides high useful conversion gains at all vhf frequencies, and the reduction in spurious responses is substantial and easily obtainable in simple circuits.

Maximum Ratings, *Absolute-Maximum Values, at T_A = 25°C*

DRAIN-TO-SOURCE VOLTAGE, V_{DS}	0 to +20	V
GATE No.1-TO-SOURCE VOLTAGE, V_{G1S}:		
Continuous (dc)	-8 to +1	V
Peak ac	-8 to +20	V
GATE No.2-TO-SOURCE VOLTAGE, V_{G2S}:		
Continuous (dc)	-8 to 40% of V_{DS}	V
Peak ac	-8 to +20	V
DRAIN-TO-GATE VOLTAGE, V_{DG1} OR V_{DG2}	+20	V
DRAIN CURRENT, I_D		
(Pulsed): Pulse duration ≤ 20 ms, duty factor ≤ 0.15	50	mA
TRANSISTOR DISSIPATION, P_T:		
At ambient temperatures: up to 25°C	400	mW
At ambient temperatures: above 25°C	derate linearly at 2.67 mW/°C	
AMBIENT TEMPERATURE RANGE:		
Storage and Operating	-65 to +175	°C
LEAD TEMPERATURE (During soldering):		
At distances ≥ 1/32 inch from seating surface for 10 seconds max.	265	°C

The 3N140 and 3N141 are hermetically sealed in metal JEDEC TO-72 packages.

* Formerly Dev. Nos. TA2644 and TA7274, respectively.

** Metal-Oxide-Semiconductor.

APPLICATIONS

- RF amplifier and mixer in military and industrial communications equipment
- aircraft and marine vehicular receivers
- CATV and MATV equipment
- telemetry and multiplex equipment

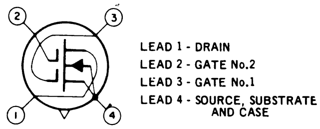
PERFORMANCE FEATURES

- wide dynamic range permits large-signal handling before overload
- dual-gate permits simplified agc circuitry
- virtually no agc power required
- greatly reduces spurious responses in fm receivers
- permits use of vacuum-tube biasing techniques
- excellent thermal stability
- superior cross-modulation performance and greater dynamic range than bipolar or single-gate FET's

DEVICE FEATURES

- low gate leakage currents - - I_{G1SS} & I_{G2SS} = 1 nA max. at T_A = 25°C
- high forward transconductance - - g_{fs} = 6000 μmho min.
- high unneutralized RF power gain - - G_{ps} = 16 dB min. at 200 MHz
- low VHF noise figure - - 4.5 dB max. at 200 MHz

TERMINAL DIAGRAM



ELECTRICAL CHARACTERISTICS, at T_A = 25°C Unless Otherwise Specified. Common-Source Circuit.

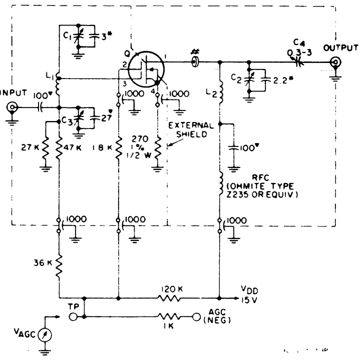
CHARACTERISTICS	SYMBOLS	TEST CONDITIONS	LIMITS TYPE 3N140 RF AMPLIFIER MIN.	TYP.	MAX.	TYPE 3N141 MIXER MIN.	TYP.	MAX.	UNITS
Gate No.1-to-Source Cutoff Voltage	$V_{G1S}(off)$	V_{DS} = +16V, I_D = 200 μA, V_{G2S} = +4V	-	-2	-4	-	-2	-4	V
Gate No.2-to-Source Cutoff Voltage	$V_{G2S}(off)$	V_{DS} = +16V, I_D = 200 μA, V_{G1S} = 0	-	-2	-4	-	-2	-4	V
Gate No.1 Leakage Current	I_{G1SS}	V_{G1S} = -20V, V_{G2S} = 0, V_{DS} = 0, T_A = 25°C	-	-	1	-	-	1	nA
		V_{G1S} = +1V, V_{G2S} = 0, V_{DS} = 0, T_A = 25°C	-	-	1	-	-	1	nA
		V_{G1S} = -20V, V_{G2S} = 0, V_{DS} = 0, T_A = 125°C	-	-	0.2	-	–	0.2	μA
Gate No.2 Leakage Current	I_{G2SS}	V_{G2S} = -20V, V_{G1S} = 0, V_{DS} = 0, T_A = 25°C	-	-	1	-	-	1	nA
		V_{G2S} = +1V, V_{DS} = 0, V_{G1S} = 0, T_A = 25°C	-	-	1	-	-	1	nA
		V_{G2S} = -20V, V_{G1S} = 0, V_{DS} = 0, T_A = 125°C	-	-	0.2	-	-	0.2	μA
Zero-Bias Drain Current	I_{DSS}•	V_{DD} = +14V, V_{G1S} = 0, V_{G2S} = +4	5	18	30	5	18	30	mA
Forward Transconductance (Gate No.1 to Drain)	g_{fs}	V_{DD} = +14V, I_D = 10 mA, V_{G2S} = +4V, f = 1 kHz	6000	10000	18000	6000	10000	18000	μmho
Cutoff Forward Transconductance (Gate No.1 to Drain)	$g_{fs}(off)$	V_{DD} = +14V, V_{G1S} = -0.5V, V_{G2S} = -2V, f = 1 kHz	-	-	100	-	-	-	μmho
Small-Signal, Short-Circuit Input Capacitance♦	C_{iss}	V_{DS} = +13V, I_D = 10 mA, V_{G2S} = +4V, f = 1 MHz	3	5.5	7	3	5.5	7	pF
Small-Signal, Short-Circuit Reverse Transfer Capacitance (Drain to Gate No.1)▲	C_{rss}	V_{DS} = +13V, I_D = 10 mA, V_{G2S} = +4V, f = 1 MHz	0.01	0.02	0.03	0.01	0.02	0.03	pF
Small-Signal Short-Circuit Output Capacitance	C_{oss}	V_{DS} = +13V, I_D = 10 mA, V_{G2S} = +4V, f = 1 MHz	-	2.2	-	-	2.2	-	pF
Power Gain (See Fig.1 for Measurement Circuit)	G_{ps}	V_{DD} = +15V, R_S = 270Ω, f = 200 MHz, R_G = 50Ω	16	18	-	-	-	-	dB
Conversion Power Gain (See Fig.2 for Measurement Circuit)	G_{psc}	V_{DD} = +15V, R_S = 120Ω, f_{IN} = 200 MHz, f_{OUT} = 30 MHz, Oscillator injection voltage● = 2.5 V (rms)	-	-	-	13	17	-	dB
Measured Noise Figure (See Fig.1 for Measurement Circuit)	NF	V_{DD} = +15V, R_S = 270Ω, f = 200 MHz, R_G = 50Ω	-	3.5	4.5	-	-	-	dB

• Pusle test: Pulse duration ≤ 20 ms, duty factor ≤ 0.15.

♦ Capacitance between Gate No.1 and all other terminals.

▲ Three-Terminal Measurement with Gate No.2 and Source Returned to Guard Terminal.

● Measured from gate No.2 to source.



Q = 3N140.

▼ Disc ceramic. All resistors in ohms

* Tubular ceramic. All capacitors in pF

\# Ferrite bead (1/2 used); Indiana General No.H1742C-(A-147), F-1157-1-H

C_1, C_2: 1.5-5 pF variable air capacitor: E.F. Johnson Type 160-102 or equivalent.

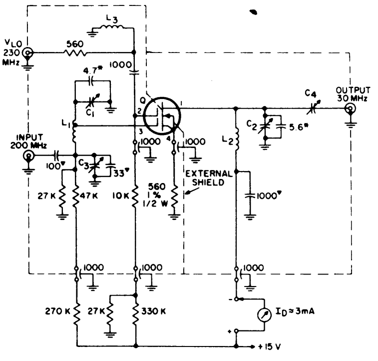
C_3: 1-10 pF piston-type variable air capacitor: JFD Type VAM-010, Johanson Type 4335, or equivalent.

C_4: 0.3-3 pF piston-type variable air capacitor: Roanwell Type MH-13 or equivalent.

L_1: 5 turns silver-plated 0.02" thick, 0.07"-0.08" wide copper ribbon. Internal diameter of winding = 0.25"; winding length approx. 0.65". Tapped at 1-1/2 turns from C_1 end of winding.

L_2: Same as L_1 except winding length approx. 0.7"; no tap.

Fig.1 - 200 MHz power gain and noise figure test circuit for type 3N140.



Q = 3N141.

▼ Disc ceramic.

* Tubular ceramic.

All resistors in ohms

All capacitors in pF

C_1, C_2: 1.5-5 pF variable air capacitor: E.F. Johnson Type 160-102 or equivalent.

C_3: 1-10 pF piston-type variable air capacitor: JFD Type VAM-010, Johanson Type 4335, or equivalent.

C_4: 0.3-3 pF piston-type variable air capacitor: Roanwell Type MH-13 or equivalent.

L_1: 5 turns silver-plated 0.02" thick, 0.07"-0.08" wide copper ribbon. Internal diameter of winding = 0.25"; winding length approx. 0.65". Tapped at 1-1/2 turns from C_1 end of winding.

L_2: Ohmite Z-144 RF choke or equivalent.

L_3: J.W. Miller Co. #4580 0.1 μH RF choke or equivalent.

Note: If 50Ω meter is used in place of sweep detector, a low pass filter must be provided to eliminate local oscillator voltage from load.

Fig.2 - Conversion power gain test circuit for type 3N141.

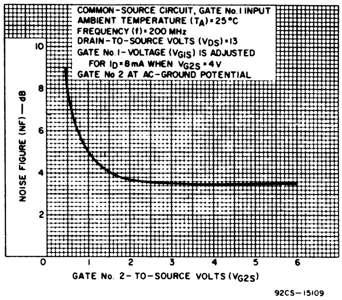


Fig.3 - NF vs V_{G2S}.

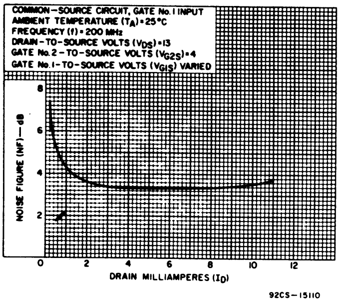


Fig.4 - NF vs I_D.

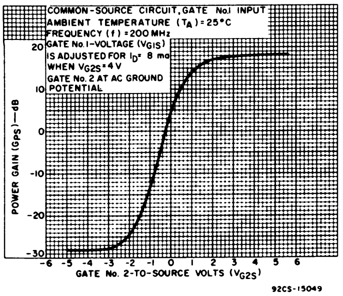


Fig.5 - G_{PS} vs V_{G2S} (For 3N140).

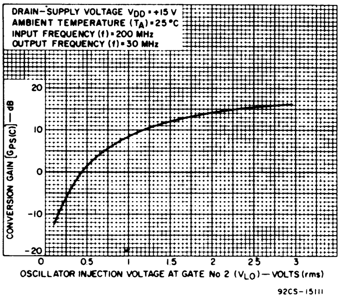


Fig.6 - $G_{PS(C)}$ vs V_{LO} (For 3N141).

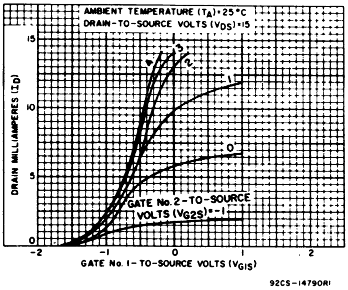


Fig.7 - I_D vs V_{G1S}.

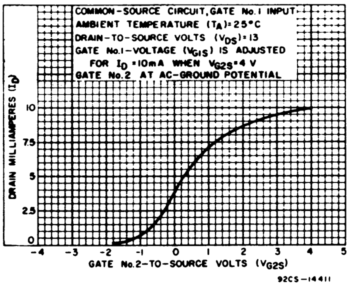


Fig.8 - I_D vs V_{G2S}.

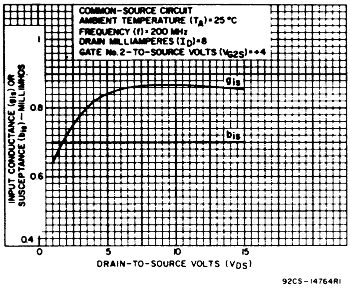


Fig.9 - y_{is} vs V_{DS}.

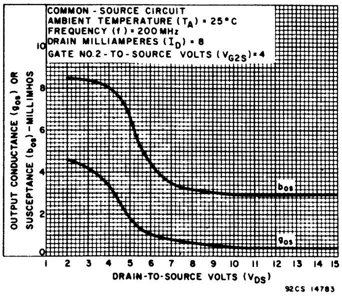


Fig.10 - y_{os} vs V_{DS}.

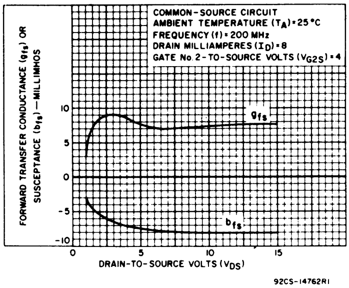


Fig.11 - y_{fs} vs V_{DS}.

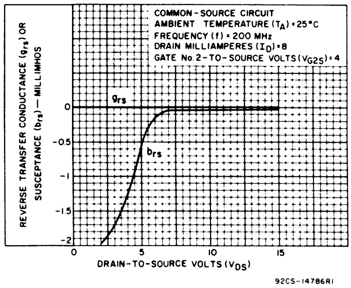


Fig.12 - y_{rs} vs V_{DS}.

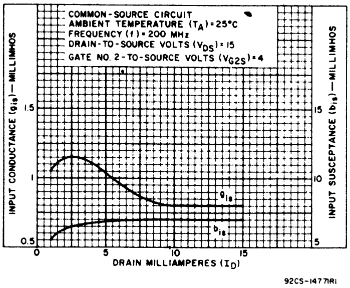


Fig.13 - y_{is} vs I_D.

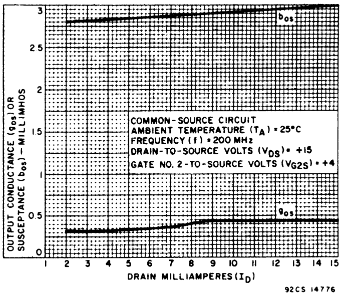


Fig.14 - y_{os} vs I_D.

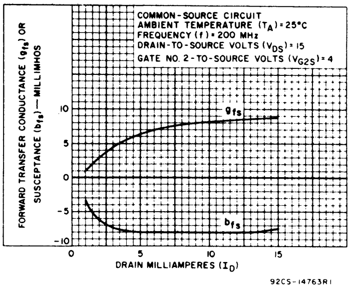


Fig.15 - y_{fs} vs I_D.

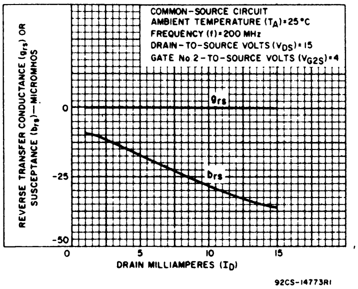


Fig.16 - y_{rs} vs I_D.

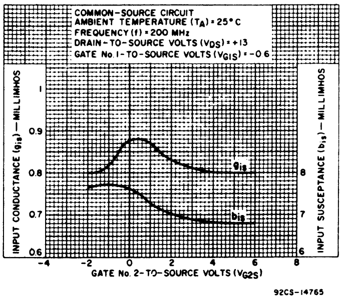


Fig.17 - y_{is} vs V_{G2S}.

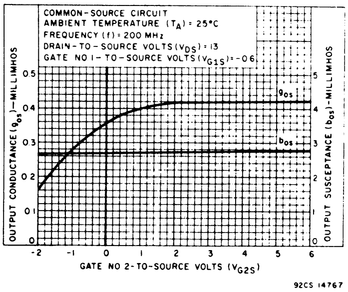


Fig.18 - y_{os} vs V_{G2S}.

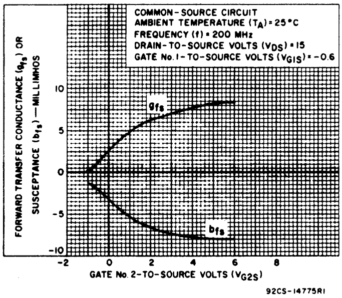


Fig.19 - y_{fs} vs V_{G2S}.

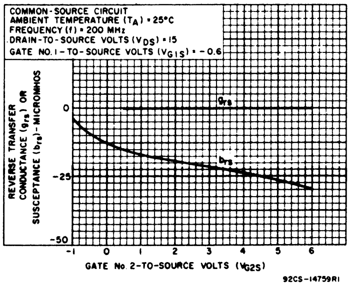


Fig.20 - y_{rs} vs V_{G2S}.

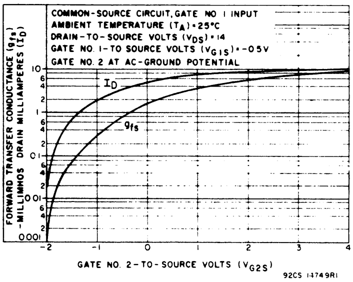


Fig.21 - g_{fs} and I_D vs V_{G2S}.

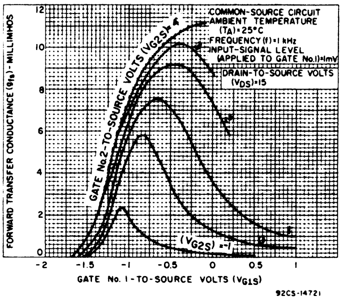


Fig.22 - g_{fs} vs V_{G1S}.

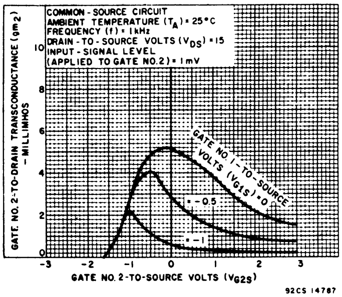


Fig.23 - g_{fs2} vs V_{G2S}.

3N152

Silicon MOS Transistor N-Channel Depletion Type

For Low-Noise RF Applications in Military & Industrial VHF Communications Equipment Operating up to 250 MHz

RCA-3N152 is an N-channel depletion-type silicon insulated gate field-effect transistor utilizing the MOS■ construction. It is intended primarily for VHF amplifier applications up to 250 MHz in military and industrial equipment.

Because of its improved transfer characteristic and exceptionally wide dynamic range, the 3N152 with the substrate in the reversed bias mode can provide substantially better cross-modulation performance in linear amplifier applications than conventional bipolar transistors. The insulated gate with its extremely low reverse (leakage) current eliminates the problem of diode-current loading of the input circuit under strong input conditions, which is common to junction-type FET's. These features in addition to low feedback capacitance permit the design of circuits providing superior high-frequency operation and high gain without neutralization. The 3N152 utilizes full-gate construction and is hermetically sealed in a JEDEC TO-72 metal package.

■ Metal-Oxide-Semiconductor.

Maximum Ratings, *Absolute-Maximum Values at T_A = 25°C:*

*DRAIN-TO-SOURCE VOLTAGE, V_{DS}	+20 max.	V
*DRAIN-TO-GATE VOLTAGE, V_{DG}	+20	V
*GATE-TO-SOURCE VOLTAGE, V_{GS}:		
* CONTINUOUS (dc)	+1, -8 max.	V
* PEAK ac	±15 max.	V
*DRAIN CURRENT, I_D	50 max.	mA
TRANSISTOR DISSIPATION:		
At ambient temperatures up to 25°C	330 max.	mW
At ambient temperatures above 25°C	derate at 2.2 mW/°C	
*AMBIENT TEMPERATURE RANGE:		
Storage	-65 to +175	°C
Operating	-65 to +175	°C
*LEAD TEMPERATURE (During Soldering): At distances not closer than 1/32 inch to seating surface for 10 seconds maximum	265 max.	°C

*In accordance with Jedec Registration Data Format JS-9 RDF 11-B.

Features

- **Low gate leakage current – I_{GSS} = 0.1 pA typ.**
- **Low feedback capacitance – C_{rss} = 0.25 pF typ.**
- **High forward transconductance – g_{fs} = 7500 μmho typ.**
- **High vhf power gain – G_{PS} = 16 dB typ. at 200 MHz**
- **Low vhf noise figure – NF = 2.5 dB typ. at 200 MHz**
- **Exceptionally good cross-modulation characteristics**

Performance

- **Large dynamic range**
- **Greatly reduced spurious responses**
- **Permits use of vacuum-tube biasing techniques**
- **Excellent thermal stability**
- **Superior cross-modulation performance and greater dynamic range than bipolar transistors**

ELECTRICAL CHARACTERISTICS AT T_A = 25°C

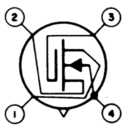
Measured with Substrate Connected to Source Unless Otherwise Specified

CHARACTERISTICS	SYMBOLS	CONDITIONS	LIMITS 3N152 Min.	Typ.	Max.	UNITS
* Gate Leakage Current	I_{GSS}	V_{DS} = 0, V_{GS} = -8V, T_A = 25°C	-	0.0001	1	nA
		V_{DS} = 0, V_{GS} = -8 V, T_A = 125°C	-	-	200	nA
* Zero-Bias Drain Current	I_{DSS}	V_{DS} = 15 V, V_{GS} = 0	5	15	30	mA
Drain-to-Source Cutoff Current	$I_D(off)$	V_{DS} = 20 V, V_{GS} = -8V	-	-	50	μA
* Gate-to-Source-Cutoff Voltage	$V_{GS}(off)$	V_{DS} = 15 V, I_D = 50 μA	-0.5	-3	-8	V
* Forward Transconductance	g_{fs}	V_{DS} = 15 V, I_D = 5 mA, f = 1 kHz	5000	7500	12,000	μmho
Drain-to-Source Channel Resistance	$r_{DS}(on)$	V_{DS} = 0, V_{GS} = 0, f = 1 kHz		200	-	Ω
* Small-Signal Short-Circuit Reverse Transfer Capacitance▲	C_{rss}	V_{DS} = 15 V, I_D = 5 mA, f = 0.1 to 1 MHz	0.15	0.25	0.35	pF
Small-Signal Short-Circuit Input Capacitance	C_{iss}	V_{DS} = 15 V, I_D = 5 mA, f = 0.1 to 1 MHz		5.5	7	pF
Input Admittance	Y_{is}	Common Source Configuration f = 200 MHz		0.4 + j7.3		mmho
Forward Transfer Admittance	Y_{fs}	V_{DS} = 15 V,	-	7-j2	-	mmho
Output Admittance	Y_{os}	I_D = 5 mA		0.28 + j1.8		mmho
Power Gain Maximum Available Gain	MAG			21		dB
Insertion Power Gain (Fixed Neutralization) See Fig.1	G_{PS}	V_{DS} = 15 V, I_D = 5 mA, f = 200 MHz	14.5	16		dB
Noise Figure (See Figs. 1 & 2)	NF	V_{DS} = 15 V, I_D = 5 mA, f = 200 MHz		2.5	3.5	dB

▲ Three-Terminal Measurement. Source Returned to Guard Terminal.

* In accordance with JEDEC Registration Data Format JS-9 RDF-11B.

TERMINAL ARRANGEMENT



1 - Drain
2 - Source
3 - Insulated Gate
4 - Bulk (Substrate) and Case

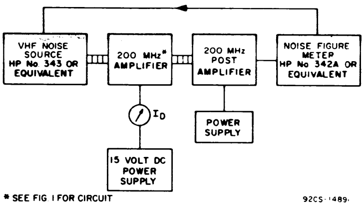


Fig. 2 - Noise figure measurement setup.

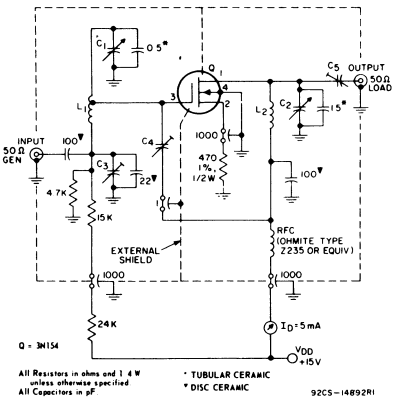


Fig. 1 - Test circuit used to measure 200-MHz maximum usable power gain and noise Figure.

C_1, C_2: 1.5-5 pF variable air capacitor: E. F. Johnson Type 160-102 or equivalent

C_3: 1-10 pF piston-type variable air capacitor: JFD Type VAM-010, Johanson Type 4335, or equivalent

C_4, C_5: 0.3-3 pF piston-type variable air capacitor: Roanwell Type MH-13 or equivalent

L_1: 5 turns silver-plated 0.02" thick, 0.07"-0.08" wide copper ribbon. Internal diameter of winding = 0.25"; winding length approx. 0.65". Tapped at 1-1/2 turns from C_1 end of winding

L_2: Same as L_1 except winding length approx. 0.7"; no tap

For characteristics curves, refer to types 3N128 and 3N143.

3N154

Silicon MOS Transistor N-Channel Depletion Type

For Critical Amplifier Applications in Military & Industrial VHF Communications Equipment Operating up to 250 MHz

RCA 3N154 is an n-channel depletion-type silicon insulated-gate field-effect transistor utilizing the MOS■ construction. It is intended primarily for vhf amplifier applications up to 250 MHz in military and industrial equipment.

Because of its improved transfer characteristic and exceptionally wide dynamic range, the 3N154 can provide substantially better crossmodulation performance in linear amplifier applications than conventional bipolar transistors. The extremely low gate leakage current eliminates diode-current loading of the input circuit under strong signal conditions, a problem which is common to junction-type FET's. These features, in addition to low feedback capacitance, permit the design of circuits providing superior high-frequency operation and high gain without neutralization. The 3N154 utilizes full-gate construction and is hermetically sealed in a JEDEC TO-72 metal package.

■ Metal-Oxide-Semiconductor

Maximum Ratings, *Absolute-Maximum Values at T_A = 25°C:*

*DRAIN-TO-SOURCE VOLTAGE, V_{DS}	+20	V
*DRAIN-TO-GATE VOLTAGE, V_{DG}	+20	V
*GATE-TO-SOURCE VOLTAGE, V_{GS}:		
* CONTINUOUS (dc)	+1, -8	V
* PEAK ac	±15	V
*DRAIN CURRENT, I_D▲	50	mA
*TRANSISTOR DISSIPATION:		
At ambient temperatures up to 25°C	330	mW
At ambient temperatures above 25°C	derate at 2.2	mW/°C
*AMBIENT TEMPERATURE RANGE:		
Storage	-65 to +175	°C
Operating	-65 to +175	°C
LEAD TEMPERATURE (During Soldering):		
At distances not closer than 1/32 inch to seating surface for 10 seconds maximum	265	°C

In accordance with JEDEC Registration Data Format JS9-RDF-11B

▲Pulsed:
Pulse duration ≤ 20 ms
Duty factor ≤ 0.15

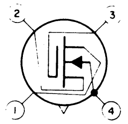
Device Feature:

- Closely controlled IDSS – 10 to 25 mA
- Low gate leakage current – I_{GSS} = 0.1 pA typ.
- Low feedback capacitance – C_{rss} = 0.25 pF typ.
- High forward transconductance – g_{fs} = 7500 μmho typ.
- High vhf power gain – Gps = 16 dB typ. at 200 MHz
- Low vhf noise figure – NF = 3.5 dB typ. at 200 MHz
- Exceptionally good cross-modulation characteristics

Performance Features

- Large dynamic range
- Greatly reduced spurious responses
- Permits use of vacuum-tube biasing techniques
- Excellent thermal stability
- Superior cross-modulation performance and greater dynamic range than bipolar transistors

TERMINAL DIAGRAM



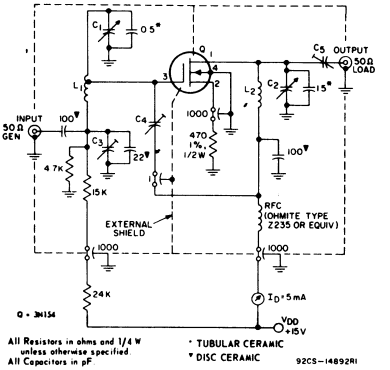
1 - Drain
2 - Source
3 - Insulated Gate
4 - Bulk (Substrate) and Case

ELECTRICAL CHARACTERISTICS: (At T_A = 25° C)

Measured with Substrate Connected to Source Unless Otherwise Specified.

CHARACTERISTICS	SYMBOLS	CONDITIONS	LIMITS 3N154 Min.	Typ.	Max.	UNITS
* Gate Leakage Current	I_{GSS}	V_{DS} = 0, V_{GS} = -8 V, T_A = 25° C	-	0.0001	0.05	nA
		V_{DS} = 0, V_{GS} = -8 V, T_A = 125° C	-	-	5	nA
		V_{DS} = 0, V_{GS} = +1, T_A = 25° C	-	0.0001	0.05	nA
		V_{DS} = 0, V_{GS} = +1, T_A = 125° C	-	-	5	nA
* Zero-Bias Drain Current	I_{DSS}	V_{DS} = 15 V, V_{GS} = 0	10	15	25	mA
Drain-to-Source Cutoff Current	$I_{D(off)}$	V_{DS} = 20 V, V_{GS} = -8 V	-	-	50	μA
* Gate-to-Source Cutoff Voltage	$V_{GS(off)}$	V_{DS} = 15 V, I_D = 50 μA	-0.5	-3	-8	V
Forward Transsconductance	g_{fs}	V_{DS} = 15 V, I_D = 5 mA, f = 1 kHz	5000	7500	12,000	μmho
Drain-to-Source Channel Resistance	$r_{DS(on)}$	V_{DS} = 0, V_{GS} = 0, f = 1 kHz	-	200	-	Ω
* Small-Signal Short-Circuit Reverse Transfer Capacitance	C_{rss}	V_{DS} = 15 V, I_D = 5 mA, f = 0.1 to 1 MHz	0.15	0.25	0.35	pF
Small-Signal Short-Circuit Input Capacitance ▲	C_{iss}	V_{DS} = 15 V, I_D = 5 mA, f = 0.1 to 1 MHz	-	5.5	7	pF
Input Admittance	Y_{is}	Common Source Configuration f = 200 MHz, V_{DS} = 15 V, I_D = 5 mA	-	0.4 + j7.3	-	mmho
Forward Transfer Admittance	Y_{fs}		-	7 – j2	-	mmho
Output Admittance	Y_{os}		-	0.28 + j1.8	-	mmho
Maximum Available Power Gain	MAG	V_{DS} = 15 V, I_D = 5 mA, f = 200 MHz	-	21	-	dB
* Insertion Power Gain (Fixed Neutralization) (see Fig. 1)	G_{PS}		13.5	16	-	dB
* Noise Figure (see Figs. 1 & 2)	NF	V_{DS} = 15 V, I_D = 5 mA, f = 200 MHz	-	3.5	5	dB

* In Accordance with JEDEC Registration Data Format JS-9 RDF-11B
▲ Three-Terminal Measurement: Source Returned to Guard Terminal



C_1, C_2: 1.5-5 pF variable air capacitor: E. F. Johnson Type 160-102 or equivalent

C_3: 1-10 pF piston-type variable air capacitor: JFD Type VAM-010, Johanson Type 4335, or equivalent

C_4, C_5: 0.3-3 pF piston-type variable air capacitor: Roanwell Type MH-13 or equivalent

Q = 3N154

L_1: 5 turns silver-plated 0.02" thick, 0.07"-0.08" wide copper ribbon. Internal diameter of winding = 0.25"; winding length approx. 0.65". Tapped at 1-1/2 turns from C_1 end of winding

L_2: Same as L_1 except winding length approx. 0.7"; no tap.

Fig. 1 - Test circuit used to measure 200-MHz maximum usable power gain and noise figure

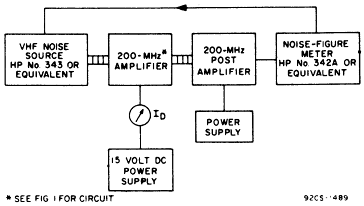


Fig. 2 - Noise figure measurement setup

For characteristics curves, refer to types 3N128 and 3N143.

SILICON DUAL INSULATED-GATE FIELD-EFFECT TRANSISTOR

N-Channel Depletion Type

For Military and Industrial Low-Noise RF-Amplifier Applications Up to 300 MHz

The 3N159 is an n-channel silicon, depletion type, dual insulated-gate, field-effect transistor utilizing the MOS** construction. It has exceptional characteristics for rf-amplifier applications at frequencies up to 300 MHz. This transistor features a series arrangement of two separate channels, each channel having an independent control gate.

Type 3N159 has an exceptionally low-noise figure, which makes this type particularly suitable for critical vhf applications. When used in a common-source configuration in which gate No.2 is ac grounded, this device reduces oscillator feedthrough to the antenna thereby minimizing oscillator radiation.

The 3N159 is hermetically sealed in the metal JEDEC TO-72 package.

** Metal-Oxide-Semiconductor.

APPLICATIONS

- RF amplifier in military and industrial communications equipment
- aircraft, marine and vehicular receivers
- CATV and MATV equipment
- telemetry and multiplex equipment

Maximum Ratings, *Absolute-Maximum Values:* at T_A = 25°C

DRAIN-TO-SOURCE VOLTAGE, V_{DS} . . . . 0 to +20 V
GATE-No.1-TO-SOURCE VOLTAGE, V_{G1S}:
Continuous (dc) . . . . -8 to +1 V
Peak ac . . . . -8 to +20 V
GATE No.2-TO-SOURCE VOLTAGE, V_{G2S}:
Continuous (dc) . . . . -8 to 40% of V_{DS} V
Peak ac . . . . -8 to +20 V
DRAIN-TO-GATE VOLTAGE:
V_{DG1} or V_{DG2} . . . . +20 V
DRAIN CURRENT, I_D
Pulsed: Pulse duration ≤ 20 ms, duty factor ≤ 0.15 . . . . 50 mA
TRANSISTOR DISSIPATION, P_T:
At ambient temperatures up to 25°C . . . . 400 mW
above 25°C . . . . derate linearly at 2.67 mW/°C
AMBIENT TEMPERATURE RANGE:
Storage and Operating . . . . -65 to +175 °C
LEAD TEMPERATURE (During soldering):
At distances ≥ 1/32 inch from seating surface for 10 seconds max. . . . . 265 °C

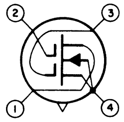
PERFORMANCE FEATURES

- wide dynamic range permits large-signal handling before overload
- dual-gate permits simplified agc circuitry
- virtually no agc power required
- greatly reduces spurious responses in FM receivers
- permits use of vacuum-tube biasing techniques
- excellent thermal stability
- superior cross-modulation performance and greater dynamic range than bipolar or single-gate field-effect transistors

DEVICE FEATURES

- low gate leakage currents – – I_{G1SS} & I_{G2SS} = 1 nA max.
- high forward transconductance – – g_{fs} = 7000 µmho min.
- high unneutralized RF power gain – – G_{ps} = 16 dB min. at 200 MHz
- low vhf noise figure – – NF = 3.5 dB max. at 200 MHz

TERMINAL DIAGRAM



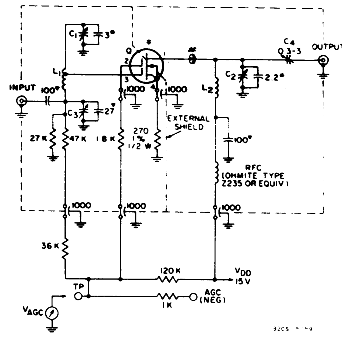
LEAD 1 - DRAIN
LEAD 2 - GATE No.2
LEAD 3 - GATE No.1
LEAD 4 - SOURCE, SUBSTRATE AND CASE

ELECTRICAL CHARACTERISTICS, at T_A = 25°C unless otherwise specified

CHARACTERISTICS	SYMBOLS	TEST CONDITIONS	LIMITS 3N159 Min.	Typ.	Max.	UNITS
Gate-No.1-to-Source Cutoff Voltage	$V_{G1S(off)}$	V_{DS} = +16V, I_D = 200 µA, V_{G2S} = +4V	-	-2	-4	V
Gate-No.2-to-Source Cutoff Voltage	$V_{G2S(off)}$	V_{DS} = +16V, I_D = 200 µA, V_{G1S} = 0	-	-2	-4	V
Gate-No.1-Leakage Current	I_{G1SS}	V_{G1S} = -20V, V_{G2S} = 0, V_{DS} = 0, T_A = 25°C	-	-	1	nA
		V_{G1S} = +1V, V_{G2S} = 0, V_{DS} = 0, T_A = 25°C	-	-	1	nA
		V_{G1S} = -20V, V_{G2S} = 0, V_{DS} = 0, T_A = 125°C	-	-	0.2	µA
Gate-No.2-Leakage Current	I_{G2SS}	V_{G2S} = -20V, V_{G1S} = 0, V_{DS} = 0, T_A = 25°C	-	-	1	nA
		V_{G2S} = +1, V_{DS} = 0, V_{G1S} = 0, T_A = 25°C	-	-	1	nA
		V_{G2S} = -20V, V_{G1S} = 0, V_{DS} = 0, T_A = 125°C	-	-	0.2	µA
Zero-Bias Drain Current	I_{DSS}*	V_{DD} = +14V, V_{G1S} = 0, V_{G2S} = +4V	5	18	30	mA
Forward Transconductance (Gate-No.1-to-Drain)	g_{fs}	V_{DD} = +14V, I_D = 10 mA, V_{G2S} = +4V, f = 1 kHz	7000	10,000	18,000	µmho
Cutoff Forward Transconductance (Gate-No.1-to-Drain)	$g_{fs(off)}$	V_{DD} = +14V, V_{G1S} = -0.5V, V_{G2S} = -2V, f = 1 kHz	-	-	100	µmho
Small-Signal, Short-Circuit Input Capacitance▲	C_{iss}	V_{DS} = +13V, I_D = 10 mA, V_{G2S} = +4V, f = 1 MHz	3	5.5	7	pF
Small-Signal, Short-Circuit, Reverse Transfer Capacitance (Drain-to-Gate No.1)♦	C_{rss}	V_{DS} = +13V, I_D = 10 mA, V_{G2S} = +4V, f = 1 MHz	0.01	0.02	0.03	pF
Small-Signal, Short-Circuit Output Capacitance	C_{oss}	V_{DS} = +13V, I_D = 10 mA, V_{G2S} = +4V, f = 1 MHz	-	2.2	-	pF
Maximum Usable Power Gain (See Fig.1 for Measurement Circuit)	MUG	V_{DD} = +15V, R_S = 270Ω, R_G = 50Ω, f = 200 MHz	16	18	22	dB
Measured Noise Figure (See Fig.1 for Measurement Circuit)	NF	V_{DD} = +15V, R_S = 270Ω, f = 200 MHz, R_G = 50Ω	-	2.5	3.5	dB

* Pulse Test: Pulse duration ≤ 20 ms, duty factor ≤ 0.15.
▲ Capacitance between Gate No.1 and all other terminals.
♦ Three-Terminal Measurement with Gate No.2 and Source Returned to Guard Terminal.

For characteristics curves refer to types 3N140, 3N141.



* Tubular ceramic
▼ Disc ceramic
Ferrite bead (1/2 used); Indiana General No. H 1742C-(A-147) or F1157-1-H or equivalent.
‡ VHF plug in socket Jettron CD72-148 and CD72149 (part No.7977-1) or equivalent.

C_1, C_2: 1.5-5pF variable air capacitor: E. F. Johnson Type 160-102 or equivalent.
C_3: 1-10 pF piston-type variable air capacitor: JFD Type VAM-010, Johanson Type 4335, or equivalent.
C_4: 0.3-3 pF piston-type variable air capacitor: Roanwell Type MH-13 or equivalent.
L_1: 5 turns silver-plated 0.02" thick, 0.07"-0.08" wide copper ribbon. Internal diameter of winding = 0.25"; winding length approx. 0.65". Tapped at 1-1 2 turns from C_1 end of winding.
L_2: Same as L_1 except winding length approx. 0.7"; no tap.

Fig.1 - 200-MHz power gain and noise-figure test circuit for type 3N159.

3N187

Silicon Dual Insulated-Gate Field-Effect Transistor

N-Channel Depletion Type

With Integrated Gate-Protection Circuits

For Military and Industrial Applications up to 300 MHz

Device Features

- Back-to-back diodes protect each gate against handling and in-circuit transients
- High forward transconductance – g_{fs} = 12,000 μmho (typ.)
- High unneutralized RF power gain – G_{ps} = 18 dB(typ.) at 200 MHz
- Low VHF noise figure – 3.5 dB(typ.) at 200 MHz

RCA-3N187 is an n-channel silicon, depletion type, dual insulated-gate field-effect transistor.

Special back-to-back diodes are diffused directly into the MOS▲ pellet and are electrically connected between each insulated gate and the FET's source. The diodes effectively bypass any voltage transients which exceed approximately ±10 volts. This protects the gates against damage in all normal handling and usage.

A feature of the back-to-back diode configuration is that it allows the 3N187 to retain the wide input signal dynamic range inherent in the MOSFET. In addition, the junction capacitance of these diodes adds little to the total capacitance shunting the signal gate.

The excellent overall performance characteristics of the RCA-3N187 make it useful for a wide variety of rf-amplifier applications at frequencies up to 300 MHz. The two serially-connected channels with independent control gates make possible a greater dynamic range and lower cross-modulation than is normally achieved using devices having only a single control element.

The two-gate arrangement of the 3N187 also makes possible a desirable reduction in feedback capacitance by operating in the common-source configuration and ac-grounding Gate No. 2. The reduced capacitance allows operation at maximum gain *without neutralization;* and, of special importance in rf-amplifiers, it reduces local oscillator feedthrough to the antenna.

The 3N187 is hermetically sealed in the metal JEDEC TO-72 package.

▲ Metal-Oxide-Semiconductor

Maximum Ratings,

Absolute-Maximum Values, at T_A = 25°C

DRAIN-TO-SOURCE VOLTAGE, V_{DS}	-0.2 to +20	V
GATE No. 1-TO-SOURCE VOLTAGE, V_{G1S}:		
Continuous (dc)	-6 to +3	V
Peak ac	-6 to +6	V
GATE No. 2-TO-SOURCE VOLTAGE, V_{G2S}:		
Continuous (dc)	-6 to 30% of V_{DS}	V
Peak ac	-6 to +6	V
* DRAIN-TO-GATE VOLTAGE, V_{DG1} OR V_{DG2}	+20	V
* DRAIN CURRENT, I_D	50	mA
* TRANSISTOR DISSIPATION P_T:		
At ambient temperatures up to 25°C	330	mW
At ambient temperatures above 25°C	derate linearly at 2.2 mW/°C	
* AMBIENT TEMPERATURE RANGE:		
Storage and Operating	-65 to +175	°C
* LEAD TEMPERATURE (During Soldering):		
At distances ≥ 1/32 inch from seating surface for 10 seconds max.	265	°C

* In accordance with JEDEC Registration Data Format JS-9 RDF-19A

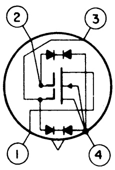
Applications

- RF amplifier, mixer, and IF amplifier in military, and industrial communications equipment
- Aircraft and marine vehicular receivers
- CATV and MATV equipment
- Telemetry and multiplex equipment

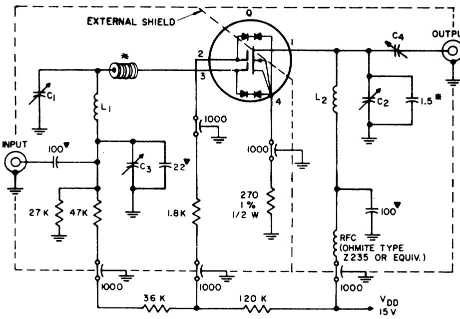
Performance Features

- Superior cross-modulation performance and greater dynamic range than bipolar or single-gate FET's
- Wide dynamic range permits large-signal handling before overload
- Virtually no agc power required
- Greatly reduces spurious responses in FM receivers

TERMINAL DIAGRAM



LEAD 1-DRAIN
LEAD 2-GATE No. 2
LEAD 3-GATE No. 1
LEAD 4-SOURCE, SUBSTRATE AND CASE



\# Ferrite bead (4); Pyroferric Co. "Carbonyl J" 0.09 in. OD; 0.03 in. ID; 0.063 in. thickness.
Q = 3N187
▼ Disc ceramic.
* Tubular ceramic.
All resistors in ohms
All capacitors in pF
C_1: 1.8–8.7 pF variable air capacitor: E.F. Johnson Type 160-104, or equivalent.
C_2: 1.5–5 pF variable air capacitor: E.F. Johnson Type 160-102, or equivalent.
C_3: 1–10 pF piston-type variable air capacitor: JFD Type VAM-010; Johanson Type 4335, or equivalent.
C_4: 0.8–4.5 pF piston type variable air capacitor: Erie 560-013 or equivalent.
L_1: 4 turns silver-plated 0.02-in. thick, 0.075-0.085-in. wide, copper ribbon. Internal diameter of winding = 0.25 in, winding length approx. 0.08 in.
L_2: 4½ turns silver-plated 0.02-in thick, 0.085-0.095-in. wide, 5/16-in. ID. Coil ≈ .90 in. long.

Fig. 1 - 200-MHz Power gain and noise-figure test circuit

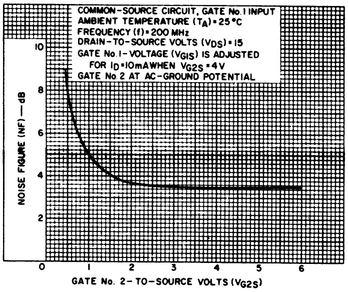


Fig. 2 - NF vs. V_{G2S}

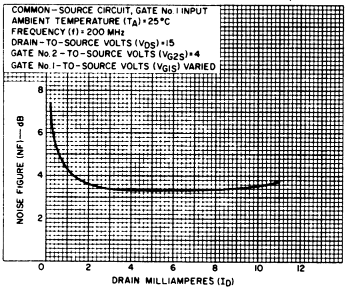


Fig. 3 - NF vs. I_D

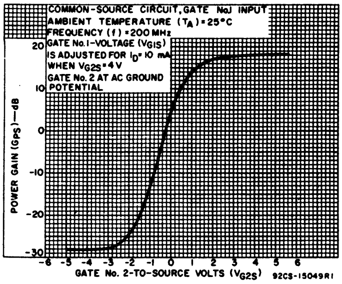


Fig. 4 - G_{PS} vs. V_{G2S}

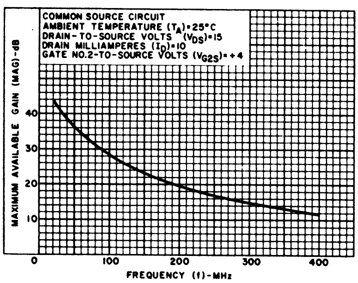


Fig. 5 - MAG. vs. f

ELECTRICAL CHARACTERISTICS, at T_A = 25°C unless otherwise specified

	CHARACTERISTICS	SYMBOL	TEST CONDITIONS		LIMITS Min.	LIMITS Typ.	LIMITS Max.	UNITS
*	Gate No. 1-to-Source Cutoff Voltage	$V_{G1S(off)}$	V_{DS} = +15 V, I_D = 50 μA, V_{G2S} = +4 V		-0.5	-2	-4	V
*	Gate No. 2-to-Source Cutoff Voltage	$V_{G2S(off)}$	V_{DS} = +15 V, I_D = 50 μA, V_{G1S} = 0		-0.5	-2	-4	V
*	Gate No. 1-Terminal Forward Current	I_{G1SSF}	V_{G1S} = +1 V	T_A = 25° C	–	–	50	nA
			V_{G2S} = V_{DS} = 0	T_A = 100° C	–	–	5	μA
*	Gate No. 1-Terminal Reverse Current	I_{G1SSR}	V_{G1S} = -6 V	T_A = 25° C	–	–	50	nA
			V_{G2S} = V_{DS}=0	T_A = 100° C	–	–	5	μA
*	Gate No. 2-Terminal Forward Current	I_{G2SSF}	V_{G2S} = +6 V	T_A = 25° C	–	–	50	nA
			V_{G1S} = V_{DS}=0	T_A = 100° C	–	–	5	μA
*	Gate No. 2-Terminal Reverse Current	I_{G2SSR}	V_{G2S} = -6 V	T_A = 25° C	–	–	50	nA
			V_{G1S} = V_{DS} = 0	T_A = 100° C	–	–	5	μA
*	Zero-Bias Drain Current	I_{DS}	V_{DS} = +15 V, V_{G2S} = +4 V, V_{G1S} = 0		5	15	30	mA
	Forward Transconductance (Gate No. 1-to-Drain)	g_{fs}	V_{DS} = +15 V, I_D = 10 mA, V_{G2S} = +4 V, f = 1kHz		7000	12,000	18,000	μmho
*	Small-Signal, Short-Circuit Input Capacitance†	C_{iss}	V_{DS} = +15 V, I_D = 10 mA, V_{G2S} = +4 V, f = 1 MHz		4.0	6.0	8.5	pF
*	Small-Signal, Short-Circuit, Reverse Transfer Capacitance (Drain-to-Gate No. 1)♦	C_{rss}			0.005	0.02	0.03	pF
*	Small-Signal, Short-Circuit Output Capacitanc	C_{oss}			–	2.0	–	pF
	Power Gain (see Fig. 1)	G_{PS}	V_{DS} = +15 V, I_D = 10 mA, V_{G2S} = +4 V, f = 200 MHz		16	18	22	dB
	Maximum Available Power Gain	MAG			–	20	–	dB
	Maximum Usable Power Gain (unneutralized)	MUG			–	20▲	–	dB
	Noise Figure (see Fig. 1)	NF			–	3.5	4.5	dB
*	Magnitude of Forward Transadmittance	$\|Y_{fs}\|$			–	12,000	–	μmho
*	Phase Angle of Forward Transadmittance	θ			–	-35	–	Degrees
	Magnitude of Reverse Transadmittance	$\|Y_{rs}\|$			–	25	–	μmho
	Angle of Reverse Transadmittance	θ_{rs}			–	-25	–	Degrees
*	Input Resistance	r_{iss}			–	1.0	–	kΩ
*	Output Resistance	r_{oss}			–	2.8	–	kΩ
*	Gate-to-Source Forward Breakdown Voltage: Gate No. 1, Gate No. 2	$V_{(BR)G1SSF}$, $V_{(BR)G2SSF}$	I_{G1SSF} = I_{G2SSF} = 100 μA		6.5	10	–	V
*	Gate-to-Source Reverse Breakdown Voltage: Gate No. 1, Gate No. 2	$V_{(BR)G1SSR}$, $V_{(BR)G2SSR}$	I_{G1SSR} = I_{G2SSR} = -100 μA		-6.5	-10	–	V

▲ Limited only by practical design considerations.
† Capacitance between Gate No. 1 and all other terminals
♦ Three-terminal measurement with Gate No. 2 and Source returned to ground terminal.
* In accordance with JEDEC Registration Data Format JS-9 RDF-19A

OPERATING CONSIDERATIONS

The flexible leads of the 3N187 are usually soldered to the circuit elements. As in the case of any high-frequency semiconductor device, the tips of soldering irons MUST be grounded.

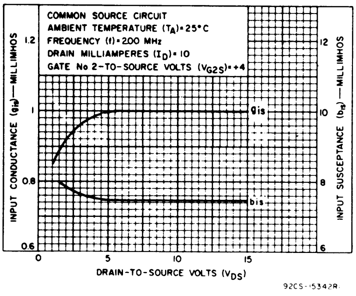


Fig. 8 - y_{is} vs. V_{DS}

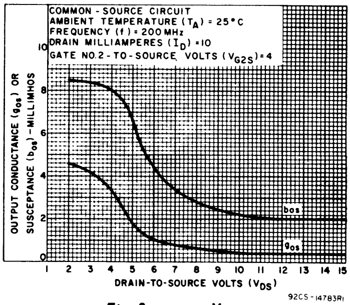


Fig. 9 - y_{os} vs. V_{DS}

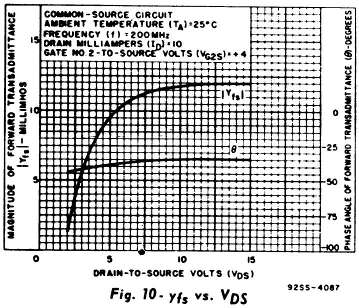


Fig. 10 - y_{fs} vs. V_{DS}

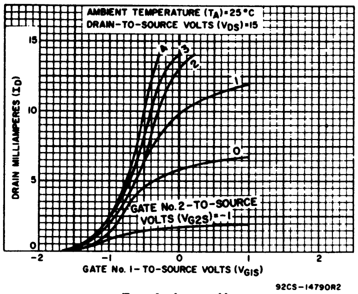


Fig. 6 - I_D vs. V_{G1S}

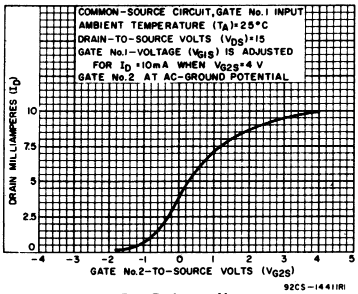


Fig. 7 - I_D vs. V_{G2S}

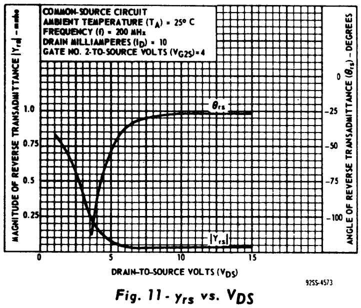


Fig. 11 - y_{rs} vs. V_{DS}

3N187

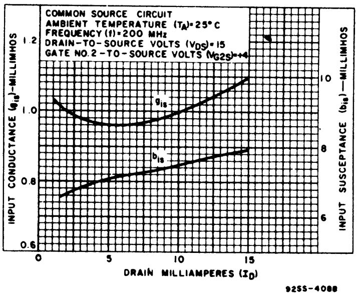


Fig. 12 - y_{is} vs. I_D

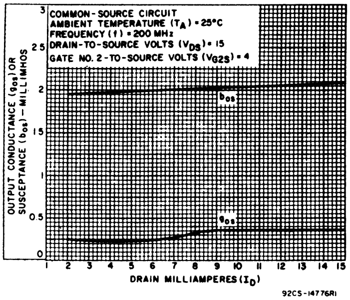


Fig. 13 - y_{os} vs. I_D

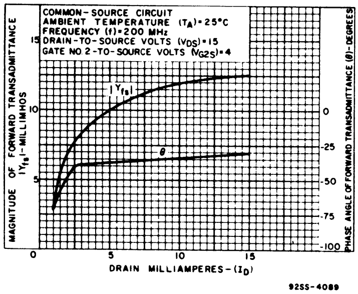


Fig. 14 - y_{fs} vs. I_D

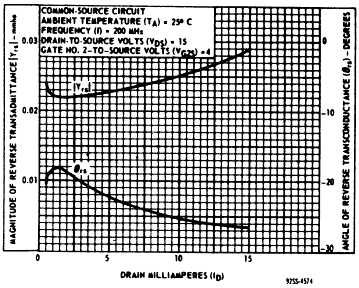


Fig. 15 - y_{rs} vs. I_D

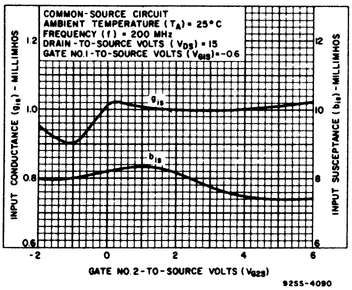


Fig. 16 - y_{is} vs. V_{G2S}

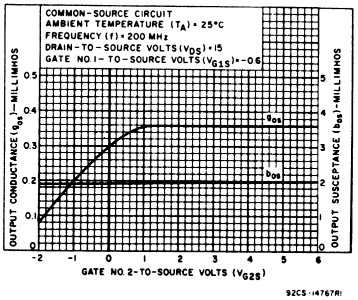


Fig. 17 - y_{os} vs. V_{G2S}

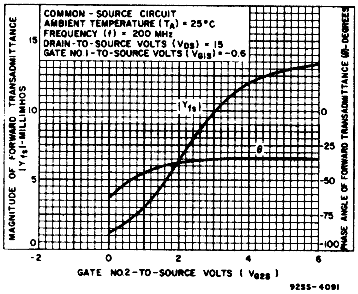


Fig. 18 - y_{fs} vs. V_{G2S}

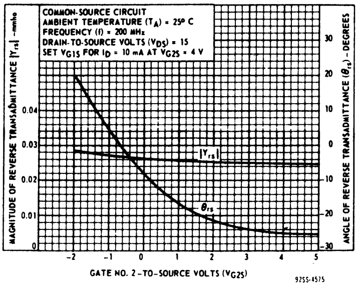


Fig. 19 - y_{rs} vs. V_{G2S}

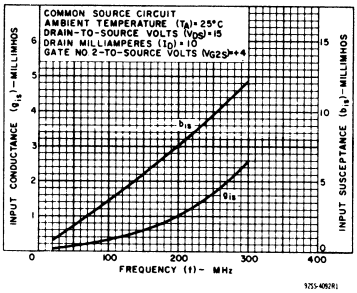


Fig. 20 - y_{is} vs. frequency

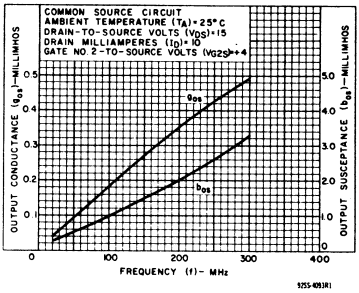


Fig. 21 - y_{os} vs. frequency

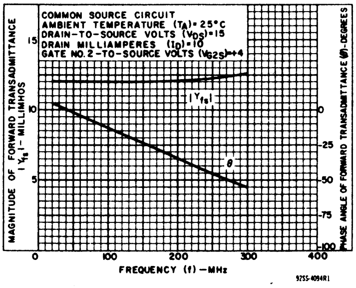


Fig. 22 - y_{fs} vs. frequency

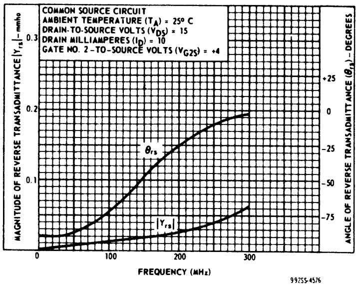


Fig. 23. - y_{rs} vs. frequency