

# RFG45N06LE, RFP45N06LE, RF1S45N06LE, RF1S45N06LESM

45A, 60V, ESD Rated, Avalanche Rated, Logic Level  
N-Channel Enhancement-Mode Power MOSFETs

July 1996

## Features

- 45A, 60V
- $r_{DS(ON)} = 0.028\Omega$
- 2kV ESD Protected
- *Temperature Compensating* PSPICE Model
- Peak Current vs Pulse Width Curve
- UIS Rating Curve
- +175°C Operating Temperature

## Ordering Information

PART NUMBER	PACKAGE	BRAND
RFG45N06LE	TO-247	FG45N06L
RFP45N06LE	TO-220AB	FP45N06L
RF1S45N06LE	TO-262AA	F45N06LE
RF1S45N06LESM	TO-263AB	F45N06LE

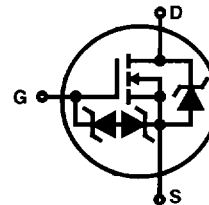
NOTE: When ordering, use the entire part number. Add the suffix 9A to obtain the TO-263AB variant in tape and reel, i.e. RF1S45N06LESM9A.

## Description

The RFG45N06LE, RFP45N06LE, RF1S45N06LE, and RF1S45N06LESM are N-Channel power MOSFETs manufactured using the MegaFET process. This process, which uses feature sizes approaching those of LSI circuits, gives optimum utilization of silicon, resulting in outstanding performance. They were designed for use in applications such as switching regulators, switching converters, motor drivers, and relay drivers. These transistors can be operated directly from integrated circuits.

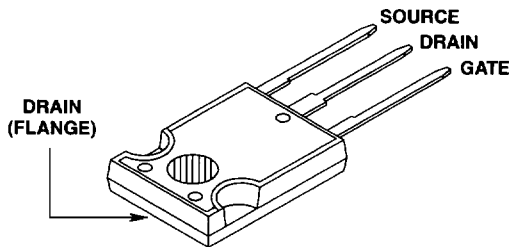
Formerly developmental type TA49177.

## Symbol

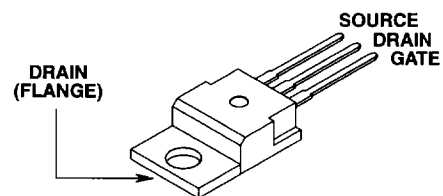


## Packaging

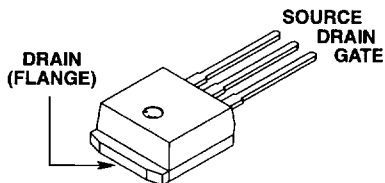
JEDEC STYLE TO-247



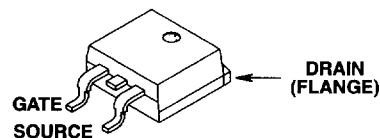
JEDEC TO-220AB



JEDEC TO-262AA



JEDEC TO-263AB



\*HRISS078\*

# RFG45N06LE, RFP45N06LE, RF1S45N06LE, RF1S45N06LESM

## Absolute Maximum Ratings $T_C = +25^\circ\text{C}$

		RFG45N06LE, RFP45N06LE, RF1S45N06LE, RF1S45N06LESM	UNITS
Drain-Source Voltage .....	$V_{DSS}$	60	V
Drain-Gate Voltage ( $R_{GS} = 1M\Omega$ ) .....	$V_{DGR}$	60	V
Gate-Source Voltage .....	$V_{GS}$	$\pm 10$	V
Drain Current			
Continuous .....	$I_D$	45	A
Pulsed Drain Current .....	$I_{DM}$	Refer to Peak Current Curve	
Pulsed Avalanche Rating .....	$E_{AS}$	Refer to UIS Curve	
Power Dissipation			
$T_C = +25^\circ\text{C}$ .....	$P_D$	142	W
Derate above $+25^\circ\text{C}$ .....		0.95	W/ $^\circ\text{C}$
Operating and Storage Temperature .....	$T_{STG}, T_J$	-55 to +175	$^\circ\text{C}$
Soldering Temperature of Leads for 10s .....	$T_L$	260	$^\circ\text{C}$
Electrostatic Discharge Rating MIL-STD-883, Category B(2) .....	ESD	2	kV

*CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.*

## Electrical Specifications $T_C = +25^\circ\text{C}$ , Unless Otherwise Specified

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNITS	
Drain-Source Breakdown Voltage	$BV_{DSS}$	$I_D = 250\mu\text{A}, V_{GS} = 0\text{V}$	60	-	-	V	
Gate Threshold Voltage	$V_{GS(TH)}$	$V_{GS} = V_{DS}, I_D = 250\mu\text{A}$	1	-	2	V	
Zero Gate Voltage Drain Current	$I_{DSS}$	$V_{DS} = 60\text{V}, V_{GS} = 0\text{V}$	$T_C = +25^\circ\text{C}$	-	-	1	$\mu\text{A}$
			$T_C = +150^\circ\text{C}$	-	-	50	$\mu\text{A}$
Gate-Source Leakage Current	$I_{GSS}$	$V_{GS} = \pm 10\text{V}$	-	-	10	$\mu\text{A}$	
On Resistance	$r_{DS(ON)}$	$I_D = 45\text{A}, V_{GS} = 5\text{V}$	-	-	0.028	$\Omega$	
Turn-On Time	$t_{ON}$	$V_{DD} = 30\text{V}, I_D = 45\text{A}, R_L = 0.67\Omega, V_{GS} = 5\text{V}, R_{GS} = 2.5\Omega$	-	-	215	ns	
Turn-On Delay Time	$t_{D(ON)}$		-	20	-	ns	
Rise Time	$t_R$		-	150	-	ns	
Turn-Off Delay Time	$t_{D(OFF)}$		-	55	-	ns	
Fall Time	$t_F$		-	90	-	ns	
Turn-Off Time	$t_{OFF}$		-	-	185	ns	
Total Gate Charge	$Q_G(TOT)$	$V_{GS} = 0\text{V to } 10\text{V}$	$V_{DD} = 48\text{V}, I_D = 45\text{A}, R_L = 1.07\Omega$	-	107	135	nC
Gate Charge at 5V	$Q_G(5)$	$V_{GS} = 0\text{V to } 5\text{V}$		-	58	75	nC
Threshold Gate Charge	$Q_G(TH)$	$V_{GS} = 0\text{V to } 1\text{V}$		-	2.4	3.0	nC
Input Capacitance	$C_{ISS}$	$V_{DS} = 25\text{V}, V_{GS} = 0\text{V}, f = 1\text{MHz}$	-	2150	-	pF	
Output Capacitance	$C_{OSS}$		-	640	-	pF	
Reverse Transfer Capacitance	$C_{RSS}$		-	240	-	pF	
Thermal Resistance Junction-to-Case	$R_{\theta JC}$		-	-	1.05	$^\circ\text{C/W}$	
Thermal Resistance Junction-to-Ambient	$R_{\theta JA}$	TO-247	-	-	30	$^\circ\text{C/W}$	
		TO-220, TO-262, and TO-263	-	-	80	$^\circ\text{C/W}$	

## Source-Drain Diode Ratings and Specifications

PARAMETER	SYMBOL	TEST CONDITIONS	MIN	TYP	MAX	UNITS
Forward Voltage	$V_{SD}$	$I_{SD} = 45\text{A}$	-	-	1.5	V
Reverse Recovery Time	$t_{RR}$	$I_{SD} = 45\text{A}, dI_{SD}/dt = 100\text{A}/\mu\text{s}$	-	-	155	ns

Typical Performance Curves

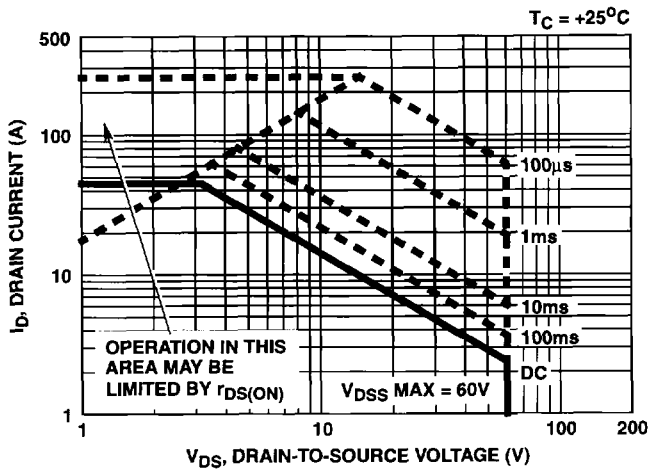


FIGURE 1. SAFE OPERATING AREA CURVE

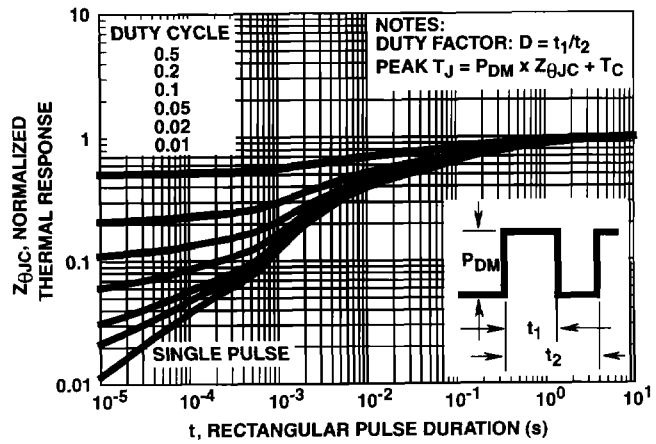


FIGURE 2. NORMALIZED MAXIMUM TRANSIENT THERMAL IMPEDANCE

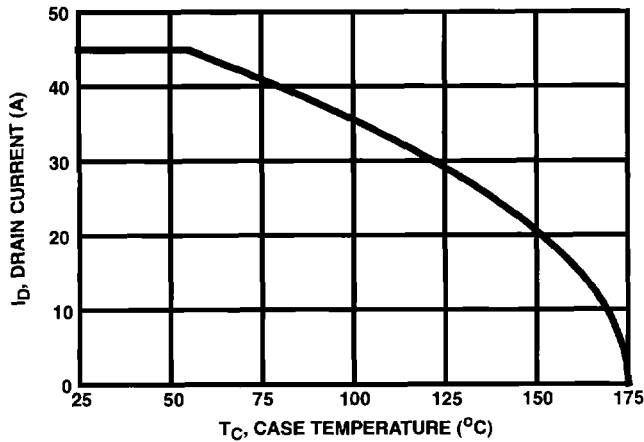


FIGURE 3. MAXIMUM CONTINUOUS DRAIN CURRENT vs TEMPERATURE

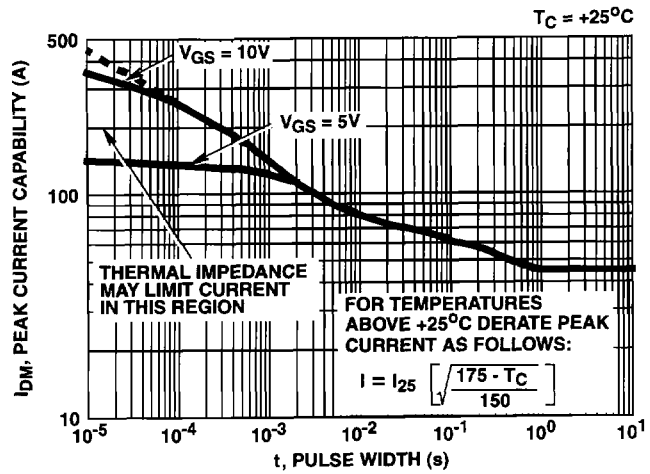


FIGURE 4. PEAK CURRENT CAPABILITY

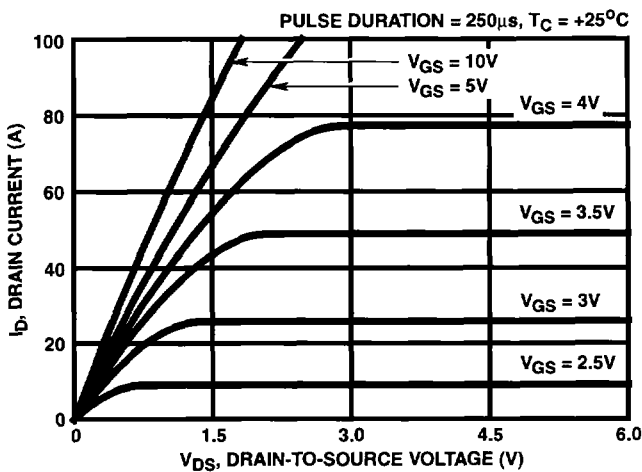


FIGURE 5. TYPICAL SATURATION CHARACTERISTICS

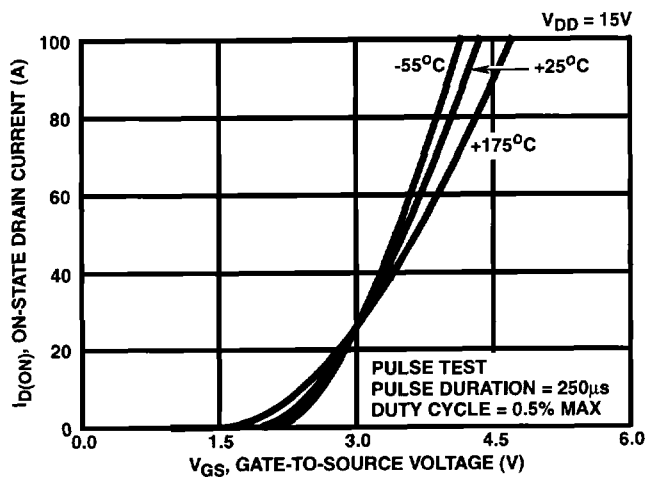


FIGURE 6. TYPICAL TRANSFER CHARACTERISTICS

Typical Performance Curves (Continued)

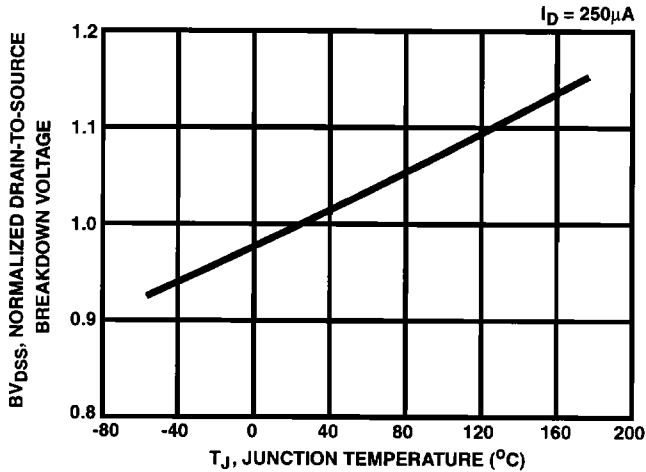


FIGURE 7. NORMALIZED DRAIN-SOURCE BREAKDOWN VOLTAGE vs JUNCTION TEMPERATURE

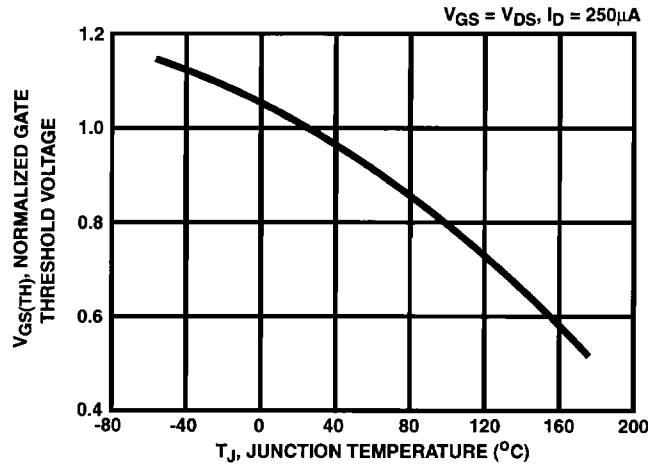


FIGURE 8. NORMALIZED GATE THRESHOLD VOLTAGE vs JUNCTION TEMPERATURE

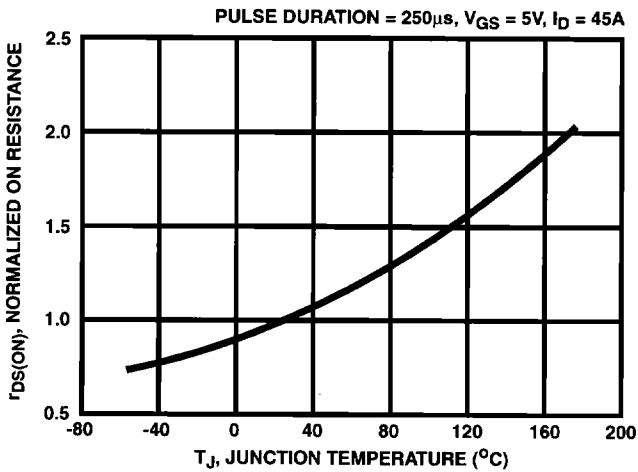


FIGURE 9. NORMALIZED  $r_{DS(ON)}$  vs JUNCTION TEMPERATURE

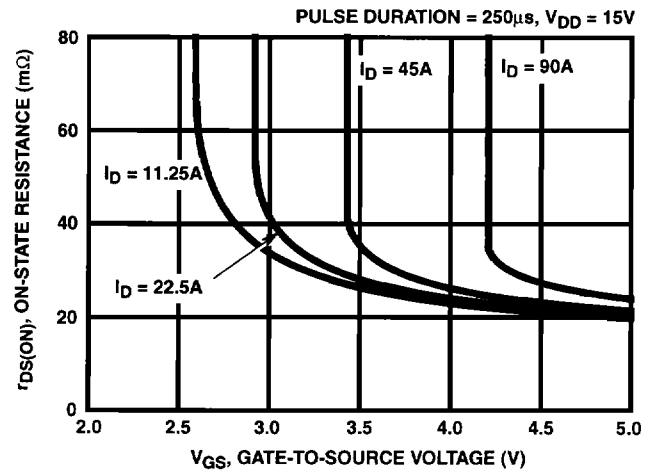


FIGURE 10.  $r_{DS(ON)}$  FOR VARYING CONDITIONS OF GATE VOLTAGE AND DRAIN CURRENT

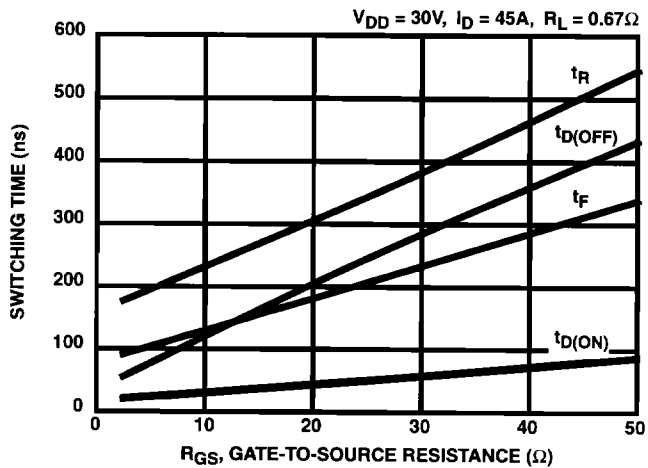


FIGURE 11. SWITCHING TIME AS A FUNCTION OF GATE RESISTANCE

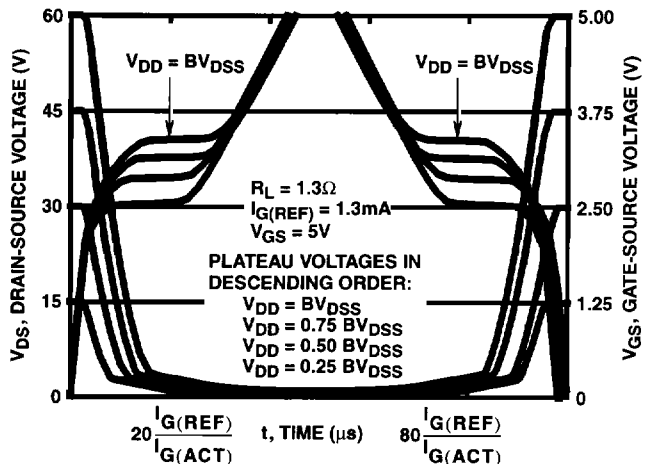


FIGURE 12. NORMALIZED SWITCHING WAVEFORMS FOR CONSTANT GATE CURRENT. REFER TO HARRIS APPLICATION NOTES AN7254 AND AN7260

Typical Performance Curves (Continued)

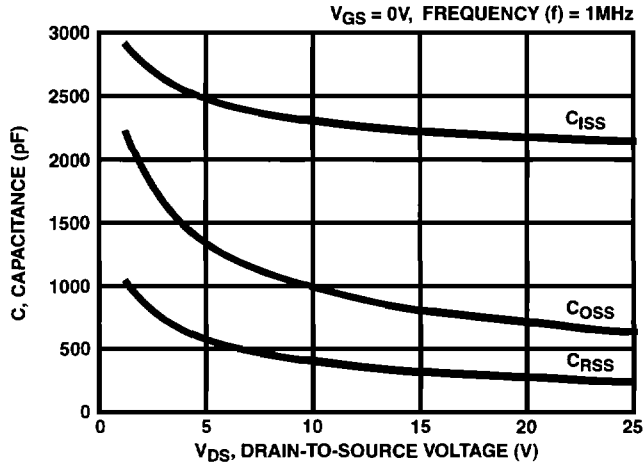


FIGURE 13. TYPICAL CAPACITANCE vs VOLTAGE

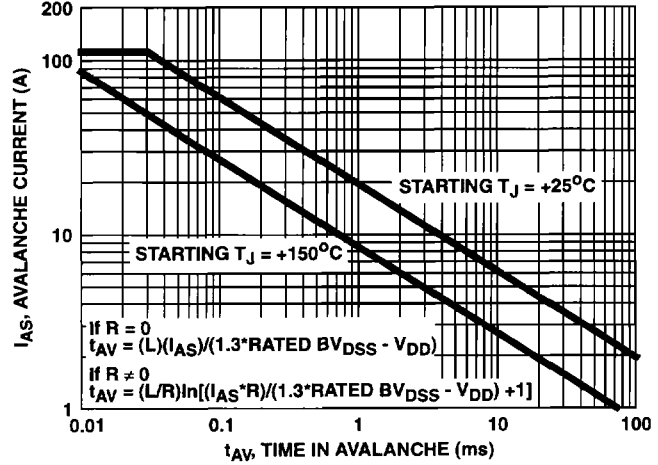


FIGURE 14. UNCLAMPED INDUCTIVE SWITCHING. REFER TO HARRIS APPLICATION NOTES AN9321 AND AN9322

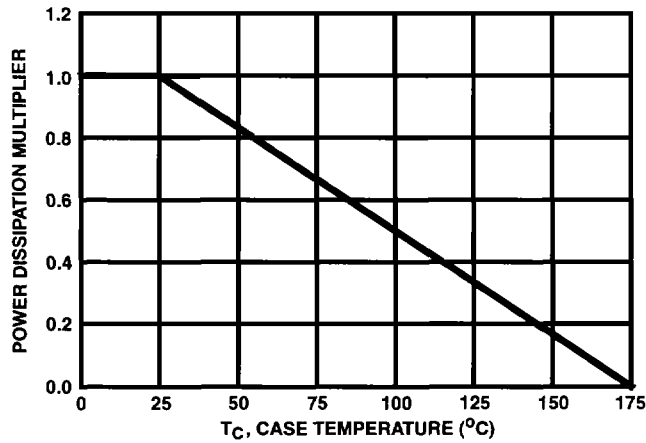


FIGURE 15. NORMALIZED POWER DISSIPATION vs TEMPERATURE DERATING CURVE

Test Circuits and Waveforms

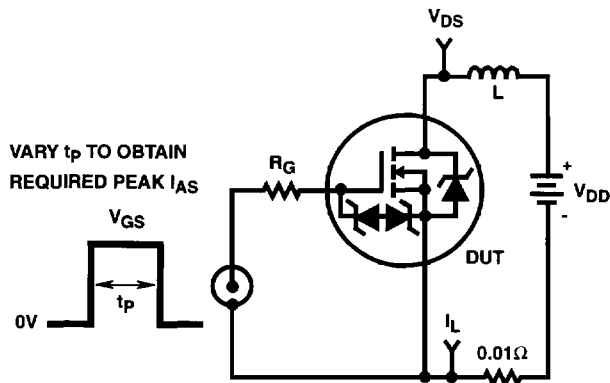


FIGURE 16. UNCLAMPED ENERGY TEST CIRCUIT

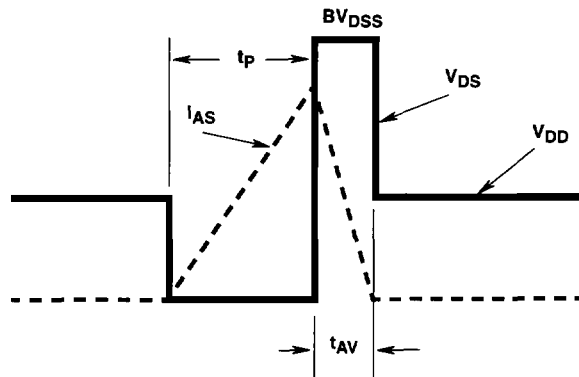


FIGURE 17. UNCLAMPED ENERGY WAVEFORMS

Test Circuits and Waveforms (Continued)

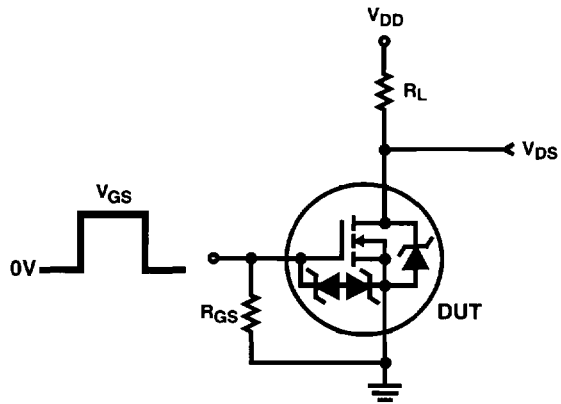


FIGURE 18. RESISTIVE SWITCHING TEST CIRCUIT

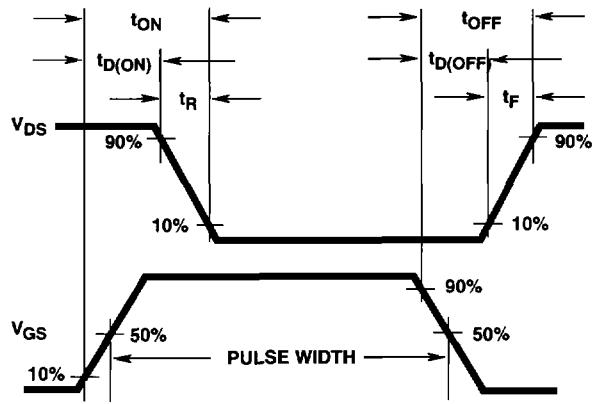


FIGURE 19. RESISTIVE SWITCHING WAVEFORMS

**RFG45N06LE, RFP45N06LE, RF1S45N06LE, RF1S45N06LESM**

**Temperature Compensated PSPICE Model for the RFG45N06LE, RFP45N06LE, RF1S45N06LE, RF1S45N06LESM**

**SUBCKT 45N06LE 2 1 3 ; rev 10/25/95**

CA 12 8 7.50e-9  
 CB 15 14 7.50e-9  
 CIN 6 8 1.90e-9

DBODY 7 5 DBODYMOD  
 DBREAK 5 11 DBREAKMOD  
 DESD1 91 9 DESD1MOD  
 DESD2 91 7 DESD2MOD  
 DPLCAP 10 5 DPLCAPMOD

EBREAK 11 7 17 18 67.53  
 EDS 14 8 5 8 1  
 EGS 13 8 6 8 1  
 ESG 6 10 6 8 1  
 EVTHRES 6 21 19 8 1  
 EVTEMP 20 6 18 22 1

IT 8 17 1

LDRAIN 2 5 1e-9  
 LGATE 1 9 7.29e-9  
 LSOURCE 3 7 6.16e-9

MMED 16 6 8 8 MMEDMOD  
 MSTRO 16 6 8 8 MSTROMOD  
 MWEAK 16 21 8 8 MWEAKMOD

RBREAK 17 18 RBREAKMOD 1  
 RDRAIN 50 16 RDRAINMOD 8.02e-3  
 RGATE 9 20 1.65  
 RLDRAIN 2 5 10  
 RLGATE 1 9 72.9  
 RLSOURCE 3 7 61.6  
 RSLC1 5 51 RSLCMOD 1e-6  
 RSLC2 5 50 1e3  
 RSOURCE 8 7 RSOURCEMOD 5.00e-3  
 RVTHRES 22 8 RVTHRESMOD 1  
 RVTEMP 18 19 RVTEMPMOD 1

S1A 6 12 13 8 S1AMOD  
 S1B 13 12 13 8 S1BMOD  
 S2A 6 15 14 13 S2AMOD  
 S2B 13 15 14 13 S2BMOD

VBAT 22 19 DC 1

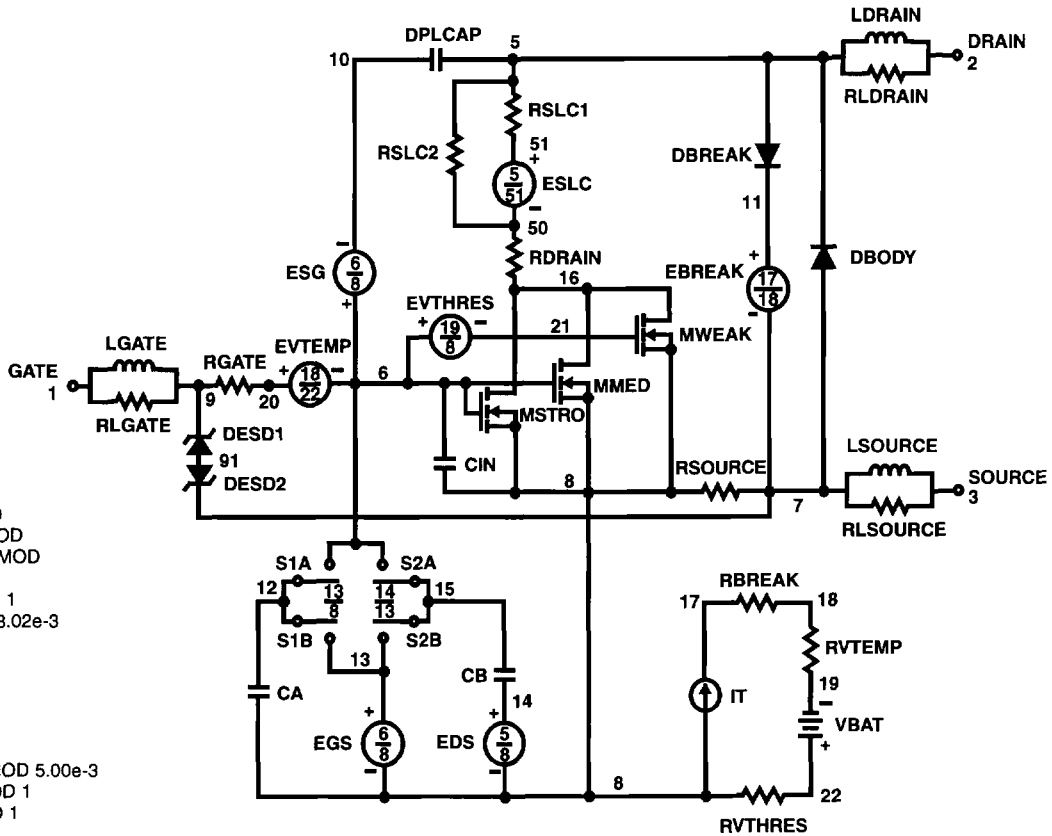
ESLC 51 50 VALUE = ((V(5,51)/ABS(V(5,51))))\*(PWR(V(5,51)/(1e-6\*190),2.1))

.MODEL DBODYMOD D (IS = 1.80e-12 RS = 6.85e-3 TRS1 = 1.85e-3 TRS2 = 3.99e-6 CJO = 1.72e-9 TT = 7.7e-8 M = 0.45)  
 .MODEL DBREAKMOD D (RS = 1.1e-1 TRS1 = 1.79e-3 TRS2 = -1.88e-5)  
 .MODEL DESD1MOD D (BV = 12.80 TBV1 = 0 TBV2 = 0 RS = 43 TRS1 = 1.07e-6 TRS2 = 0)  
 .MODEL DESD2MOD D (BV = 12.85 TBV1 = 0 TBV2 = 0 RS = 0 TRS1 = 1.07e-6 TRS2 = 0)  
 .MODEL DPLCAPMOD D (CJO = 1.69e-9 IS = 1e-30 N = 10 M = 0.60)  
 .MODEL MMEDMOD NMOS (VTO = 1.54 KP = 2.50 IS = 1e-30 N = 10 TOX = 1 L = 1u W = 1u RG = 1.65)  
 .MODEL MSTROMOD NMOS (VTO = 1.877 KP = 47.50 IS = 1e-30 N = 10 TOX = 1 L = 1u W = 1u)  
 .MODEL MWEAKMOD NMOS (VTO = 1.335 KP = 0.10 IS = 1e-30 N = 10 TOX = 1 L = 1u W = 1u RG = 16.5 RS = 0.1)  
 .MODEL RBREAKMOD RES (TC1 = 9.94e-4 TC2 = 3.94e-7)  
 .MODEL RDRAINMOD RES (TC1 = 7.70e-3 TC2 = 3.17e-5)  
 .MODEL RSLCMOD RES (TC1 = 1.16e-3 TC2 = 2.02e-5)  
 .MODEL RSOURCEMOD RES (TC1 = 0 TC2 = 0)  
 .MODEL RVTHRESMOD RES (TC1 = -7.89e-4 TC2 = -9.45e-6)  
 .MODEL RVTEMPMOD RES (TC1 = -1.60e-3 TC2 = 1.24e-6)  
 .MODEL S1AMOD VSWITCH (RON = 1e-5 ROFF = 0.1 VON = -4.80 VOFF = -1.80)  
 .MODEL S1BMOD VSWITCH (RON = 1e-5 ROFF = 0.1 VON = -1.80 VOFF = -4.80)  
 .MODEL S2AMOD VSWITCH (RON = 1e-5 ROFF = 0.1 VON = -1.10 VOFF = 1.90)  
 .MODEL S2BMOD VSWITCH (RON = 1e-5 ROFF = 0.1 VON = 1.90 VOFF = -1.10)

ENDS

NOTE:

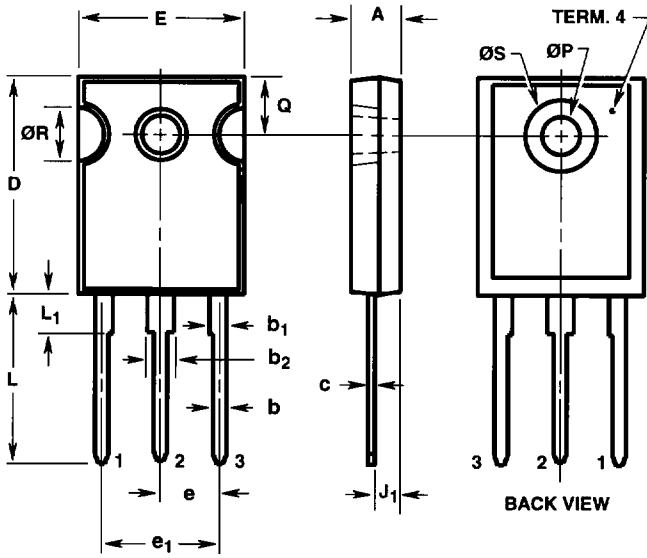
- For further discussion of the PSPICE model, consult **A New PSPICE Sub-Circuit for the Power MOSFET Featuring Global Temperature Options**; IEEE Power Electronics Specialist Conference Records, 1991.



RFG45N06LE, RFP45N06LE, RF1S45N06LE, RF1S45N06LESM

TO-247

3 LEAD JEDEC STYLE TO-247 PLASTIC PACKAGE



- LEAD NO. 1 - GATE
- LEAD NO. 2 - DRAIN
- LEAD NO. 3 - SOURCE
- TERM. 4 - DRAIN

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.180	0.190	4.58	4.82	-
b	0.046	0.051	1.17	1.29	2, 3
b <sub>1</sub>	0.060	0.070	1.53	1.77	1, 2
b <sub>2</sub>	0.095	0.105	2.42	2.66	1, 2
c	0.020	0.026	0.51	0.66	1, 2, 3
D	0.800	0.820	20.32	20.82	-
E	0.605	0.625	15.37	15.87	-
e	0.219 TYP		5.56 TYP		4
e <sub>1</sub>	0.438 BSC		11.12 BSC		4
J <sub>1</sub>	0.090	0.105	2.29	2.66	5
L	0.620	0.640	15.75	16.25	-
L <sub>1</sub>	0.145	0.155	3.69	3.93	1
ØP	0.138	0.144	3.51	3.65	-
Q	0.210	0.220	5.34	5.58	-
ØR	0.195	0.205	4.96	5.20	-
ØS	0.260	0.270	6.61	6.85	-

NOTES:

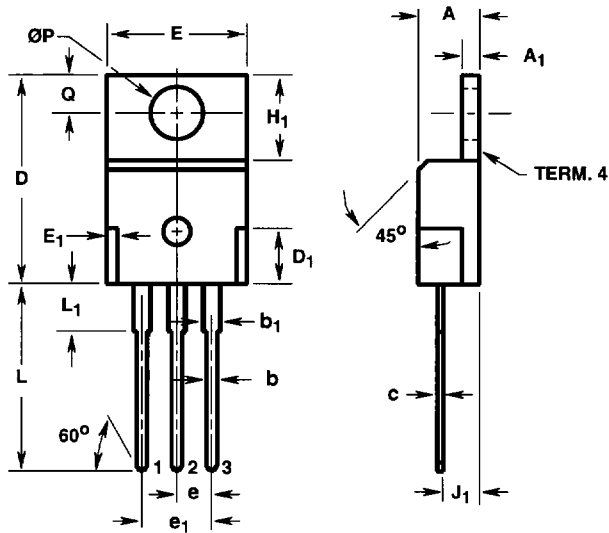
1. Lead dimension and finish uncontrolled in L<sub>1</sub>.
2. Lead dimension (without solder).
3. Add typically 0.002 inches (0.05mm) for solder coating.
4. Position of lead to be measured 0.250 inches (6.35mm) from bottom of dimension D.
5. Position of lead to be measured 0.100 inches (2.54mm) from bottom of dimension D.
6. Controlling dimension: Inch.
7. Revision 1 dated 1-93.



RF1S45N06LE, RFP45N06LE, RFG45N06LE, RF1S45N06LESM

**TO-220AB**

3 LEAD JEDEC TO-220AB PLASTIC PACKAGE



- LEAD NO. 1 - GATE
- LEAD NO. 2 - DRAIN
- LEAD NO. 3 - SOURCE
- TERM. 4 - DRAIN

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.170	0.180	4.32	4.57	-
A <sub>1</sub>	0.048	0.052	1.22	1.32	-
b	0.030	0.034	0.77	0.86	3, 4
b <sub>1</sub>	0.045	0.055	1.15	1.39	2, 3
c	0.014	0.019	0.36	0.48	2, 3, 4
D	0.590	0.610	14.99	15.49	-
D <sub>1</sub>	-	0.160	-	4.06	-
E	0.395	0.410	10.04	10.41	-
E <sub>1</sub>	-	0.030	-	0.76	-
e	0.100 TYP		2.54 TYP		5
e <sub>1</sub>	0.200 BSC		5.08 BSC		5
H <sub>1</sub>	0.235	0.255	5.97	6.47	-
J <sub>1</sub>	0.100	0.110	2.54	2.79	6
L	0.530	0.550	13.47	13.97	-
L <sub>1</sub>	0.130	0.150	3.31	3.81	2
ØP	0.149	0.153	3.79	3.88	-
Q	0.102	0.112	2.60	2.84	-

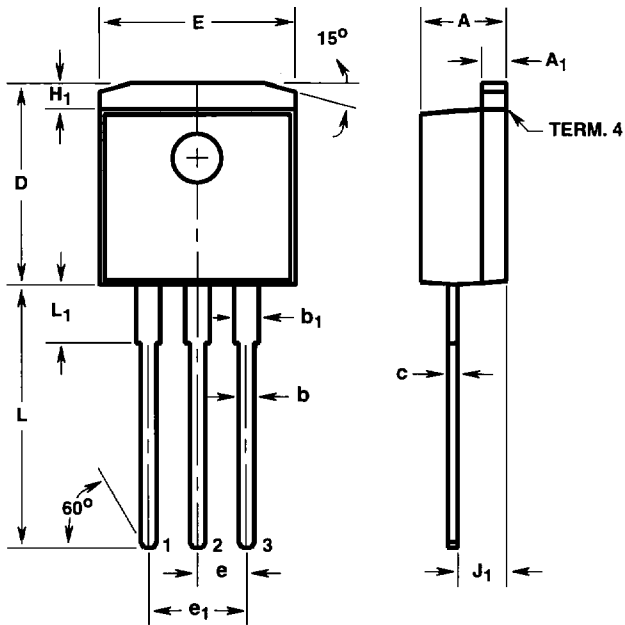
NOTES:

1. These dimensions are within allowable dimensions of Rev. J of JEDEC TO-220AB outline dated 3-24-87.
2. Lead dimension and finish uncontrolled in L<sub>1</sub>.
3. Lead dimension (without solder).
4. Add typically 0.002 inches (0.05mm) for solder coating.
5. Position of lead to be measured 0.250 inches (6.35mm) from bottom of dimension D.
6. Position of lead to be measured 0.100 inches (2.54mm) from bottom of dimension D.
7. Controlling dimension: Inch.
8. Revision 1 dated 1-93.

**RF1S45N06LE, RFP45N06LE, RFG45N06LE, RF1S45N06LESM**

**TO-262AA**

3 LEAD JEDEC TO-262AA PLASTIC PACKAGE



LEAD NO. 1 - GATE  
 LEAD NO. 2 - DRAIN  
 LEAD NO. 3 - SOURCE  
 TERM. 4 - DRAIN

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.170	0.180	4.32	4.57	-
A <sub>1</sub>	0.048	0.052	1.22	1.32	3, 4
b	0.030	0.034	0.77	0.86	3, 4
b <sub>1</sub>	0.045	0.055	1.15	1.39	3, 4
c	0.018	0.022	0.46	0.55	3, 4
D	0.405	0.425	10.29	10.79	-
E	0.395	0.405	10.04	10.28	-
e	0.100 TYP		2.54 TYP		5
e <sub>1</sub>	0.200 BSC		5.08 BSC		5
H <sub>1</sub>	0.045	0.055	1.15	1.39	-
J <sub>1</sub>	0.095	0.105	2.42	2.66	6
L	0.530	0.550	13.47	13.97	-
L <sub>1</sub>	0.110	0.130	2.80	3.30	2

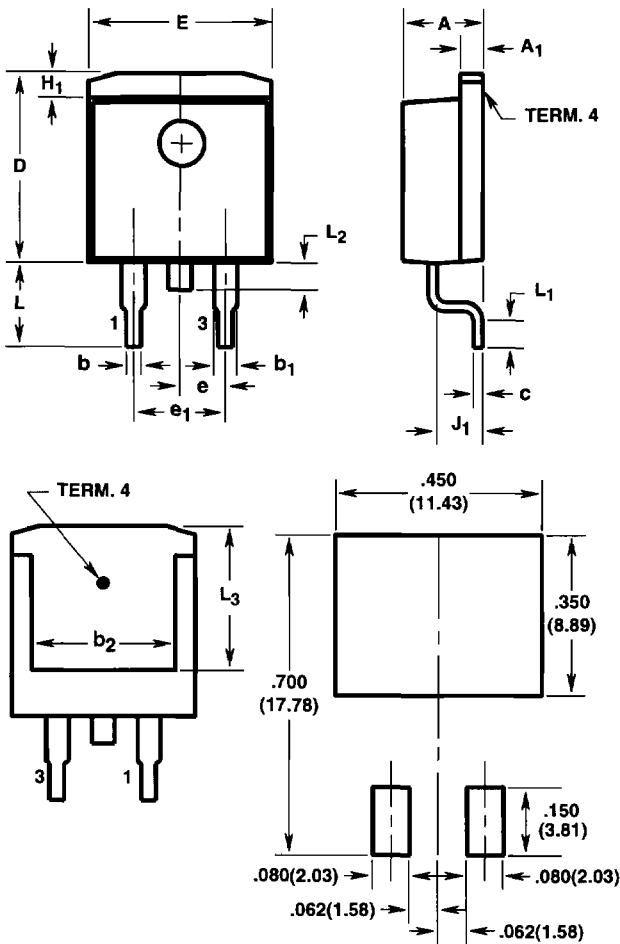
NOTES:

1. These dimensions are within allowable dimensions of Rev. A of JEDEC TO-262AA outline dated 6-90.
2. Solder finish uncontrolled in this area.
3. Dimension (without solder).
4. Add typically 0.002 inches (0.05mm) for solder plating.
5. Position of lead to be measured 0.250 inches (6.35mm) from bottom of dimension D.
6. Position of lead to be measured 0.100 inches (2.54mm) from bottom of dimension D.
7. Controlling dimension: Inch.
8. Revision 4 dated 10-95.

RFG45N06LE, RFP45N06LE, RF1S45N06LE, RF1S45N06LESM

**TO-263AB**

SURFACE MOUNT JEDEC TO-263AB PLASTIC PACKAGE



**MINIMUM PAD SIZE RECOMMENDED FOR SURFACE-MOUNTED APPLICATIONS**

- LEAD NO. 1 - GATE
- LEAD NO. 3 - SOURCE
- TERM. 4 - DRAIN

SYMBOL	INCHES		MILLIMETERS		NOTES
	MIN	MAX	MIN	MAX	
A	0.170	0.180	4.32	4.57	-
A <sub>1</sub>	0.048	0.052	1.22	1.32	4, 5
b	0.030	0.034	0.77	0.86	4, 5
b <sub>1</sub>	0.045	0.055	1.15	1.39	4, 5
b <sub>2</sub>	0.310	-	7.88	-	2
c	0.018	0.022	0.46	0.55	4, 5
D	0.405	0.425	10.29	10.79	-
E	0.395	0.405	10.04	10.28	-
e	0.100 TYP		2.54 TYP		7
e <sub>1</sub>	0.200 BSC		5.08 BSC		7
H <sub>1</sub>	0.045	0.055	1.15	1.39	-
J <sub>1</sub>	0.095	0.105	2.42	2.66	-
L	0.175	0.195	4.45	4.95	-
L <sub>1</sub>	0.090	0.110	2.29	2.79	4, 6
L <sub>2</sub>	0.050	0.070	1.27	1.77	3
L <sub>3</sub>	0.315	-	8.01	-	2

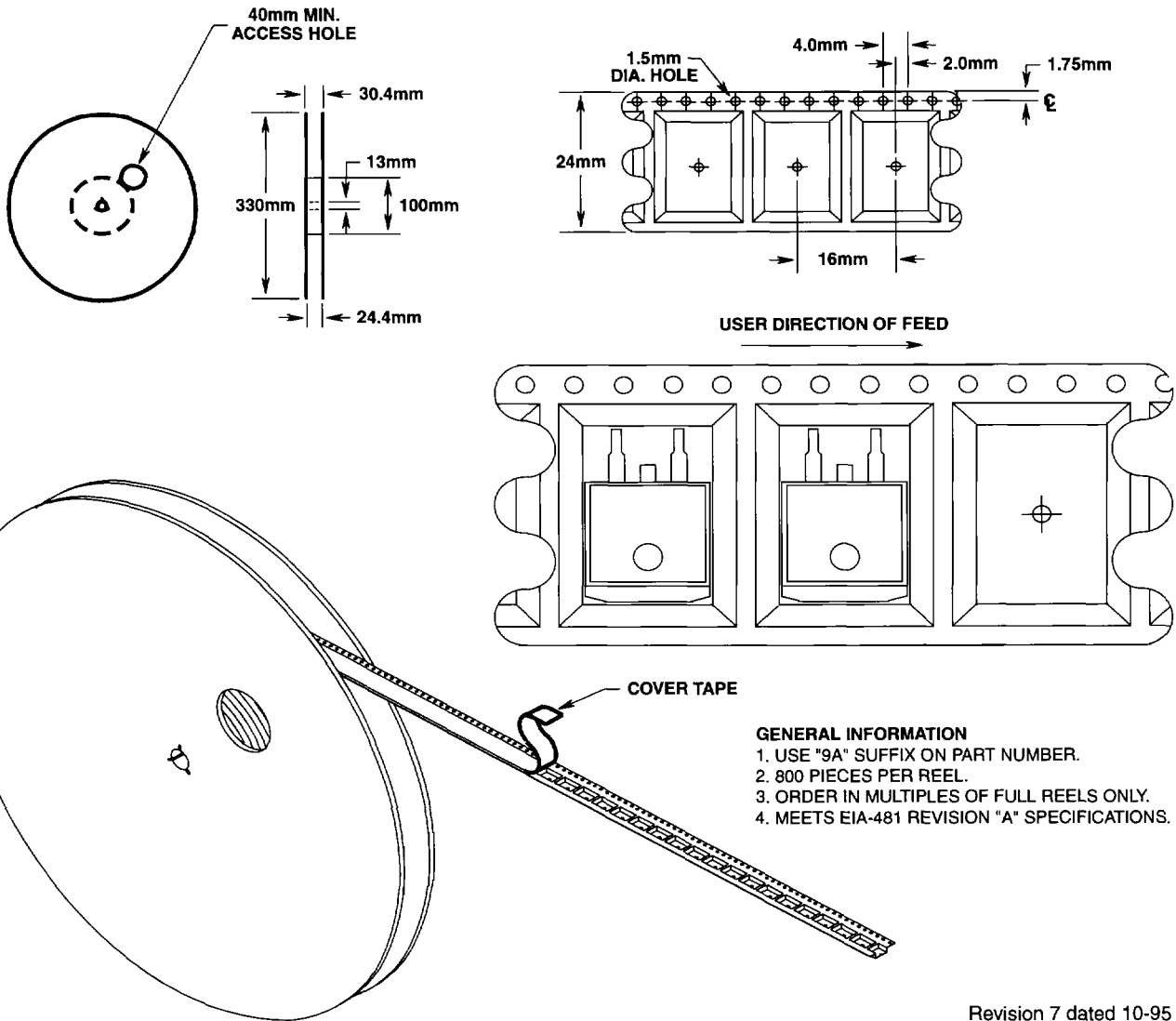
**NOTES:**

1. These dimensions are within allowable dimensions of Rev. C of JEDEC TO-263AB outline dated 2-92.
2. L<sub>3</sub> and b<sub>2</sub> dimensions established a minimum mounting surface for terminal 4.
3. Solder finish uncontrolled in this area.
4. Dimension (without solder).
5. Add typically 0.002 inches (0.05mm) for solder plating.
6. L<sub>1</sub> is the terminal length for soldering.
7. Position of lead to be measured 0.120 inches (3.05mm) from bottom of dimension D.
8. Controlling dimension: Inch.
9. Revision 7 dated 10-95.

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24mm TAPE AND REEL



- GENERAL INFORMATION**
1. USE "9A" SUFFIX ON PART NUMBER.
  2. 800 PIECES PER REEL.
  3. ORDER IN MULTIPLES OF FULL REELS ONLY.
  4. MEETS EIA-481 REVISION "A" SPECIFICATIONS.

Revision 7 dated 10-95

All Harris Semiconductor products are manufactured, assembled and tested under **ISO9000** quality systems certification.

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