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# MTP5N40E

Designer's™ Data Sheet

**TMOS E-FET™**

**High Energy Power FET**

**N-Channel Enhancement-Mode Silicon Gate**



**ON Semiconductor®**

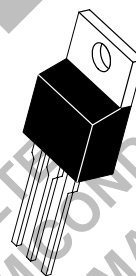
<http://onsemi.com>

This advanced high voltage TMOS E-FET is designed to withstand high energy in the avalanche mode and switch efficiently. This new high energy device also offers a drain-to-source diode with fast recovery time. Designed for high voltage, high speed switching applications such as power supplies, PWM motor controls and other inductive loads, the avalanche energy capability is specified to eliminate the guesswork in designs where inductive loads are switched and offer additional safety margin against unexpected voltage transients.

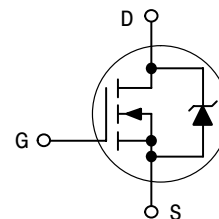
- Avalanche Energy Capability Specified at Elevated Temperature
- Low Stored Gate Charge for Efficient Switching
- Internal Source-to-Drain Diode Designed to Replace External Zener Transient Suppressor — Absorbs High Energy in the Avalanche Mode
- Source-to-Drain Diode Recovery Time Comparable to Discrete Fast Recovery Diode

**TMOS POWER FET**  
**5.0 AMPERES, 400 VOLTS**

$R_{DS(on)} = 1.0 \Omega$



TO-220AB  
CASE 221A-06  
Style 5



**Designer's Data for "Worst Case" Conditions** — The Designer's Data Sheet permits the design of most circuits entirely from the information presented. SOA Limit curves — representing boundaries on device characteristics — are given to facilitate "worst case" design.

**Preferred** devices are Motorola recommended choices for future use and best overall value.

# MTP5N40E

## MAXIMUM RATINGS (T<sub>C</sub> = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Drain-Source Voltage	V <sub>DSS</sub>	400	Vdc
Drain-Gate Voltage (R <sub>GS</sub> = 1.0 MΩ)	V <sub>DGR</sub>	400	Vdc
Gate-Source Voltage — Continuous — Non-repetitive	V <sub>GS</sub> V <sub>GSM</sub>	±20 ±40	Vdc Vpk
Drain Current — Continuous — Pulsed	I <sub>D</sub> I <sub>DM</sub>	5.0 12	Adc
Total Power Dissipation @ T <sub>C</sub> = 25°C Derate above 25°C	P <sub>D</sub>	75 0.6	Watts W/°C
Operating and Storage Temperature Range	T <sub>J</sub> , T <sub>stg</sub>	-55 to 150	°C

## UNCLAMPED DRAIN-TO-SOURCE AVALANCHE CHARACTERISTICS (T<sub>J</sub> < 150°C)

Single Pulse Drain-to-Source Avalanche Energy — T <sub>J</sub> = 25°C — T <sub>J</sub> = 100°C	W <sub>DSR</sub> (1)	290 46	mJ
Repetitive Pulse Drain-to-Source Avalanche Energy	W <sub>DSR</sub> (2)	7.4	

## THERMAL CHARACTERISTICS

Thermal Resistance — Junction to Case — Junction to Ambient	R <sub>θJC</sub> R <sub>θJA</sub>	1.67 62.5	°C/W
Maximum Lead Temperature for Soldering Purposes, 1/8" from case for 10 seconds	T <sub>L</sub>	260	°C

(1) V<sub>DD</sub> = 50 V, I<sub>D</sub> = 5.0 A

(2) Pulse Width and frequency is limited by T<sub>J</sub>(max) and thermal response

# MTP5N40E

## ELECTRICAL CHARACTERISTICS (T<sub>J</sub> = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
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### OFF CHARACTERISTICS

Drain-to-Source Breakdown Voltage (V <sub>GS</sub> = 0, I <sub>D</sub> = 250 μAdc)	V <sub>(BR)DSS</sub>	400	—	—	Vdc
Zero Gate Voltage Drain Current (V <sub>DS</sub> = 400 V, V <sub>GS</sub> = 0) (V <sub>DS</sub> = 320 V, V <sub>GS</sub> = 0, T <sub>J</sub> = 125°C)	I <sub>DSS</sub>	— —	— —	0.25 1.0	mAdc
Gate-Body Leakage Current, Forward (V <sub>GSF</sub> = 20 Vdc, V <sub>DS</sub> = 0)	I <sub>GSSF</sub>	—	—	100	nAdc
Gate-Body Leakage Current, Reverse (V <sub>GSR</sub> = 20 Vdc, V <sub>DS</sub> = 0)	I <sub>GSSR</sub>	—	—	100	nAdc

### ON CHARACTERISTICS\*

Gate Threshold Voltage (V <sub>DS</sub> = V <sub>GS</sub> , I <sub>D</sub> = 250 μAdc) (T <sub>J</sub> = 125°C)	V <sub>GS(th)</sub>	2.0 1.5	— —	4.0 3.5	Vdc
Static Drain-Source On-Resistance (V <sub>GS</sub> = 10 Vdc, I <sub>D</sub> = 2.5 Adc)	R <sub>DS(on)</sub>	—	0.8	1.0	Ohm
Drain-Source On-Voltage (V <sub>GS</sub> = 10 Vdc) (I <sub>D</sub> = 5.0 A) (I <sub>D</sub> = 2.5 A, T <sub>J</sub> = 100°C)	V <sub>DS(on)</sub>	— —	— —	6.2 5.0	Vdc
Forward Transconductance (V <sub>DS</sub> = 15 Vdc, I <sub>D</sub> = 2.5 Adc)	g <sub>FS</sub>	2.0	—	—	mhos

### DYNAMIC CHARACTERISTICS

Input Capacitance	(V <sub>DS</sub> = 25 V, V <sub>GS</sub> = 0, f = 1.0 MHz)	C <sub>iss</sub>	—	775	—	pF
Output Capacitance		C <sub>oss</sub>	—	96	—	
Transfer Capacitance		C <sub>rss</sub>	—	22	—	

### SWITCHING CHARACTERISTICS\*

Turn-On Delay Time	(V <sub>DD</sub> = 250 V, I <sub>D</sub> ≈ 5.0 A, R <sub>G</sub> = 12 Ω, R <sub>L</sub> = 50 Ω, V <sub>GS(on)</sub> = 10 V)	t <sub>d(on)</sub>	—	24	—	ns
Rise Time		t <sub>r</sub>	—	34	—	
Turn-Off Delay Time		t <sub>d(off)</sub>	—	60	—	
Fall Time		t <sub>f</sub>	—	36	—	
Total Gate Charge	(V <sub>DS</sub> = 320 V, I <sub>D</sub> = 5.0 A, V <sub>GS</sub> = 10 V)	Q <sub>g</sub>	—	27	32	nC
Gate-Source Charge		Q <sub>gs</sub>	—	3.5	—	
Gate-Drain Charge		Q <sub>gd</sub>	—	14	—	

### SOURCE-DRAIN DIODE CHARACTERISTICS\*

Forward On-Voltage	(I <sub>S</sub> = 5.0 A, di/dt = 100 A/μs)	V <sub>SD</sub>	—	—	1.4	Vdc
Forward Turn-On Time		t <sub>on</sub>	—	**	—	ns
Reverse Recovery Time		t <sub>rr</sub>	—	—	660	

### INTERNAL PACKAGE INDUCTANCE

Internal Drain Inductance (Measured from the contact screw on tab to center of die) (Measured from the drain lead 0.25" from package to center of die)	L <sub>d</sub>	— —	— —	3.5 4.5	— —	nH
Internal Source Inductance (Measured from the source lead 0.25" from package to source bond pad)	L <sub>s</sub>	—	—	7.5	—	

\* Indicates Pulse Test: Pulse Width = 300 μs Max, Duty Cycle ≤ 2.0%.

\*\* Limited by circuit inductance.

## TYPICAL ELECTRICAL CHARACTERISTICS

# MTP5N40E

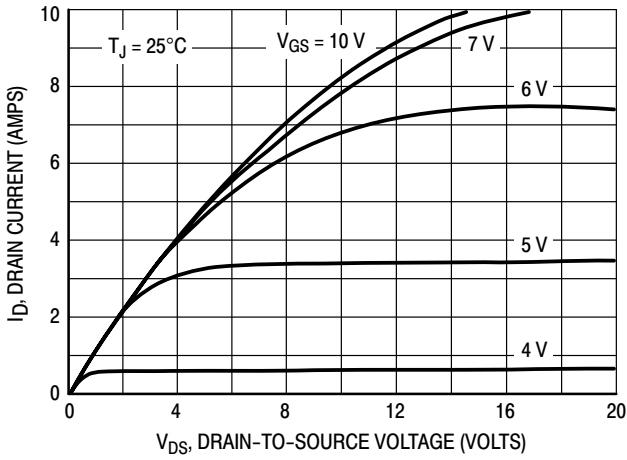


Figure 1. On-Region Characteristics

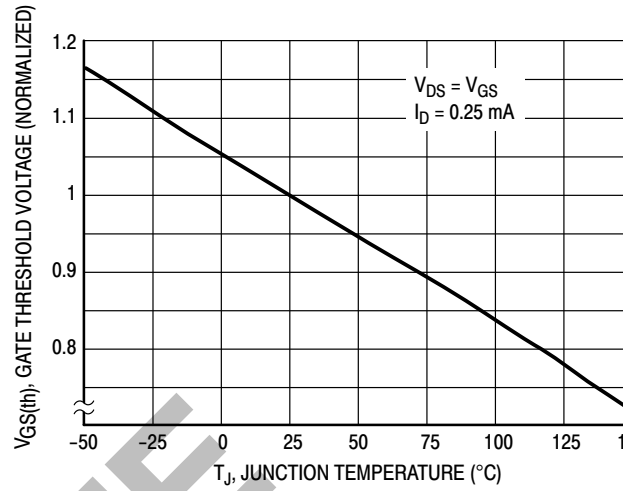


Figure 2. Gate-Threshold Voltage Variation With Temperature

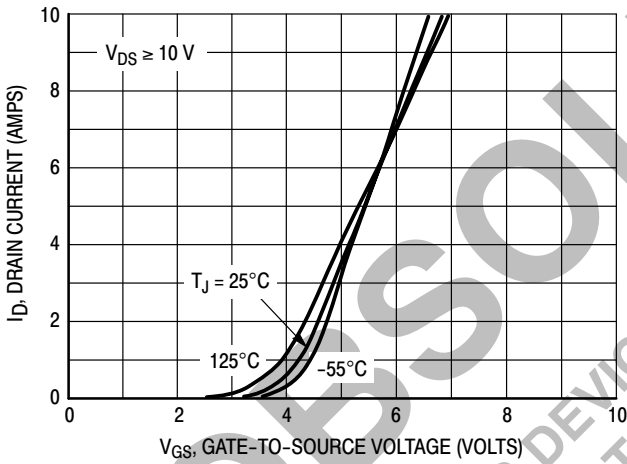


Figure 3. Transfer Characteristics

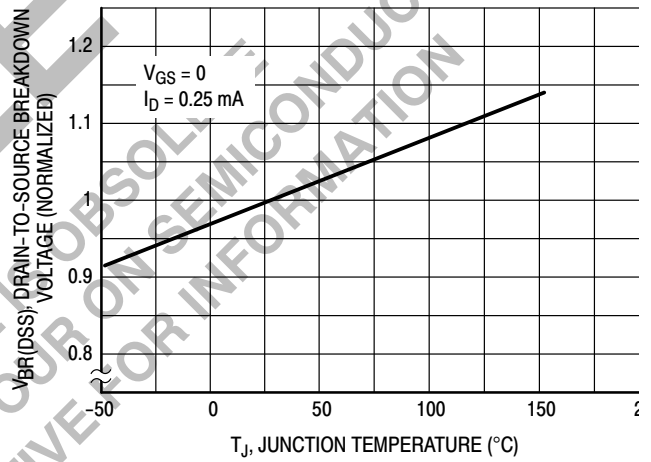


Figure 4. Breakdown Voltage Variation With Temperature

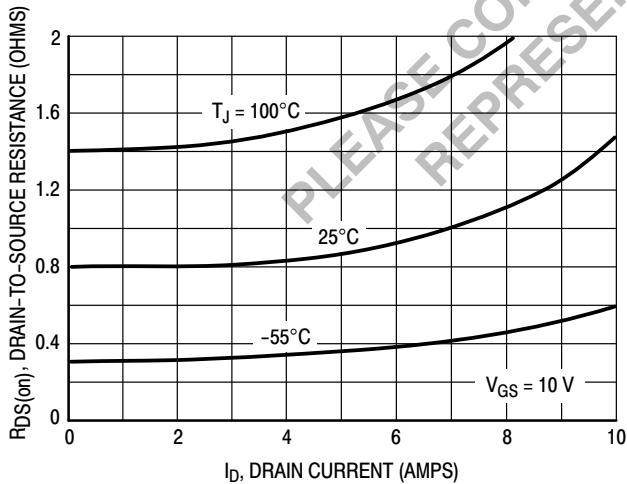


Figure 5. On-Resistance versus Drain Current

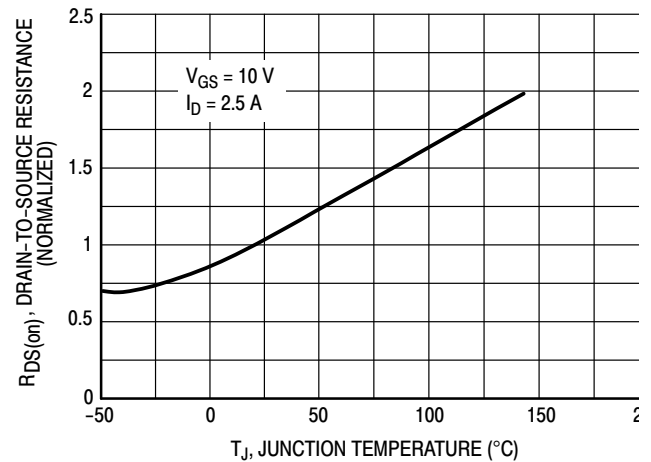


Figure 6. On-Resistance Variation With Temperature

SAFE OPERATING AREA INFORMATION

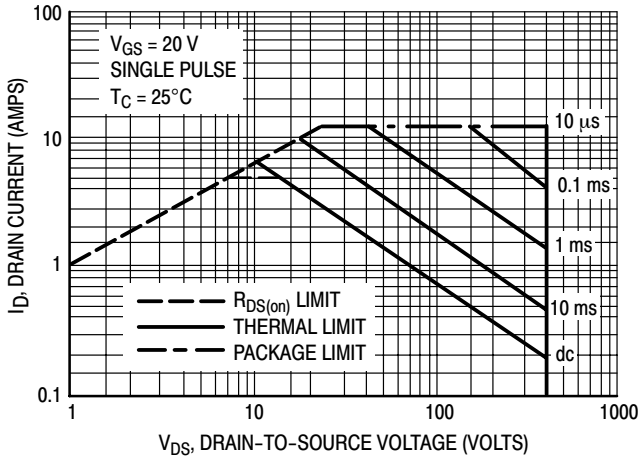


Figure 7. Maximum Rated Forward Biased Safe Operating Area

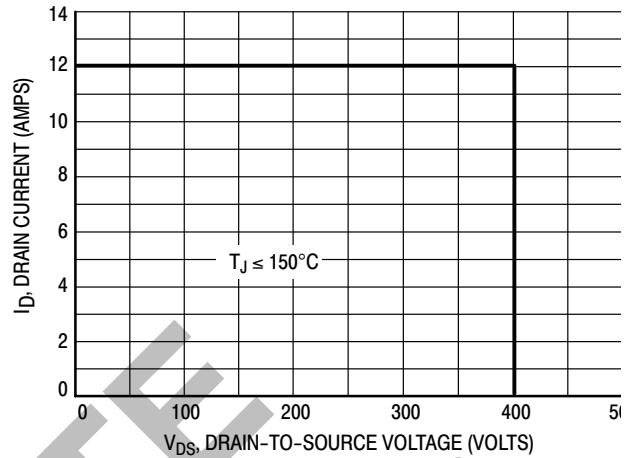


Figure 8. Maximum Rated Switching Safe Operating Area

FORWARD BIASED SAFE OPERATING AREA

The FBSOA curves define the maximum drain-to-source voltage and drain current that a device can safely handle when it is forward biased, or when it is on, or being turned on. Because these curves include the limitations of simultaneous high voltage and high current, up to the rating of the device, they are especially useful to designers of linear systems. The curves are based on a case temperature of 25°C and a maximum junction temperature of 150°C. Limitations for repetitive pulses at various case temperatures can be determined by using the thermal response curves. Motorola Application Note, AN569, "Transient Thermal Resistance—General Data and Its Use" provides detailed instructions.

SWITCHING SAFE OPERATING AREA

The switching safe operating area (SOA) of Figure 8 is the boundary that the load line may traverse without incurring damage to the MOSFET. The fundamental limits are the peak current,  $I_{DM}$  and the breakdown voltage,  $V_{(BR)DSS}$ . The switching SOA shown in Figure 8 is

applicable for both turn-on and turn-off of the devices for switching times less than one microsecond.

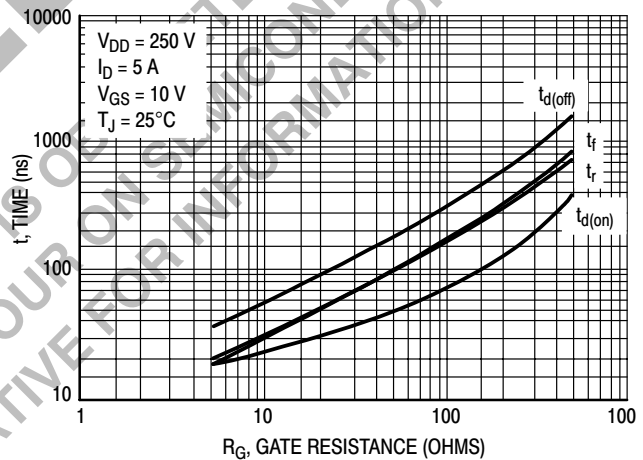


Figure 9. Resistive Switching Time Variation versus Gate Resistance

MTP5N40E

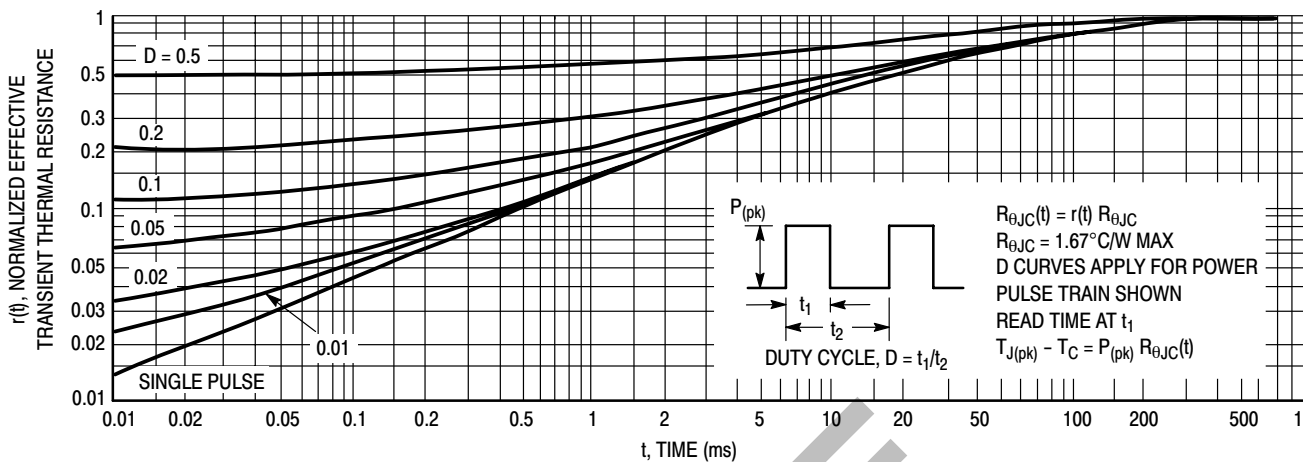


Figure 10. Thermal Response

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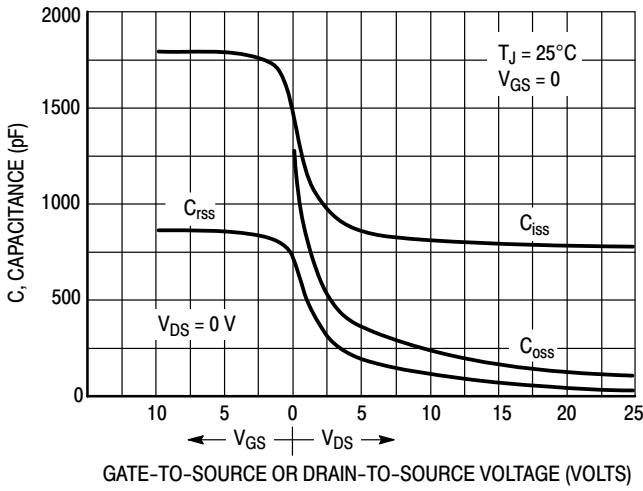


Figure 11. Capacitance Variation

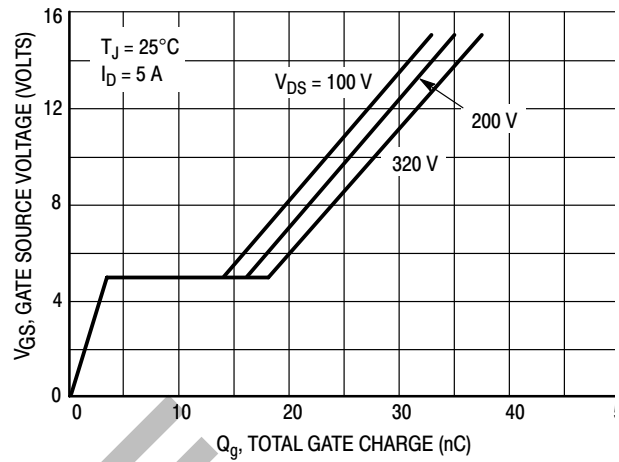


Figure 12. Gate Charge versus Gate-To-Source Voltage

**COMMUTATING SAFE OPERATING AREA (CSOA)**

The Commutating Safe Operating Area (CSOA) of Figure 14 defines the limits of safe operation for commutated source-drain current versus re-applied drain voltage when the source-drain diode has undergone forward bias. The curve shows the limitations of  $I_{FM}$  and peak  $V_{DS}$  for a given rate of change of source current. It is applicable when waveforms similar to those of Figure 11 are present. Full or half-bridge PWM DC motor controllers are common applications requiring CSOA data.

Device stresses increase with increasing rate of change of source current so  $di_s/dt$  is specified with a maximum value. Higher values of  $di_s/dt$  require an appropriate derating of  $I_{FM}$ , peak  $V_{DS}$  or both. Ultimately  $di_s/dt$  is limited primarily by device, package, and circuit impedances. Maximum device stress occurs during  $t_{rr}$  as the diode goes from conduction to reverse blocking.

$V_{DS(pk)}$  is the peak drain-to-source voltage that the device must sustain during commutation;  $I_{FM}$  is the maximum forward source-drain diode current just prior to the onset of commutation.

$V_R$  is specified at 80% of  $V_{(BR)DSS}$  to ensure that the CSOA stress is maximized as  $I_S$  decays from  $I_{RM}$  to zero.

$R_{GS}$  should be minimized during commutation.  $T_J$  has only a second order effect on CSOA.

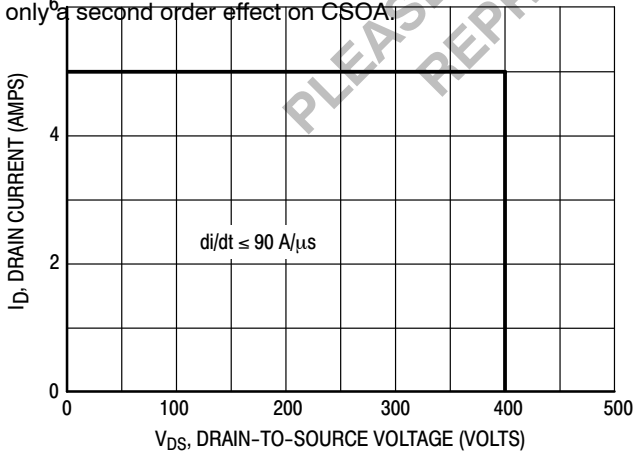


Figure 13. Commutating Safe Operating Area (CSOA)

Stray inductances in Motorola's test circuit are assumed to be practical minimums.  $dV_{DS}/dt$  in excess of 10 V/ns was attained with  $di_s/dt$  of 400 A/ $\mu$ s.

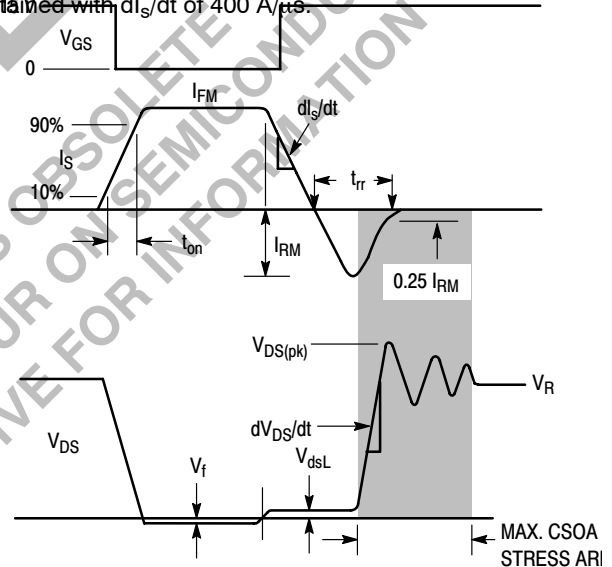


Figure 15. Commutating Waveforms

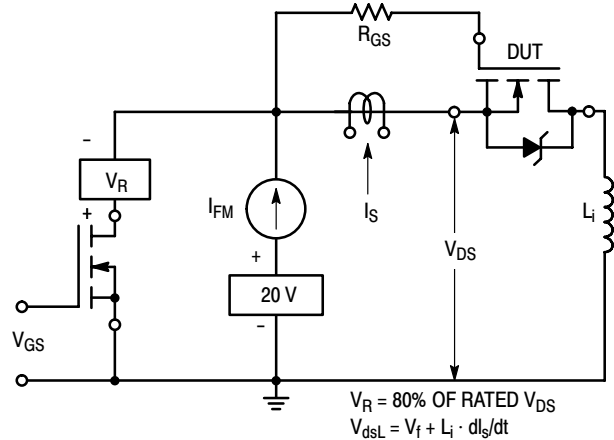


Figure 14. Commutating Safe Operating Area Test Circuit



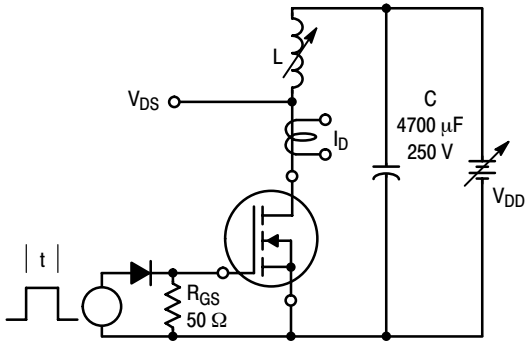


Figure 16. Unclamped Inductive Switching Test Circuit

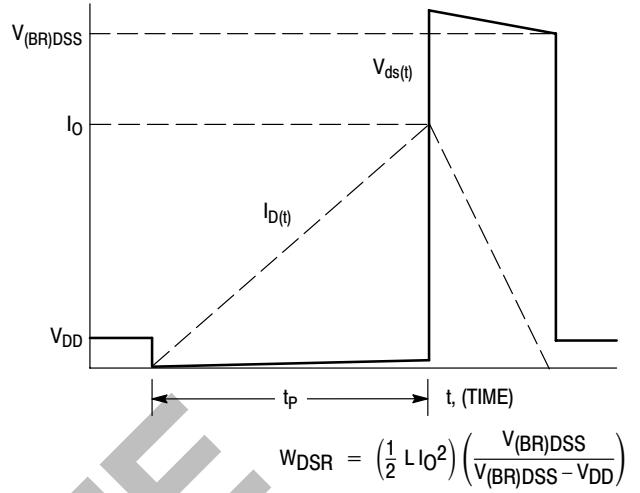
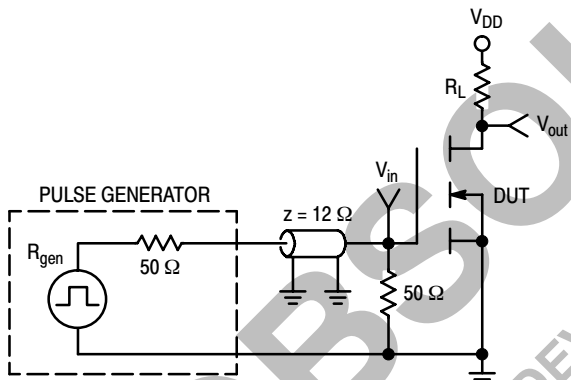


Figure 17. Unclamped Inductive Switching Waveforms

RESISTIVE SWITCHING



\*Note: The Mirror is shorted to the Kelvin terminal for this test.

Figure 18. Switching Test Circuit

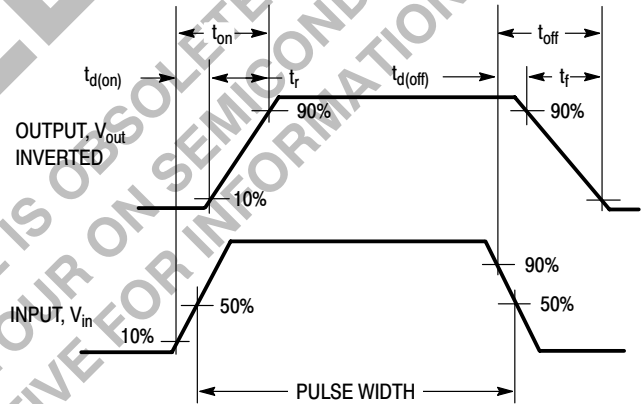
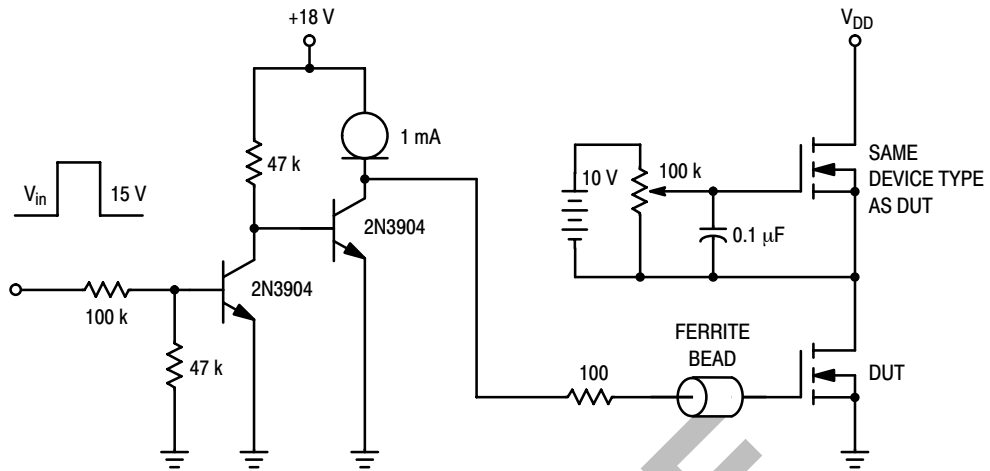


Figure 19. Switching Waveforms

# MTP5N40E



$V_{in} = 15 V_{pk}$ ; PULSE WIDTH  $\leq 100 \mu s$ , DUTY CYCLE  $\leq 10\%$

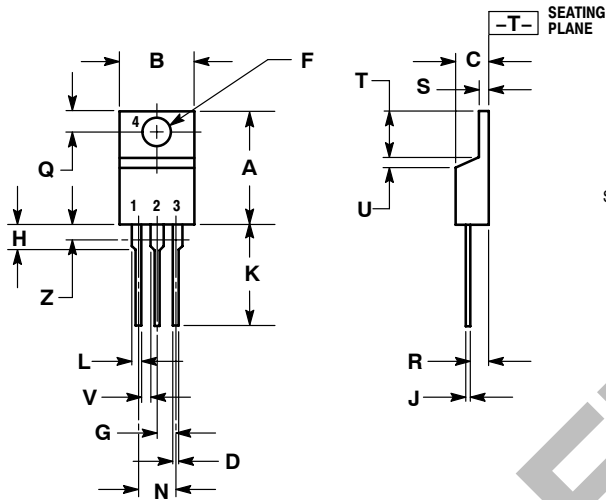
Figure 20. Gate Charge Test Circuit

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# MTP5N40E

## PACKAGE DIMENSIONS

### CASE 221A-06 ISSUE Y



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

- NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
  2. CONTROLLING DIMENSION: INCH.
  3. DIMENSION Z DEFINES A ZONE WHERE ALL BODY AND LEAD IRREGULARITIES ARE ALLOWED.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.570	0.620	14.48	15.75
B	0.380	0.405	9.66	10.28
C	0.160	0.190	4.07	4.82
D	0.025	0.035	0.64	0.88
F	0.142	0.147	3.61	3.73
G	0.095	0.105	2.42	2.66
H	0.110	0.155	2.80	3.93
J	0.018	0.025	0.46	0.64
K	0.500	0.562	12.70	14.27
L	0.045	0.060	1.15	1.52
N	0.190	0.210	4.83	5.33
Q	0.100	0.120	2.54	3.04
R	0.080	0.110	2.04	2.79
S	0.045	0.055	1.15	1.39
T	0.235	0.255	5.97	6.47
U	0.000	0.050	0.00	1.27
V	0.045		1.15	
Z	---	0.080	---	2.04

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