

## N- and P-Channel Enhancement-Mode MOSFET Pair

### Features

- Integrated Gate-to-Source Resistor
- Integrated Gate-to-Source Zener Diode
- Low Threshold
- Low On-Resistance
- Low Input Capacitance
- Fast Switching Speeds
- Free from Secondary Breakdown
- Low Input and Output Leakage
- Independent, Electrically Isolated N- and P-Channels
- 8-Lead Very Thin Plastic Dual Flat, No Lead, 6 x 5 mm VDFN Package

### Applications

- High-Voltage Pulser
- Amplifiers
- Buffers
- Piezoelectric Transducer Drivers
- General-Purpose Line Drivers
- Logic-Level Interfaces

### Description

The TC6321 consists of high-voltage, low-threshold N-channel and P-channel MOSFETs in an 8-Lead VDFN package. Both MOSFETs have integrated gate-to-source resistors and gate-to-source Zener diode clamps, which are desired for high-voltage pulser applications.

The TC6321 is a complimentary, high-speed, high-voltage, gate-clamped N- and P-channel MOSFET pair, which utilizes an advanced vertical DMOS structure and the well-proven silicon-gate manufacturing process. This combination produces a device with the power-handling capabilities of bipolar transistors and with the high-input impedance and positive temperature coefficient inherent in MOS devices. Characteristic of all MOS structures, this device is free from thermal runaway and thermally-induced secondary breakdown.

Vertical DMOS FETs are ideally suited to a wide range of switching and amplifying applications where very low threshold voltage, high breakdown voltage, high input impedance, low input capacitance and fast switching speeds are desired.

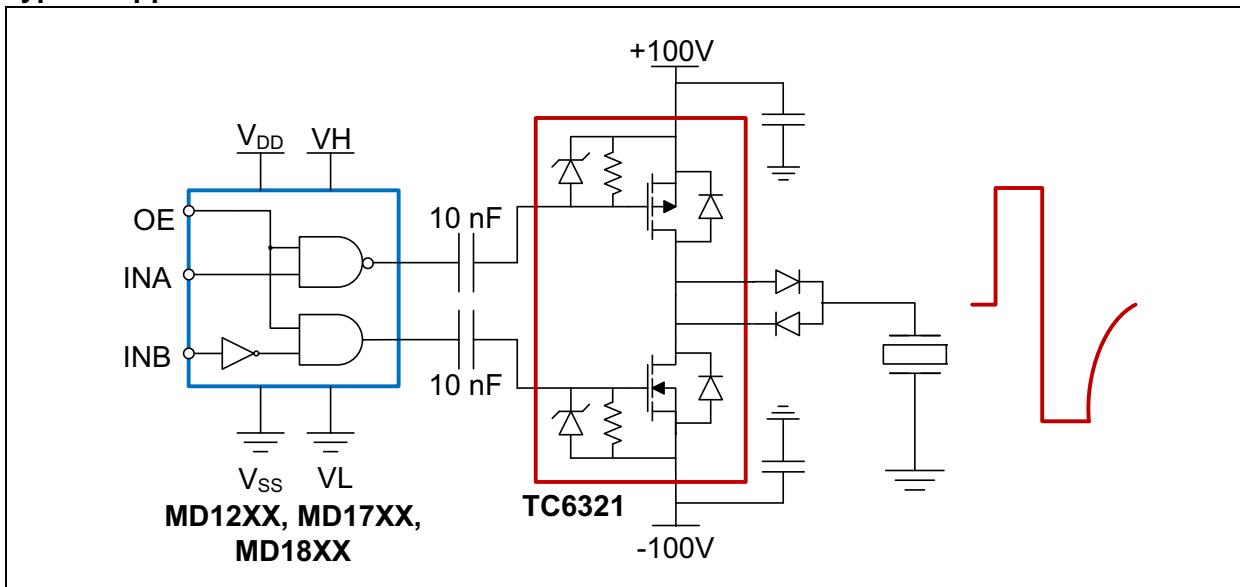
### Package Types

TC6321 6 x 5 VDFN*			
SN	1	8	DN
GN	2	7	DN
GP	3	6	DP
SP	4	5	DP

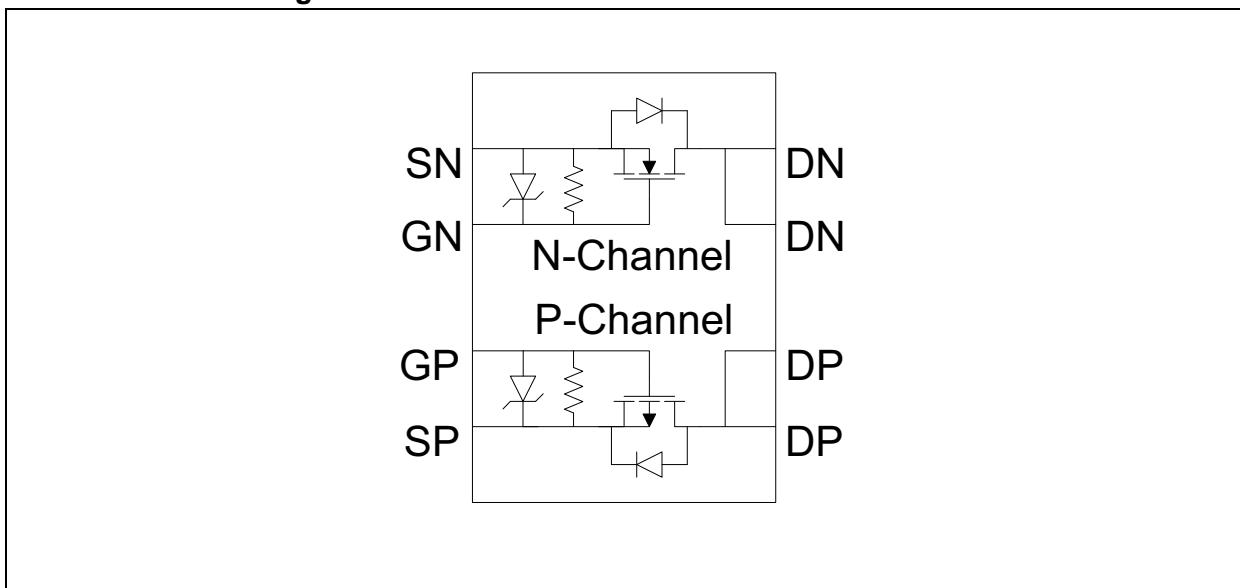
\* Includes Dual Exposed Thermal Pads (EP); see [Table 3-1](#).

# TC6321

## Typical Application Circuit



## Functional Block Diagram



## 1.0 ELECTRICAL CHARACTERISTICS

### Absolute Maximum Ratings †

Drain-to-Source Voltage .....	$BV_{DSX}$
Drain-to-Gate Voltage .....	$BV_{DGX}$
Operating and Storage Temperature .....	-55°C to +175°C

† Notice: Stresses above those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress rating only and functional operation of the device at those or any other conditions above those indicated in the operational listings of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

### N-CHANNEL DC AND AC ELECTRICAL CHARACTERISTICS

Unless otherwise noted, $T_A = T_J = +25^\circ C$ .						
Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
<b>DC Parameters (Note 1)</b>						
Drain-to-Source Breakdown Voltage	$BV_{DSS}$	200	—	—	V	$V_{GS} = 0V, I_D = 2.0 \text{ mA}$
Gate Threshold Voltage	$V_{GS(\text{th})}$	1.0	—	2.0	V	$V_{GS} = V_{DS}, I_D = 1.0 \text{ mA}$
Change in $V_{GS(\text{th})}$ with Temperature	$\Delta V_{GS(\text{th})}$	—	—	-4.5	mV/°C	$V_{GS} = V_{DS}, I_D = 1.0 \text{ mA}$ <b>(Note 2)</b>
Gate-to-Source Shunt Resistor	$R_{GS}$	10	—	50	kΩ	$I_{GS} = 100 \mu\text{A}$
Gate-to-Source Zener Voltage	$VZ_{GS}$	13.2	—	25	V	$I_{GS} = 2 \text{ mA}$
Zero Gate Voltage Drain Current	$I_{DSS}$	—	—	10.0	μA	$V_{DS} = 200V$ $V_{GS} = 0V$
		—	—	1.0	mA	$V_{DS} = 200V, V_{GS} = 0V$ $T_J = +125^\circ C$ <b>(Note 2)</b>
On-State Drain Current	$I_{D(\text{ON})}$	1.0	—	—	A	$V_{GS} = 4.5V, V_{DS} = 25V$
		2.0	—	—		$V_{GS} = 10V, V_{DS} = 25V$
Static Drain-to-Source On-State Resistance	$R_{DS(\text{ON})}$	—	—	8.0	Ω	$V_{GS} = 4.5V, I_D = 150 \text{ mA}$
		—	—	7.0		$V_{GS} = 10V, I_D = 1.0A$
Change in $R_{DS(\text{ON})}$ with Temperature	$\Delta R_{DS(\text{ON})}$	—	—	1.0	%/°C	$V_{GS} = 4.5V, I_D = 150 \text{ mA}$ <b>(Note 2)</b>
<b>AC Parameters (Note 2)</b>						
Forward Transconductance	$G_{FS}$	400	—	—	mmho	$V_{GS} = 25V, I_D = 500 \text{ mA}$
Input Capacitance	$C_{ISS}$	—	—	110	pF	$V_{GS} = 0V$ $V_{DS} = 25V$ $f = 1.0 \text{ MHz}$
Common Source Output Capacitance	$C_{OSS}$	—	—	60		
Reverse Transfer Capacitance	$C_{RSS}$	—	—	23		
Turn-On Delay Time	$t_{d(\text{ON})}$	—	—	10	ns	$V_{GS} = 10V$ $V_{DS} = 25V$ $I_D = 1.0A$ $R_{GEN} = 25\Omega$
Rise Time	$t_r$	—	—	15		
Turn-Off Delay Time	$t_{d(\text{OFF})}$	—	—	20		
Fall Time	$t_f$	—	—	15		

Note 1: Unless otherwise stated, all DC parameters are 100% tested at  $+25^\circ C$ . Pulse test: 300  $\mu\text{s}$  pulse, 2% duty cycle.

2: Specification is obtained by characterization and is not 100% tested.

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## N-CHANNEL DC AND AC ELECTRICAL CHARACTERISTICS (CONTINUED)

Unless otherwise noted, $T_A = T_J = +25^\circ\text{C}$ .						
Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
<b>Diode Parameters</b>						
Diode Forward Voltage Drop	$V_{SD}$	—	—	1.8	V	$V_{GS} = 0\text{V}$ , $I_{SD} = 500 \text{ mA}$ <b>(Note 1)</b>
Reverse Recovery Time	$t_{rr}$	—	100	—	ns	$V_{GS} = 0\text{V}$ , $I_{SD} = 500 \text{ mA}$ $d_{IF}/dt = 25 \text{ A}/\mu\text{s}$ <b>(Note 2)</b>

**Note 1:** Unless otherwise stated, all DC parameters are 100% tested at  $+25^\circ\text{C}$ . Pulse test: 300  $\mu\text{s}$  pulse, 2% duty cycle.

**2:** Specification is obtained by characterization and is not 100% tested.

## P-CHANNEL DC AND AC ELECTRICAL CHARACTERISTICS

Unless otherwise noted, $T_A = T_J = +25^\circ\text{C}$ .						
Parameter	Sym.	Min.	Typ.	Max.	Unit	Condition
<b>DC Parameters (Note 1)</b>						
Drain-to-Source Breakdown Voltage	$BV_{DSS}$	-200	—	—	V	$V_{GS} = 0\text{V}$ , $I_D = -2.0 \text{ mA}$
Gate Threshold Voltage	$V_{GS(\text{th})}$	-1.0	—	-2.4	V	$V_{GS} = V_{DS}$ , $I_D = -1.0 \text{ mA}$
Change in $V_{GS(\text{th})}$ with Temperature	$\Delta V_{GS(\text{th})}$	—	—	4.5	mV/ $^\circ\text{C}$	$V_{GS} = V_{DS}$ , $I_D = -1.0 \text{ mA}$ <b>(Note 2)</b>
Gate-to-Source Shunt Resistor	$R_{GS}$	10	—	50	k $\Omega$	$I_{GS} = 100 \mu\text{A}$
Gate-to-Source Zener Voltage	$VZ_{GS}$	13.2	—	25	V	$I_{GS} = -2 \text{ mA}$
Zero Gate Voltage Drain Current	$I_{DSS}$	—	—	-10.0	$\mu\text{A}$	$V_{DS} = 200\text{V}$ , $V_{GS} = 0\text{V}$
		—	—	-1.0	mA	$V_{DS} = 200\text{V}$ , $V_{GS} = 0\text{V}$ $T_J = +125^\circ\text{C}$ , <b>(Note 2)</b>
On-State Drain Current	$I_{D(\text{ON})}$	-1.0	—	—	A	$V_{GS} = -4.5\text{V}$ , $V_{DS} = -25\text{V}$
		-2.0	—	—		$V_{GS} = -10\text{V}$ , $V_{DS} = -25\text{V}$
Static Drain-to-Source On-State Resistance	$R_{DS(\text{ON})}$	—	—	10	$\Omega$	$V_{GS} = -4.5\text{V}$ , $I_D = -150 \text{ mA}$
		—	—	8.0		$V_{GS} = -10\text{V}$ , $I_D = -1.0\text{A}$
Change in $R_{DS(\text{ON})}$ with Temperature	$\Delta R_{DS(\text{ON})}$	—	—	1.0	%/ $^\circ\text{C}$	$V_{GS} = -25\text{V}$ , $I_D = -200 \text{ mA}$ <b>(Note 2)</b>
<b>AC Parameters (Note 2)</b>						
Forward Transconductance	$G_{FS}$	400	—	—	mmho	$V_{GS} = -25\text{V}$ , $I_D = -500 \text{ mA}$
Input Capacitance	$C_{ISS}$	—	—	200	pF	$V_{GS} = 0\text{V}$ $V_{DS} = -25\text{V}$ $f = 1.0 \text{ MHz}$
Common Source Output Capacitance	$C_{OSS}$	—	—	55		
Reverse Transfer Capacitance	$C_{RSS}$	—	—	30		
Turn-On Delay Time	$t_{d(\text{ON})}$	—	—	10	ns	$V_{GS} = -10\text{V}$ $V_{DS} = -25\text{V}$ $I_D = -1.0\text{A}$ $R_{GEN} = 25\Omega$
Rise Time	$t_r$	—	—	15		
Turn-Off Delay Time	$t_{d(\text{OFF})}$	—	—	20		
Fall Time	$t_f$	—	—	15		

**Note 1:** Unless otherwise stated, all DC parameters are 100% tested at  $+25^\circ\text{C}$ . Pulse test: 300  $\mu\text{s}$  pulse, 2% duty cycle.

**2:** Specification is obtained by characterization and is not 100% tested.

**P-CHANNEL DC AND AC ELECTRICAL CHARACTERISTICS (CONTINUED)**

Unless otherwise noted, $T_A = T_J = +25^\circ\text{C}$ .						
Parameter	Sym.	Min.	Typ.	Max.	Unit	Condition
<b>Diode Parameters</b>						
Diode Forward Voltage Drop	$V_{SD}$	—	—	-1.8	V	$V_{GS} = 0\text{V}$ , $I_{SD} = -500\text{ mA}$ <b>(Note 1)</b>
Reverse Recovery Time	$t_{rr}$	—	100	—	ns	$V_{GS} = 0\text{V}$ , $I_{SD} = -500\text{ mA}$ $d_iF/dt = -25\text{ A}/\mu\text{s}$ <b>(Note 2)</b>

**Note 1:** Unless otherwise stated, all DC parameters are 100% tested at  $+25^\circ\text{C}$ . Pulse test: 300  $\mu\text{s}$  pulse, 2% duty cycle.

**2:** Specification is obtained by characterization and is not 100% tested.

**TEMPERATURE SPECIFICATIONS**

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
<b>Temperature Ranges</b>						
Operating Temperature	$T_J$	-40	—	+150	$^\circ\text{C}$	
Storage Temperature	$T_A$	-55	—	+175	$^\circ\text{C}$	
<b>Thermal Package Resistances</b>						
Thermal Resistance, 6x5 mm VDFN-8LD	$\theta_{JC}$	—	1.43	—	$^\circ\text{C}/\text{W}$	
	$\theta_{JA}$	—	34.4	—	$^\circ\text{C}/\text{W}$	

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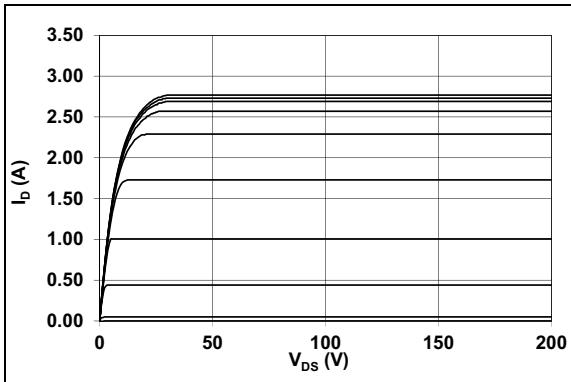
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## NOTES:

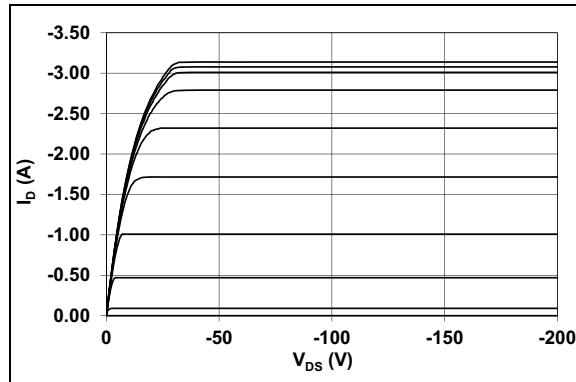
## 2.0 TYPICAL PERFORMANCE CURVES

**Note:** The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only. The performance characteristics listed herein are not tested or guaranteed. In some graphs or tables, the data presented may be outside the specified operating range (e.g., outside specified power supply range) and therefore outside the warranted range.

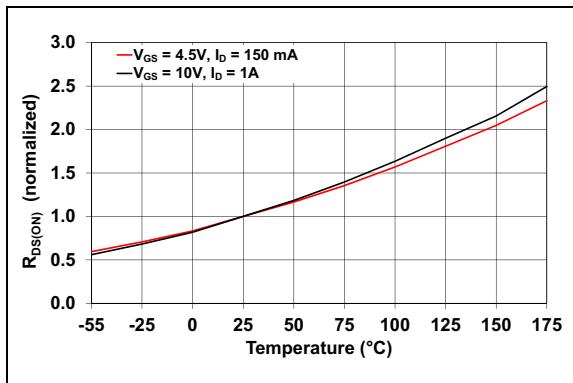
**Note:** Unless otherwise indicated,  $T_A = T_J = 25^\circ\text{C}$ .



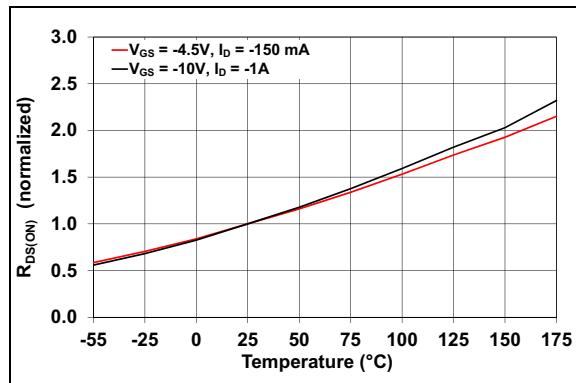
**FIGURE 2-1:** N-Channel  $I_D$  vs.  $V_{DS}$  (Output Characteristics).



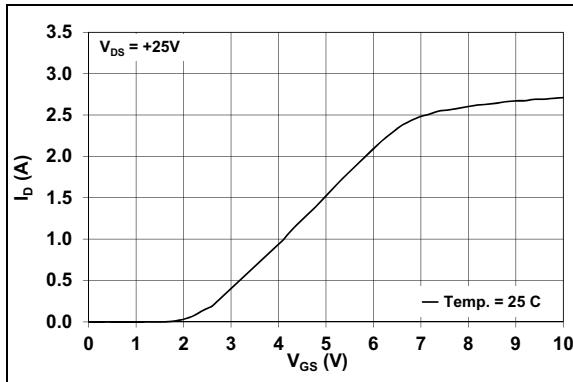
**FIGURE 2-4:** P-Channel  $I_D$  vs.  $V_{DS}$  (Output Characteristics).



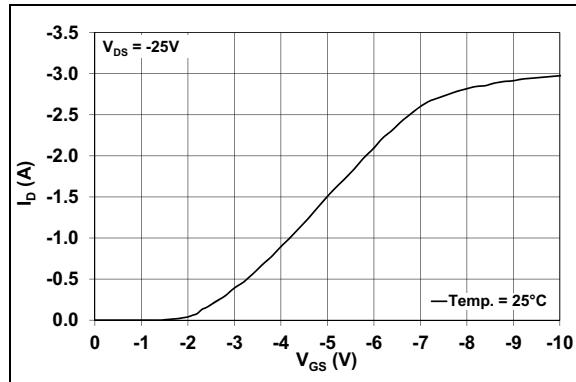
**FIGURE 2-2:** N-Channel On-Resistance vs. Temperature.



**FIGURE 2-5:** P-Channel On-Resistance vs. Temperature.



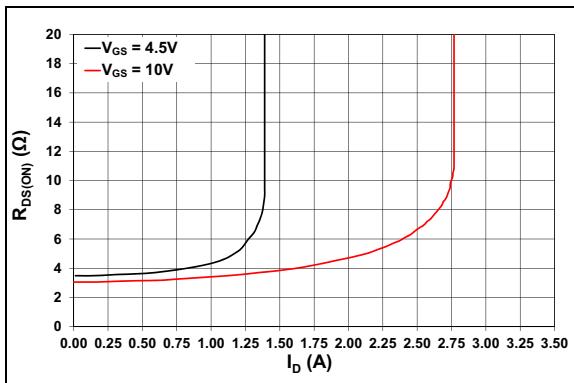
**FIGURE 2-3:** N-Channel  $I_D$  vs.  $V_{GS}$ .



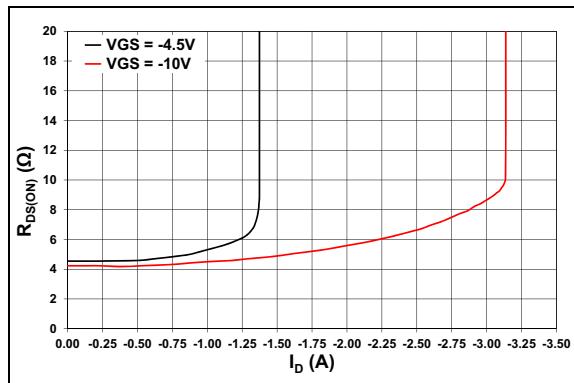
**FIGURE 2-6:** P-Channel  $I_D$  vs.  $V_{GS}$ .

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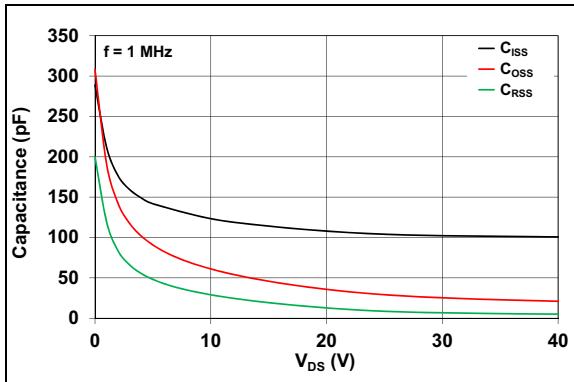
Note: Unless otherwise indicated,  $T_A = T_J = 25^\circ\text{C}$ .



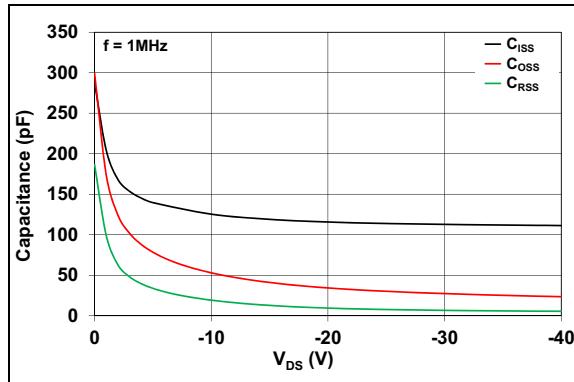
**FIGURE 2-7:** N-Channel On-Resistance vs. Drain Current.



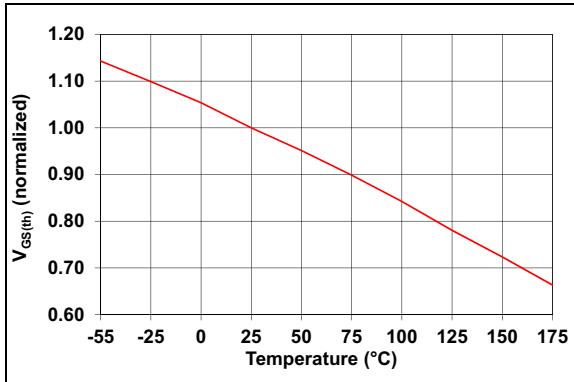
**FIGURE 2-10:** P-Channel On-Resistance vs. Drain Current.



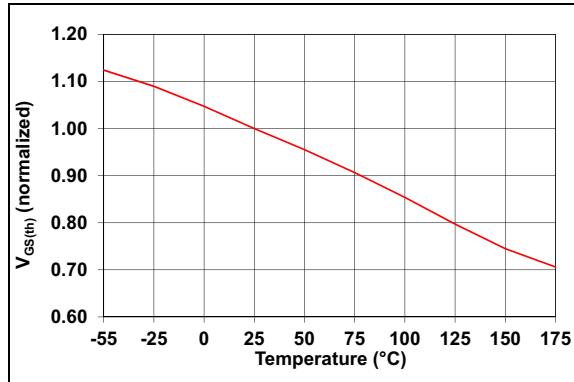
**FIGURE 2-8:** N-Channel Capacitance vs. Drain-to-Source Voltage.



**FIGURE 2-11:** P-Channel Capacitance vs. Drain-to-Source Voltage.

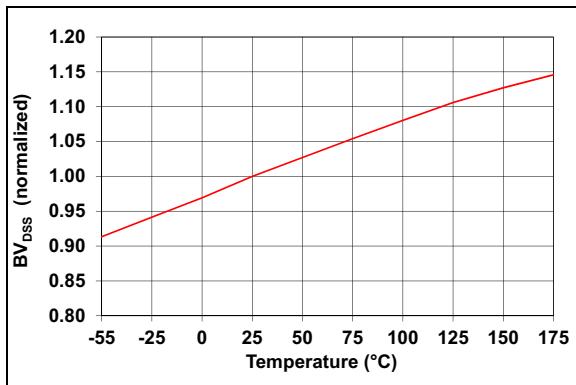


**FIGURE 2-9:** N-Channel  $V_{GS(th)}$  vs. Temperature.

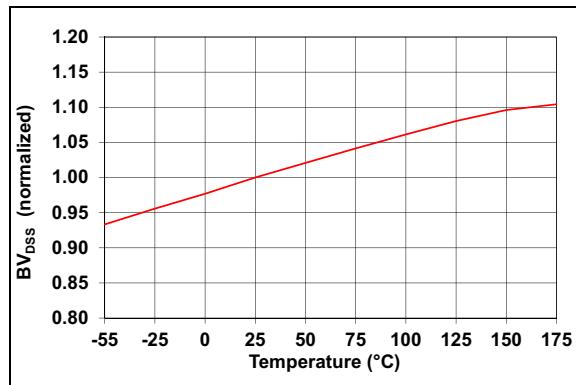


**FIGURE 2-12:** P-Channel  $V_{GS(th)}$  vs. Temperature.

**Note:** Unless otherwise indicated,  $T_A = T_J = 25^\circ\text{C}$ .



**FIGURE 2-13:** N-Channel  $BV_{DSS}$  vs. Temperature.



**FIGURE 2-14:** P-Channel  $BV_{DSS}$  vs. Temperature.

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## NOTES:

## 3.0 PIN DESCRIPTION

The descriptions of the pins are listed in [Table 3-1](#).

**TABLE 3-1: PIN FUNCTION TABLE**

TC6321 6x5 VDFN	Name	Description
1	SN	Source N-Channel
2	GN	Gate N-Channel
3	GP	Gate P-Channel
4	SP	Source P-Channel
5, 6	DP	Drain P-Channel
7,8	DN	Drain N-Channel
9	EP	Dual Exposed Thermal Pads

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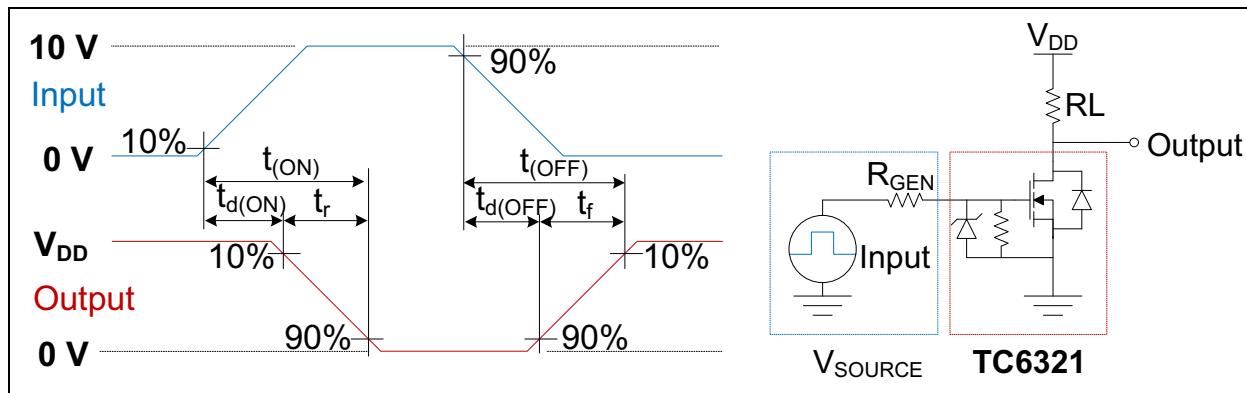
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## NOTES:

## 4.0 FUNCTIONAL DESCRIPTION

### 4.1 N-Channel Switching Waveforms and Test Circuit

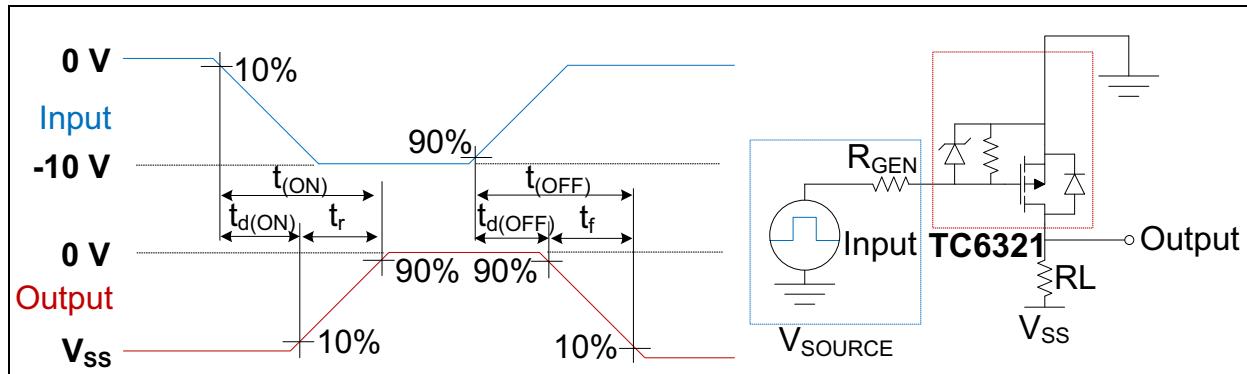
Figure 4-1 shows the N-channel switching waveforms and test circuit.



**FIGURE 4-1:** N-Channel Switching Waveforms and Test Circuit.

### 4.2 P-Channel Switching Waveforms and Test Circuit

Figure 4-2 shows the P-channel switching waveforms and test circuit.



**FIGURE 4-2:** P-Channel Switching Waveforms and Test Circuit.

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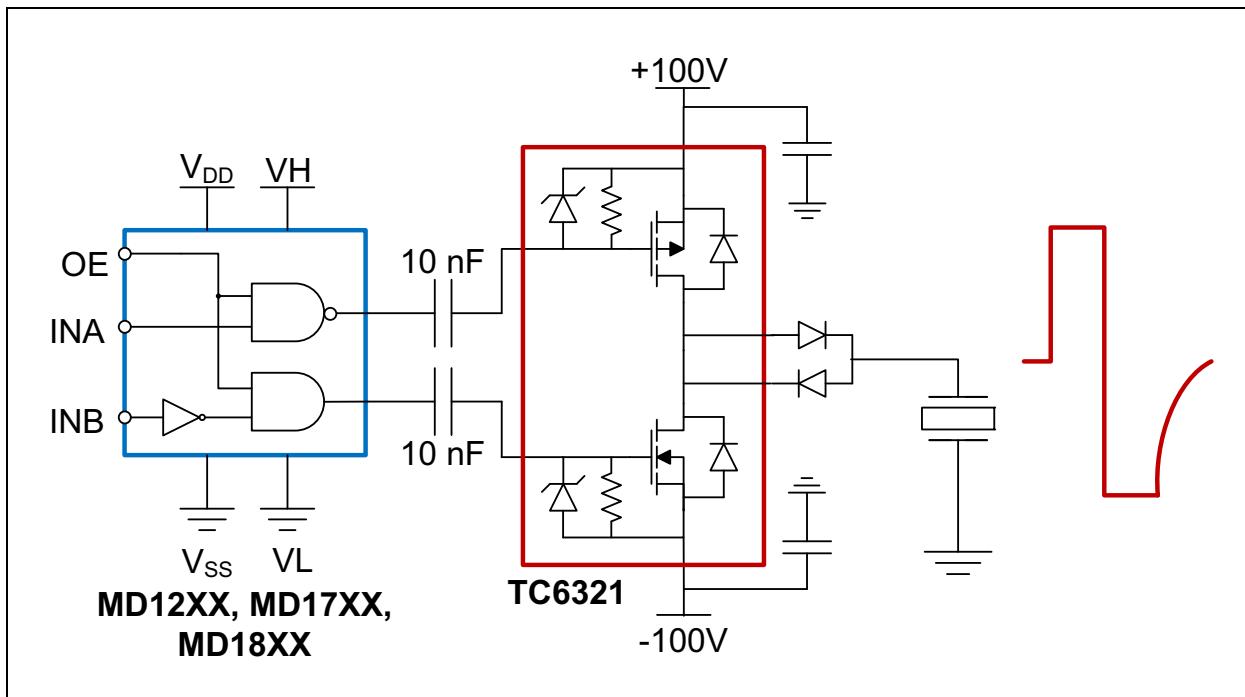
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## NOTES:

## 5.0 APPLICATION INFORMATION

The TC6321 N- and P-MOSFET pair is designed for a wide range of switching and amplifying applications where high-voltage, high-current drive and fast switching speeds are required, especially for medical ultrasound applications.

A typical application pairs the TC6321 with any of MD12xx, MD17xx, or MD18xx ultrasound family MOSFET Drivers in order to form a high-speed and high-voltage (+/-100V 2.5A) pulser circuit. [Figure 5-1](#) illustrates the application circuit diagram for a two level pulser.



**FIGURE 5-1:** TC6321 - Application Circuit Diagram.

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## NOTES:

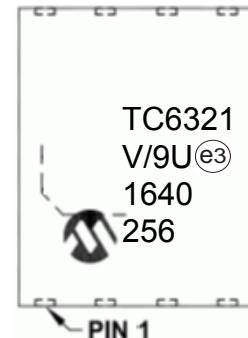
## 6.0 PACKAGING INFORMATION

### 6.1 Package Marking Information

8-Lead VDFN (6 x 5 mm)



Example



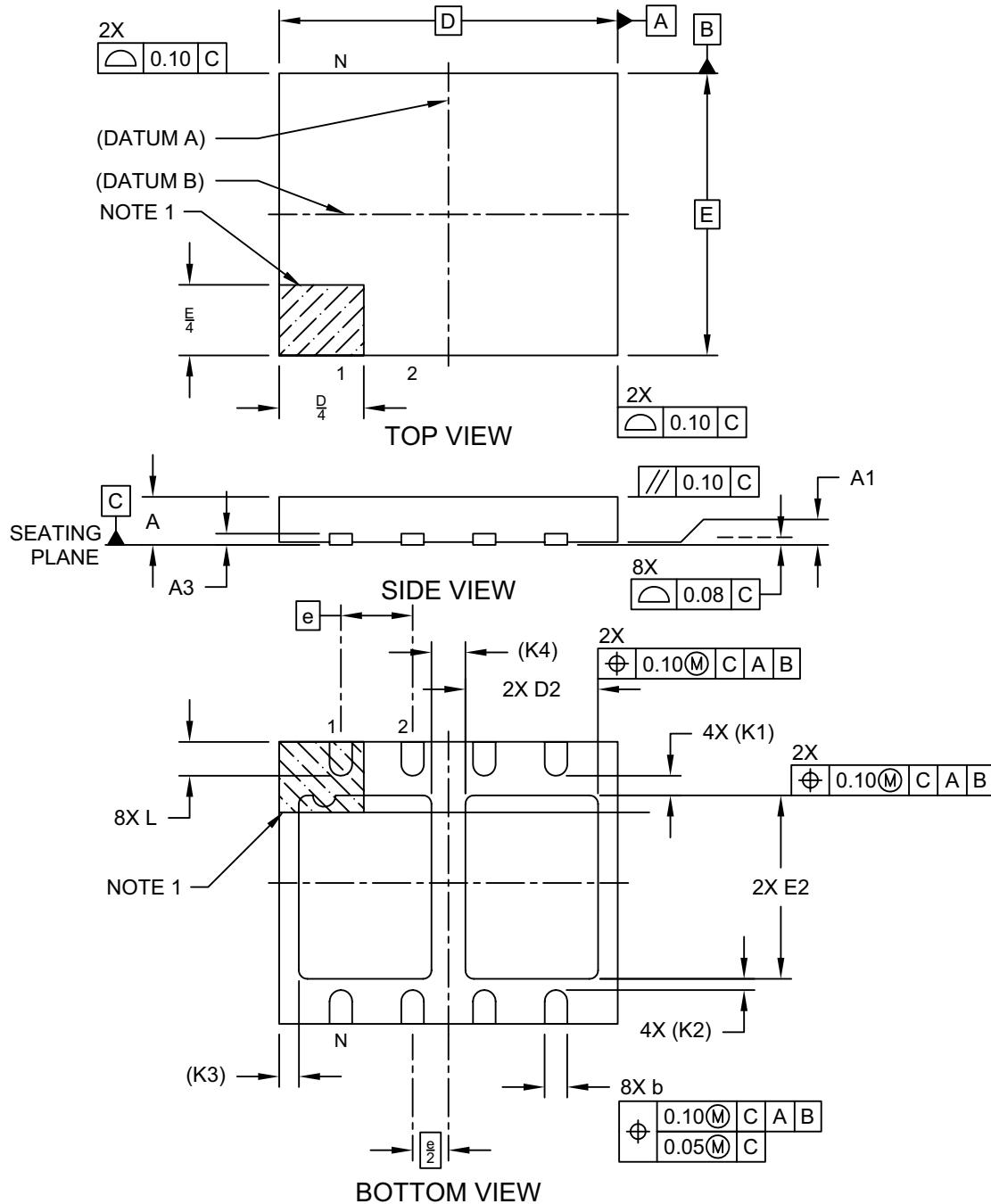
<b>Legend:</b>	XX...X Customer-specific information
Y	Year code (last digit of calendar year)
YY	Year code (last 2 digits of calendar year)
WW	Week code (week of January 1 is week '01')
NNN	Alphanumeric traceability code
(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
*	This package is Pb-free. The Pb-free JEDEC designator (e3) can be found on the outer packaging for this package.

**Note:** In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information.

# TC6321

## 8-Lead Very Thin Plastic Dual Flat, No Lead (9U) - 6x5 mm Body [VDFN] With Dual Exposed Pads

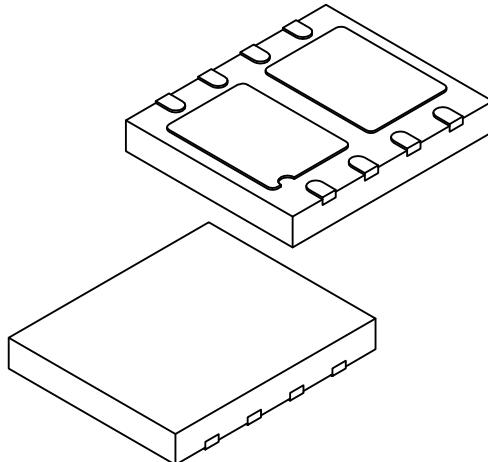
**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Microchip Technology Drawing C04-413A Sheet 1 of 2

**8-Lead Very Thin Plastic Dual Flat, No Lead (9U) - 6x5 mm Body [VDFN]  
With Dual Exposed Pads**

**Note:** For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Terminals	N		8	
Pitch	e		1.27 BSC	
Overall Height	A	0.80	0.85	0.90
Standoff	A1	0.00	0.02	0.05
Terminal Thickness	A3		0.20 REF	
Overall Length	D		6.00 BSC	
Exposed Pad Length (X2)	D2	2.25	2.35	2.45
Overall Width	E		5.00 BSC	
Exposed Pad Width (X2)	E2	3.15	3.25	3.35
Terminal Width	b	0.35	0.40	0.45
Terminal Length	L	0.55	0.60	0.65
Terminal to Exposed Pad (X4)	K1		0.35 REF	
Terminal to Exposed Pad (X4)	K2		0.20 REF	
Molded Package Edge to Exposed Pad	K3		0.35 REF	
Exposed Pad to Exposed Pad	K4		0.60 REF	

Notes:

1. Pin 1 visual index feature may vary, but must be located within the hatched area.

2. Package is saw singulated

3. Dimensioning and tolerancing per ASME Y14.5M

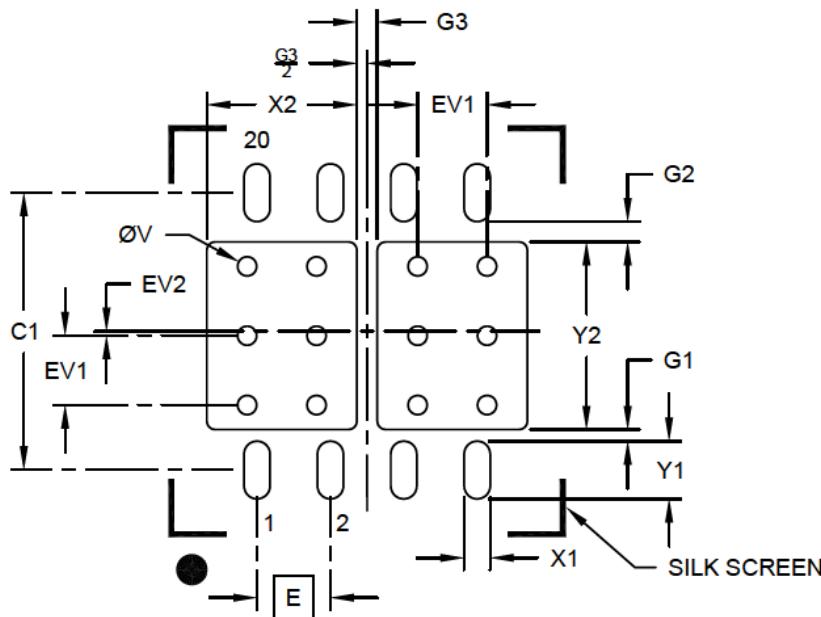
BSC: Basic Dimension. Theoretically exact value shown without tolerances.

REF: Reference Dimension, usually without tolerance, for information purposes only.

# TC6321

## 8-Lead Very Thin Plastic Dual Flat, No Lead (9U) - 6x5 mm Body [VDFN] With Dual Exposed Pads

Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



### RECOMMENDED LAND PATTERN

Dimension	Units	MILLIMETERS		
		MIN	NOM	MAX
Contact Pitch	E		1.27 BSC	
Optional Center Pad Width (X2)	X2			2.60
Optional Center Pad Length	Y2			3.25
Contact Pad Spacing	C1		4.80	
Contact Pad Width (X8)	X1			0.45
Contact Pad Length (X8)	Y1			0.80
Contact Pad to Center Pad (X4)	G1	0.20		
Contact Pad to Center Pad (X4)	G2	0.35		
Center Pad to Center Pad	G3		0.35	
Thermal Via Diameter (X12)	V		0.33	
Thermal Via Pitch	EV1		1.20	
Thermal Via Offset	EV2		0.08	

#### Notes:

1. Dimensioning and tolerancing per ASME Y14.5M  
BSC: Basic Dimension. Theoretically exact value shown without tolerances.
2. For best soldering results, thermal vias, if used, should be filled or tented to avoid solder loss during reflow process

Microchip Technology Drawing C04-2413A

## APPENDIX A: REVISION HISTORY

### Revision A (March 2017)

- Original Release of this Document.

# TC6321

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## NOTES:

## PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, refer to the factory or the listed sales office.

PART NO.	X/	XX	Device Temperature Package	Examples:
Device:	TC6321T:	N- and P-Channel Enhancement-Mode MOSFET Pair, Tape and Reel		a) TC6321T-E/MQ: Tape and Reel, Various temperature levels, 8-LD VDFN package
Temperature:	V	=	-55°C to +175°C (Various temperature levels) <sup>(1)</sup>	Note 1: Shipment of these devices may require an end-use/end-user certificate per SPI-43508.
Package Type:	9U	=	Very Thin Plastic Dual Flat, No Lead, VDFN, 8-Lead, 6x5 mm Body, with Dual Exposed Pads	

# TC6321

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## NOTES:

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**Note the following details of the code protection feature on Microchip devices:**

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