MIC5232

10 mA Ultra-Low Quiescent Current µCap LDO

Features

- Input Voltage Range: 2.7V to 7.0V
- Ultra-Low I_Q: Only 1.8 µA Operating Current
- Stable with 0.47 µF Ceramic Output Capacitor
- Low Dropout Voltage of 100 mV @ 10 mA
- Reverse Battery Protection
- High Output Accuracy:
  - ±2.0% Initial Accuracy
  - ±3.0% over Temperature
- Logic-Level Enable Input
- Miniature 6-Lead 2 mm x 2 mm VDFN Package
- Lead-Free Thin SOT-23-5 Package
- Tight Load and Line Regulation

Applications

- Real-Time Clock Power Supply
- Standby Power Supply
- SRAM Memory Backup Supply
- Cellular Telephones and Notebook Computers

General Description

The MIC5232 is an ultra-low quiescent current, low-dropout linear regulator that is capable of operating from a single-cell lithium ion battery. Consuming only 1.8 µA of quiescent current while operating, the MIC5232 is ideal for stand-by applications like powering real-time clocks or memory in battery operated electronics.

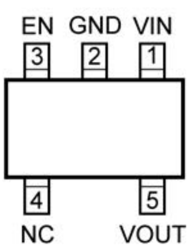
The MIC5232 is capable of providing 10 mA of output current and has low output noise, providing a small, efficient solution ideal for any keep-alive application. This includes reverse current protection, keeping reverse leakage (V_{OUT} > V_{IN}) down to 20 nA.

The MIC5232 is a µCap design, operating with very small ceramic output capacitors for stability, reduction of required board space and component cost.

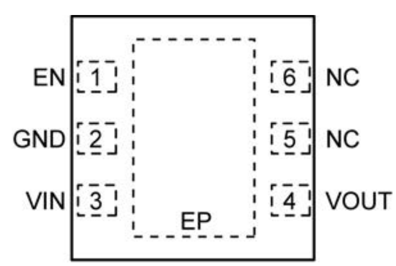
The MIC5232 is available in fixed output voltages in the miniature 6-lead 2 mm x 2 mm VDFN package and thin SOT-23-5 package with an operating junction temperature range of –40°C to 125°C.

Package Types

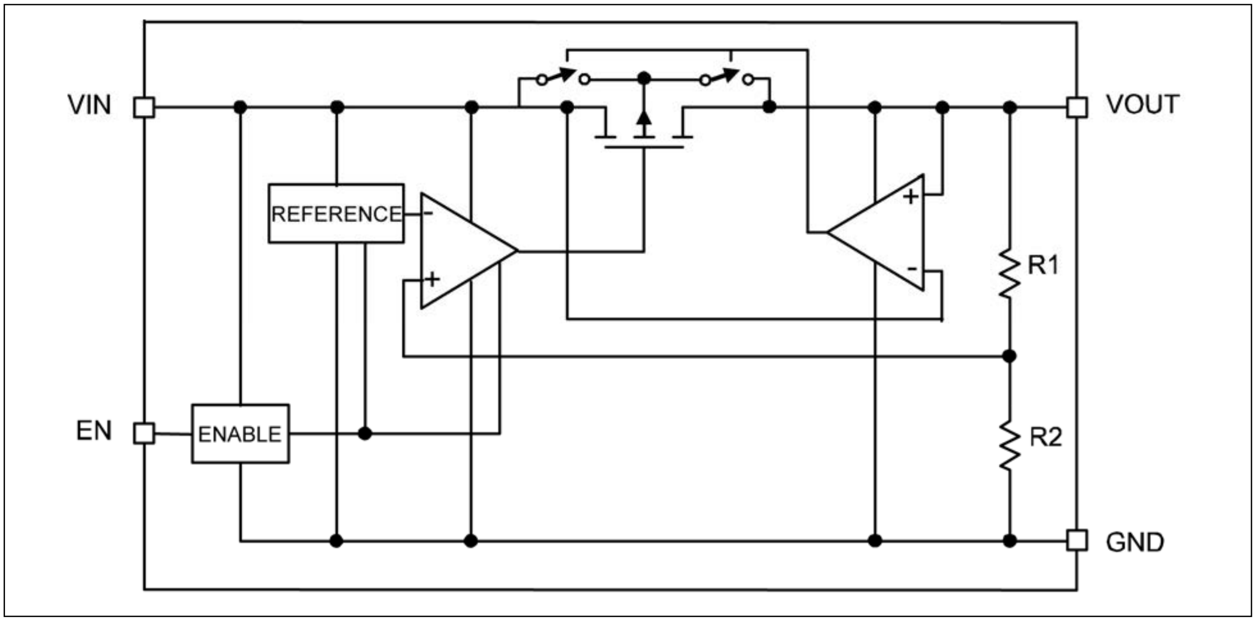
MIC23050
Thin SOT-23-5 (D5)
(Top View)



MIC23050
6-Lead VDFN (ML)
(Top View)



Functional Block Diagram



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Input Voltage (V_{IN}) .... 0V to +8V
Enable Input Voltage (V_{EN}) .... 0V to +8V
Power Dissipation (P_D, Note 1) .... Internally Limited
ESD Rating (Note 2) .... ±2 kV

Operating Ratings ‡

Supply Voltage (V_{IN}) .... +2.7V to +7V
Enable Input Voltage (V_{EN}) .... 0V to V_{IN}

† 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 sections of this specification is not intended. Exposure to maximum rating conditions for extended periods may affect device reliability.

‡ Notice: The device is not guaranteed to function outside its operating ratings.

Note 1: The maximum allowable power dissipation of any T_A (ambient temperature) is $P_{D(MAX)} = (T_{J(MAX)} – T_A)/θ_{JA}$. Exceeding the maximum allowable power dissipation will result in excessive die temperature.

2: Device is ESD sensitive. Handling precautions are recommended. Human body model, 1.5 kΩ in series with 100 pF.

ELECTRICAL CHARACTERISTICS

$V_{IN} = V_{OUT} + 1.0V$, C_{OUT} = 0.47 µF, I_{OUT} = 100 µA, T_J = +25°C, **bold** values valid for –40°C to +125°C, unless noted. Note 1

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Output Voltage Accuracy		–2.0	—	2.0	%	Variation from nominal V_{OUT}
		–3.0	—	**3.0**		
Output Voltage Temperature Coefficient		—	40	—	ppm/°C	—
Line Regulation	$ΔV_{OUT}/(V_{OUT} \times ΔV_{IN})$	—	0.02	**0.25**	%/V	$V_{IN} = V_{OUT}$ + 1V to 7V
Load Regulation	$ΔV_{OUT}/V_{OUT}$	—	0.2	1.0	%	I_{OUT} = 10 µA to 10 mA
		—	—	**1.5**		
Dropout Voltage (Note 2)	V_{DO}	—	60	—	mV	I_{OUT} = 100 µA
		—	100	**300**		I_{OUT} = 10 mA
Ground Pin Current	I_{GND}	—	1.8	3	µA	I_{OUT} = 10 µA
Ground Pin Current in Shutdown	I_{GND_SD}	—	0.1	**1.5**	µA	V_{EN} ≤ 0.18V
Current Limit	I_{LIM}	—	70	**120**	mA	V_{OUT} = 0V
Reverse Current ($V_{OUT} > V_{IN}$)		—	0.02	**1**	µA	$V_{OUT} = V_{IN}$ + 1V
Ripple Rejection	PSRR	—	55	—	dB	f = 10 Hz
		—	35	—		f = 1 kHz
Output Voltage Noise	e_n	—	400	—	$µV_{RMS}$	C_{OUT} = 0.47 µF; 10 Hz to 100 kHz

ELECTRICAL CHARACTERISTICS (CONTINUED)

$V_{IN} = V_{OUT} + 1.0V$, $C_{OUT} = 0.47\ \mu F$, $I_{OUT} = 100\ \mu A$, $T_J = +25°C$, **bold** values valid for –40°C to +125°C, unless noted. Note 1

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Enable Input						
Enable Input Voltage	V_{EN}	—	—	**0.18**	V	Logic Low (Regulator Shutdown)
		1.4	—	—		Logic High (Regulator Enabled)
Enable Input Current	I_{EN}	—	1	—	nA	$V_{IL} \le 0.18V$ (Regulator Shutdown)
		—	1	—		$V_{IH} \ge 1.4V$ (Regulator Enabled)
Turn-On Time (Note 3)	t_{ON}	—	0.75	1.5	ms	$C_{OUT} = 0.47\ \mu F$

Note 1: Specification for packaged product only.

2: Dropout voltage is defined as the input-to-output differential at which the output voltage drops 2% below its nominal V_{OUT}. For outputs below 2.7V, dropout voltage is the input-to-output differential with the minimum input voltage 2.7V.

3: Turn-on time is measured from 10% of the positive edge of the enable signal to 90% of the rising edge of the output voltage of the regulator.

TEMPERATURE SPECIFICATIONS

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Storage Temperature Range	T_S	–65	—	+150	°C	—
Junction Temperature Range	T_J	–40	—	+125	°C	—
Lead Temperature	T_{LEAD}	—	—	+260	°C	Soldering, 5 sec.
Package Thermal Resistances						
Thermal Resistance, TSOT-23-5	θ_{JA}	—	235	—	°C/W	—
Thermal Resistance, 6-Ld VDFN	θ_{JA}	—	90	—	°C/W	—

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.

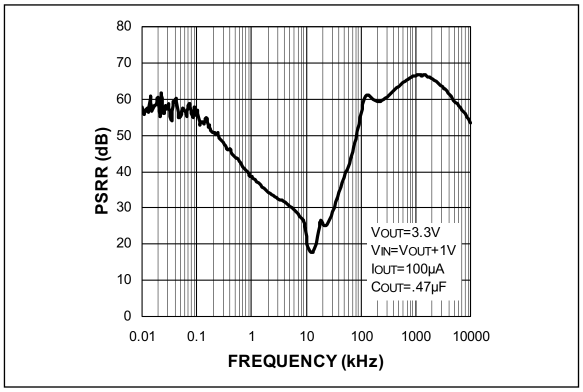


FIGURE 2-1: *Ripple Rejection.*

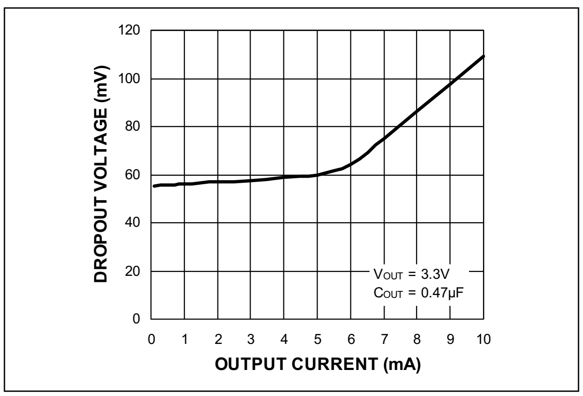


FIGURE 2-2: *Dropout Voltage vs. Output Current.*

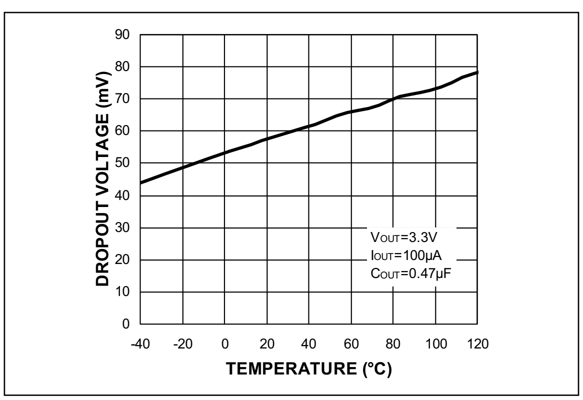


FIGURE 2-3: *Dropout Voltage vs. Temperature.*

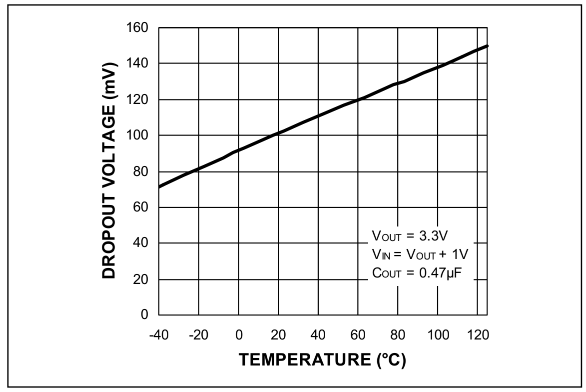


FIGURE 2-4: *Dropout Voltage vs. Temperature.*

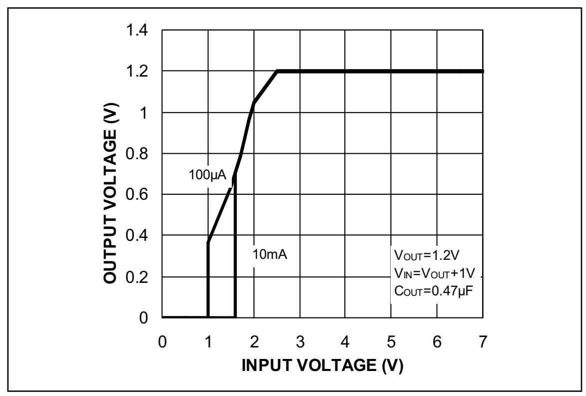


FIGURE 2-5: *Output Voltage vs. Input Voltage.*

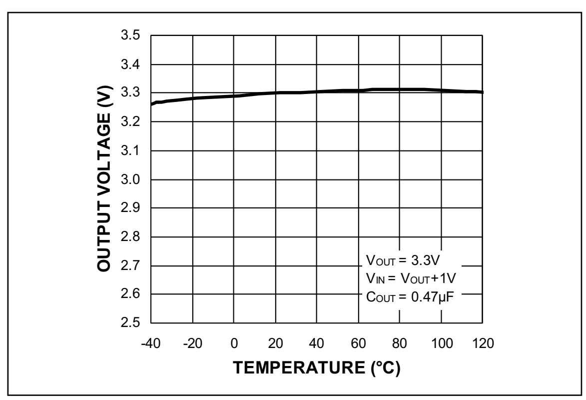


FIGURE 2-6: *Output Voltage vs. Temperature.*

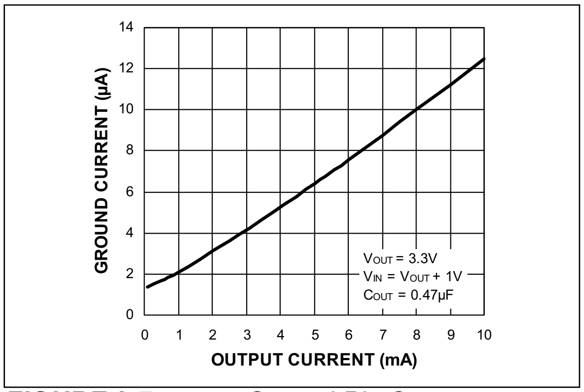


FIGURE 2-7: *Ground Pin Current vs. Output Current.*

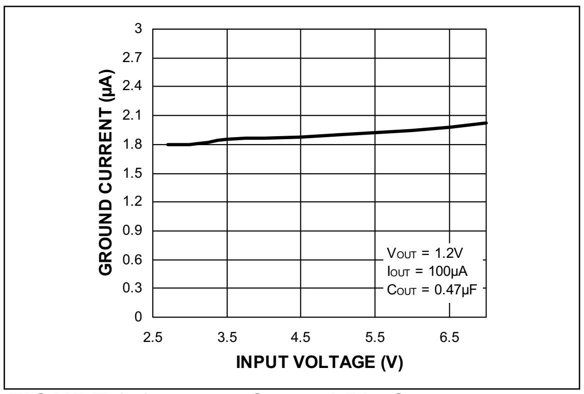


FIGURE 2-8: *Ground Pin Current vs. Input Voltage.*

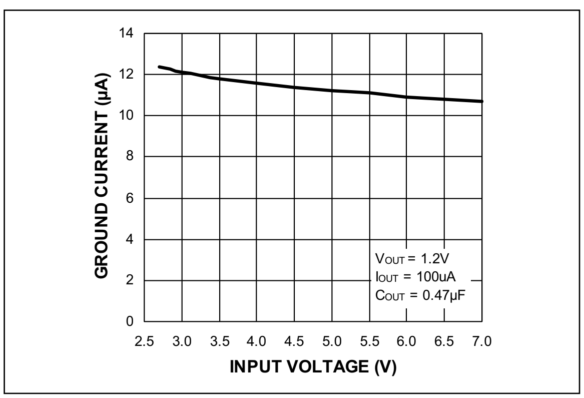


FIGURE 2-9: *Ground Pin Current vs. Input Voltage.*

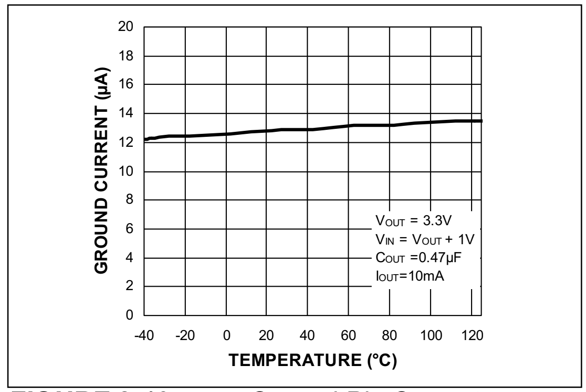


FIGURE 2-10: *Ground Pin Current vs. Temperature.*

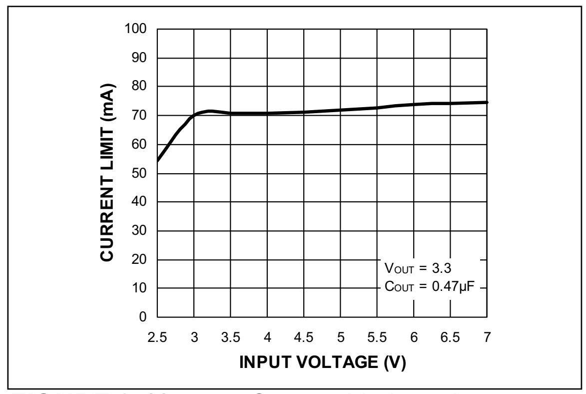


FIGURE 2-11: *Current Limit vs. Input Voltage.*

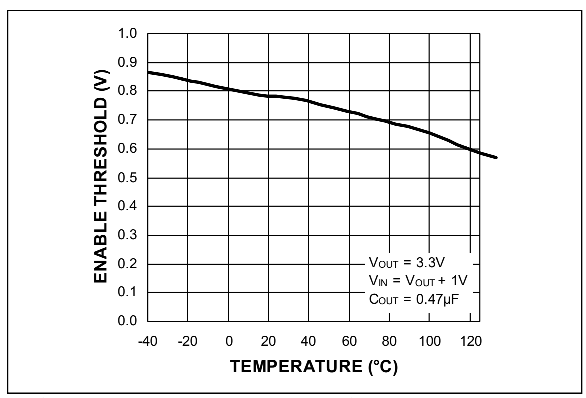


FIGURE 2-12: *Enable-On Threshold vs. Temperature.*

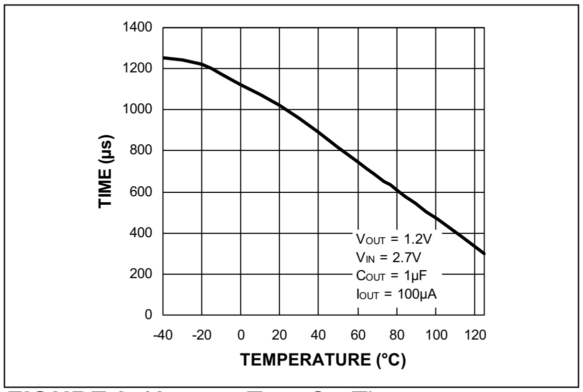


FIGURE 2-13: *Turn-On Time.*

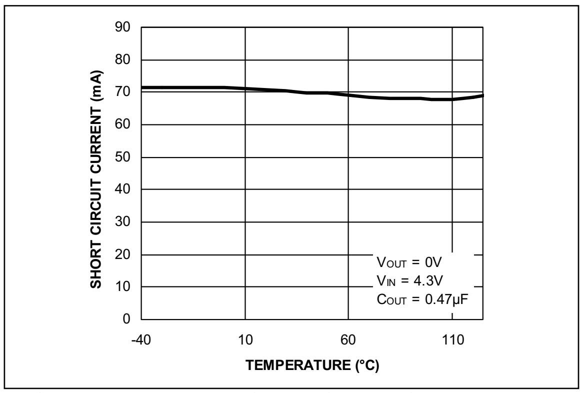


FIGURE 2-14: *Short-Circuit Current vs. Temperature.*

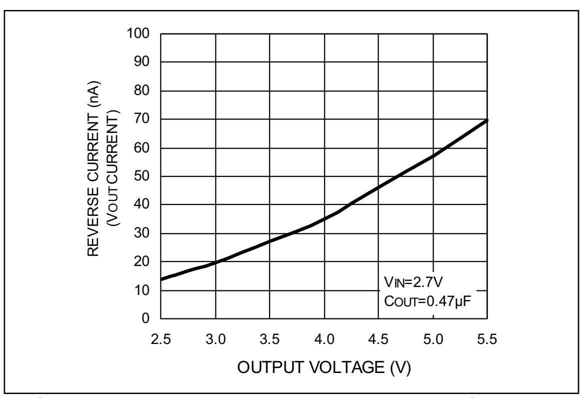


FIGURE 2-15: *Reverse Leakage Current (V_{OUT} > V_{IN}).*

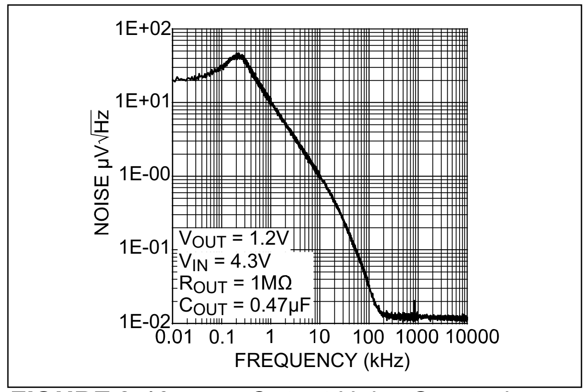


FIGURE 2-16: *Output Noise Spectral Density.*

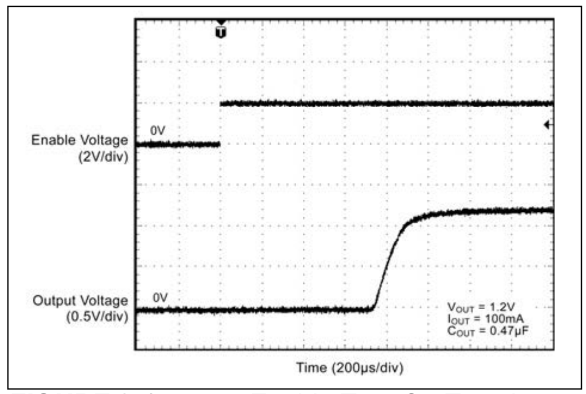


FIGURE 2-17: *Enable Turn-On Transient.*

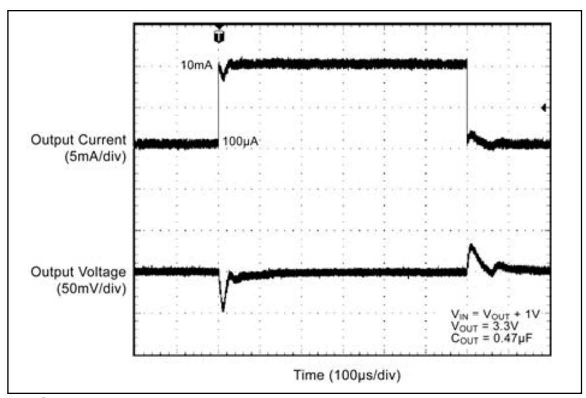


FIGURE 2-18: *Load Transient Response.*

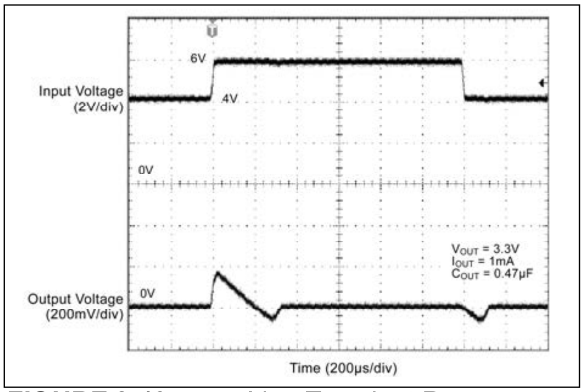


FIGURE 2-19: *Line Transient Response.*

3.0 PIN DESCRIPTIONS

The descriptions of the pins are listed in Table 3-1.

TABLE 3-1: PIN FUNCTION TABLE

Pin Number TSOT-23-5	Pin Number VDFN-6	Pin Name	Description
1	3	VIN	Supply Input.
2	2	GND	Ground.
3	1	EN	Enable Input. Active High. High = on, Low = off. Do not leave floating.
4	5	NC	Not Internally Connected.
5	4	VOUT	Output (10 mA output current).
—	6	NC	Not Internally Connected.
—	EP	ePAD	Exposed pad, connected to ground.

4.0 APPLICATION INFORMATION

4.1 Input Capacitor

If there is more than 20 cm of wire between IN and the AC filter capacitor or if supplied from a battery, a 1 µF (or larger) capacitor should be placed from the IN (supply input) to GND (ground).

4.2 Output Capacitor

The MIC5232 requires an output capacitor for stability. A 0.47 µF, or larger capacitor, is recommended between VOUT (output) and GND to improve the regulator's transient response. A 0.47 µF capacitor can be used to reduce overshoot recovery time at the expense of overshoot amplitude. The ESR (effective series resistance) of this capacitor has no effect on regulator stability, but low-ESR capacitors improve the high frequency transient response. The value of this capacitor may be increased without limit, but values larger than 10 µF tend to increase the settling time after a step change in input voltage or output current.

4.3 Minimum Load Current

The MIC5232 does not require a minimum load for proper operation. This allows the device to operate in applications where very light output currents are required for keep-alive purposes. This is important for powering SRAM or Flash memory in low-power modes for handheld devices.

4.4 Safe Operating Conditions

The MIC5232 incorporates current limit in the design. There is also reverse circuit protection circuitry built into the device. The maximum junction temperature for the device is +125°C, and it is important that this is not exceeded for any length of time.

4.5 Thermal Considerations

The MIC5232 is designed to provide 10 mA of continuous current in a very small package. Maximum ambient operating temperature can be calculated based on the output current and the voltage drop across the part. Given that the input voltage is 4.3V, the output voltage is 3.3V and the output current equals 10 mA.

The actual power dissipation of the regulator circuit can be determined using the following equation:

EQUATION 4-1:

$$P_D = (V_{IN} - V_{OUT}) \times I_{OUT} + V_{IN} \times I_{GND}$$

Because this device is CMOS and the ground current is typically <15 µA over the load range, the power dissipation contributed by the ground current is <1% and can be ignored for this calculation.

EQUATION 4-2:

$$P_D = (4.3V - 3.3V) \times 10mA$$
$$P_D = 0.01W$$

To determine the maximum ambient operating temperature of the package, use the junction-to-ambient thermal resistance of the device and the following basic equation:

EQUATION 4-3:

$$P_{D(MAX)} = \frac{T_{J(MAX)} - T_A}{\theta_{JA}}$$

Where:

$T_{J(MAX)}$ = 125°C, the maximum junction temperature of the die.

90°C/W = The thermal resistance for the VDFN package.

Substituting P_D for $P_{D(MAX)}$, and solving for the ambient operating temperature, will give the maximum operating conditions for the regulator circuit. The junction-to-ambient thermal resistance for the minimum footprint is 90°C/W. The maximum power dissipation must not be exceeded for proper operation.

For example, when operating the MIC5232-3.3YML at an input voltage of 4.3V and 10 mA load with a minimum footprint layout, the maximum ambient operating temperature T_A can be determined as follows:

EQUATION 4-4:

$$0.01W = \frac{125°C - T_A}{90°C/W}$$
$$T_A = 124°C$$

Therefore, a 3.3V application at 10 mA of output current can accept an ambient operating temperature of 124°C in a 2 mm x 2 mm VDFN-6 package. For a full discussion of heat sinking and thermal effects on voltage regulators, refer to the "Regulator Thermals" section of Microchip's "Designing with Low-Dropout Voltage Regulators" handbook.

5.0 PACKAGING INFORMATION

5.1 Package Marking Information

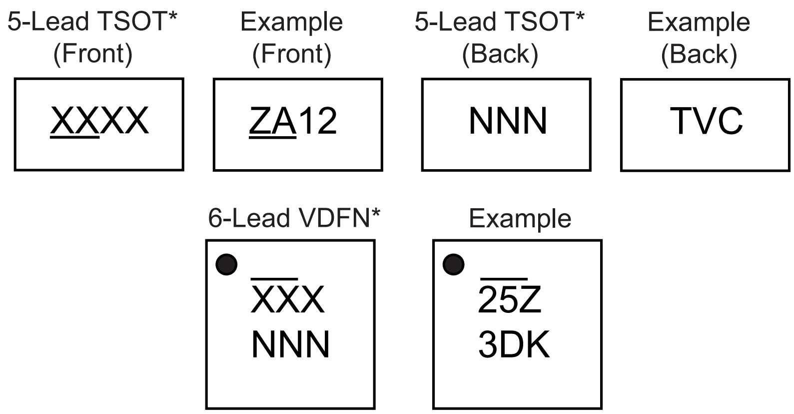


TABLE 5-1: MARKING CODES

Part Number	Marking Code	Voltage	Package
MIC5232-1.2YD5	ZA12	1.2V	TSOT-23-5
MIC5232-1.8YD5	ZA18	1.8V	TSOT-23-5
MIC5232-2.5YD5	ZA25	2.5V	TSOT-23-5
MIC5232-2.8YD5	ZA28	2.8V	TSOT-23-5
MIC5232-3.3YD5	ZA33	3.3V	TSOT-23-5
MIC5232-1.2YML	12Z	1.2V	6-Lead 2 mm x 2 mm VDFN
MIC5232-1.8YML	18Z	1.8V	6-Lead 2 mm x 2 mm VDFN
MIC5232-2.5YML	25Z	2.5V	6-Lead 2 mm x 2 mm VDFN
MIC5232-2.8YML	28Z	2.8V	6-Lead 2 mm x 2 mm VDFN
MIC5232-3.3YML	33Z	3.3V	6-Lead 2 mm x 2 mm VDFN

Legend:

XX...X	Product code or 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.

●, ▲, ▼ Pin one index is identified by a dot, delta up, or delta down (triangle mark).

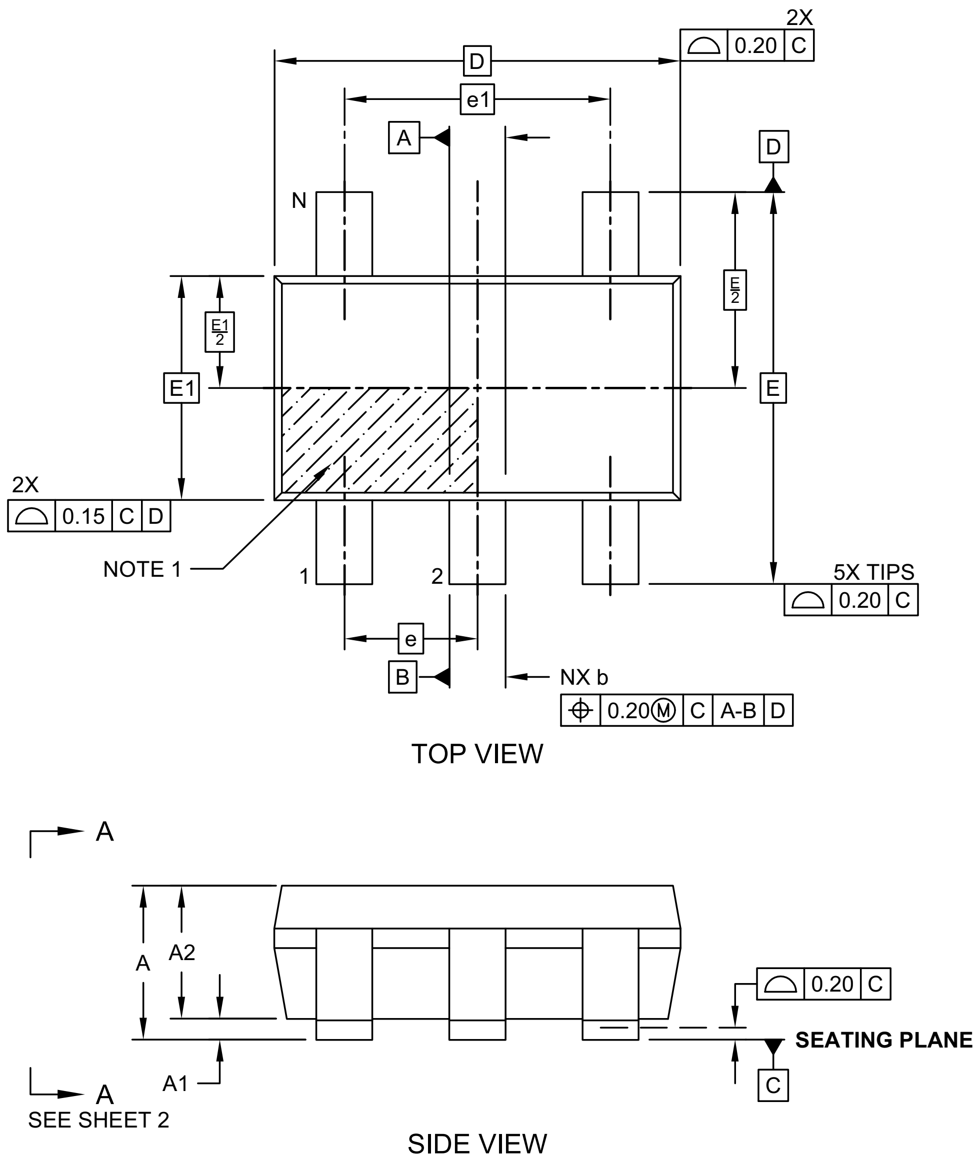
Note: In the event the full Microchip part number cannot be marked on one line, it will be carried over to the next line, thus limiting the number of available characters for customer-specific information. Package may or may not include the corporate logo.

Underbar (_) and/or Overbar (‾) symbol may not be to scale.

Note: If the full seven-character YYWWNNN code cannot fit on the package, the following truncated codes are used based on the available marking space:
6 Characters = YWWNNN; 5 Characters = WWNNN; 4 Characters = WNNN; 3 Characters = NNN;
2 Characters = NN; 1 Character = N

5-Lead Plastic Thin Small Outline Transistor (D5A) [TSOT]
Micrel Legacy Package TSOT-5LD-PL-1

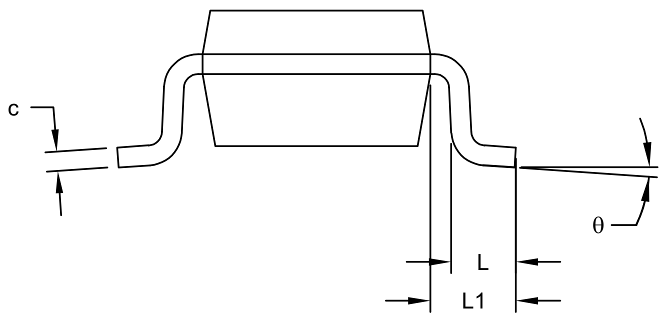
Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



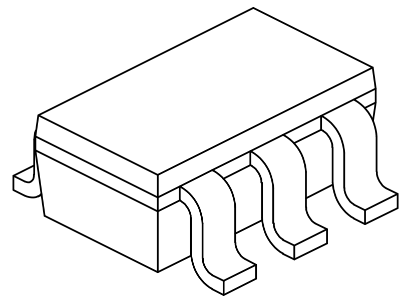
Microchip Technology Drawing C04-1179 Rev A Sheet 1 of 2

5-Lead Plastic Thin Small Outline Transistor (D5A) [TSOT]
Micrel Legacy Package TSOT-5LD-PL-1

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



VIEW A-A
SHEET 1



	Units	MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Number of Leads	N		5	
Pitch	e		0.95 BSC	
Outside lead pitch	e1		1.90 BSC	
Overall Height	A	-	-	1.00
Molded Package Thickness	A2	0.84	0.87	0.90
Standoff	A1	0.00	-	0.10
Overall Width	E		2.80 BSC	
Molded Package Width	E1		1.60 BSC	
Overall Length	D		2.90 BSC	
Foot Length	L	0.30	0.40	0.50
Footprint	L1		0.60 REF	
Foot Angle	ϕ	0°	-	4°
Lead Thickness	c		0.127 REF	
Lead Width	b	0.30	-	0.50

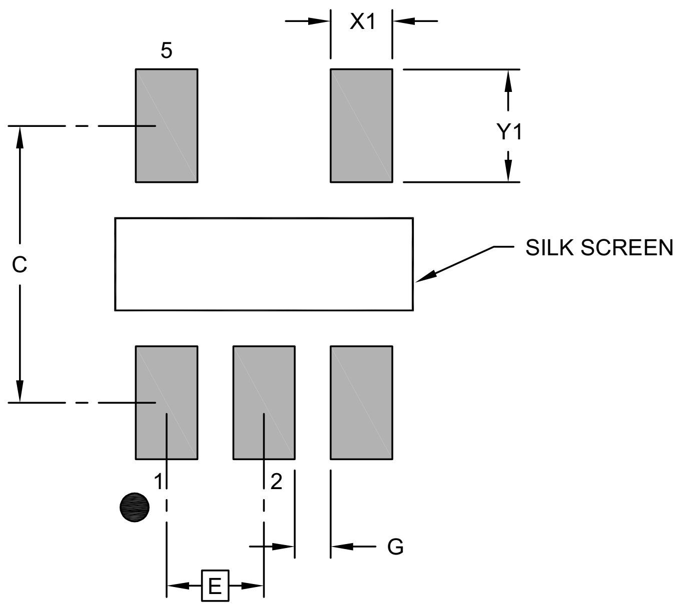
Notes:

1. Dimensions D and E1 do not include mold flash or protrusions. Mold flash or protrusions shall not exceed 0.25mm per side.
2. 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.

Microchip Technology Drawing C04-1179 Rev A Sheet 1 of 2

5-Lead Plastic Thin Small Outline Transistor (D5A) [TSOT]
Micrel Legacy Package TSOT-5LD-PL-1

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



RECOMMENDED LAND PATTERN

	Units	MILLIMETERS		
	Dimension Limits	MIN	NOM	MAX
Contact Pitch	E	0.95 BSC		
Contact Pad Spacing	C		2.60	
Contact Pad Width (X5)	X1			0.60
Contact Pad Length (X5)	Y1			1.10
Contact Pad to Center Pad (X2)	G	0.20		

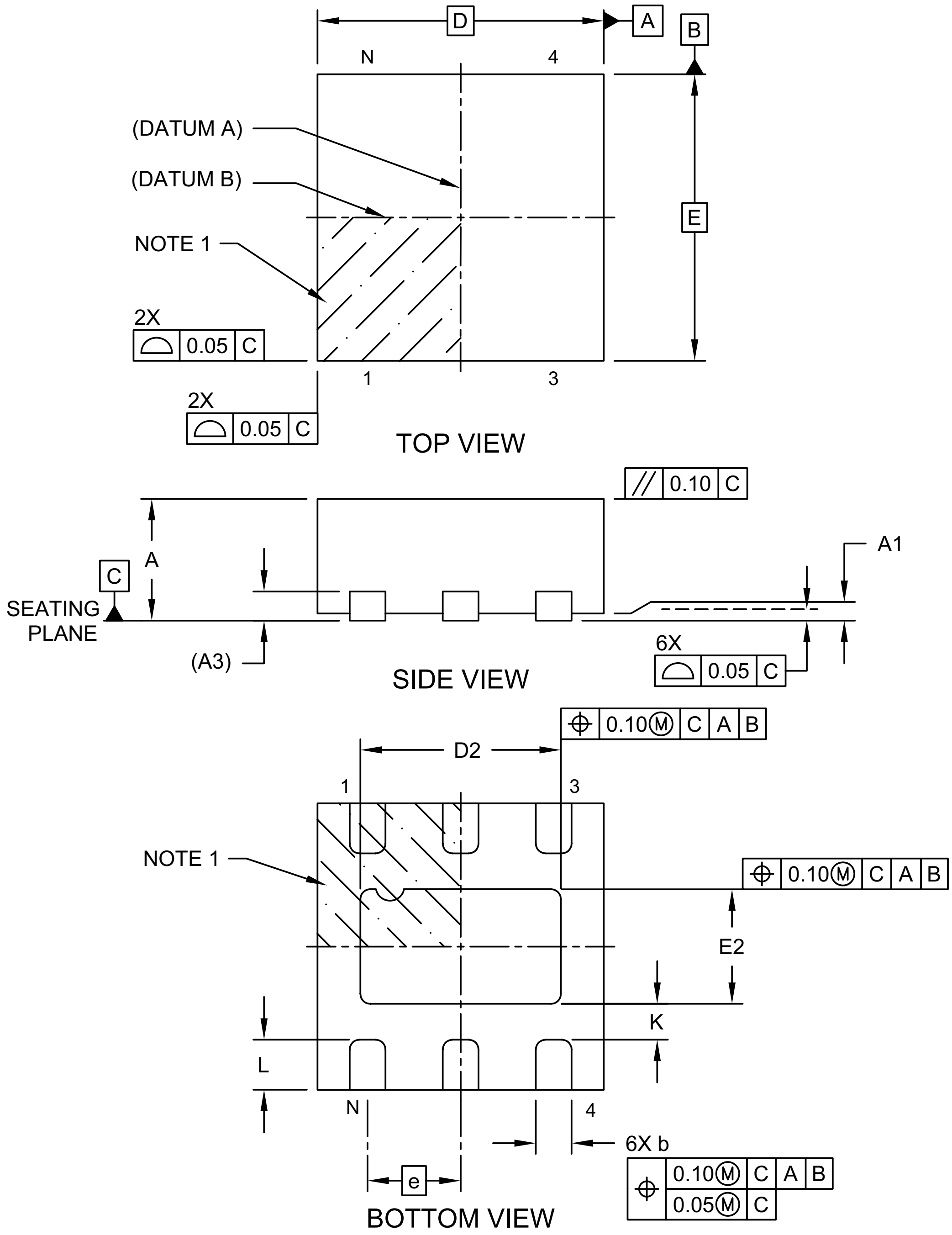
Notes:

1. Dimensioning and tolerancing per ASME Y14.5M
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

Microchip Technology Drawing C04-3179 Rev A

6-Lead Very Thin Plastic Dual Flat, No Lead Package (JDA) - 2x2 mm Body [VDFN] Micrel Legacy Package

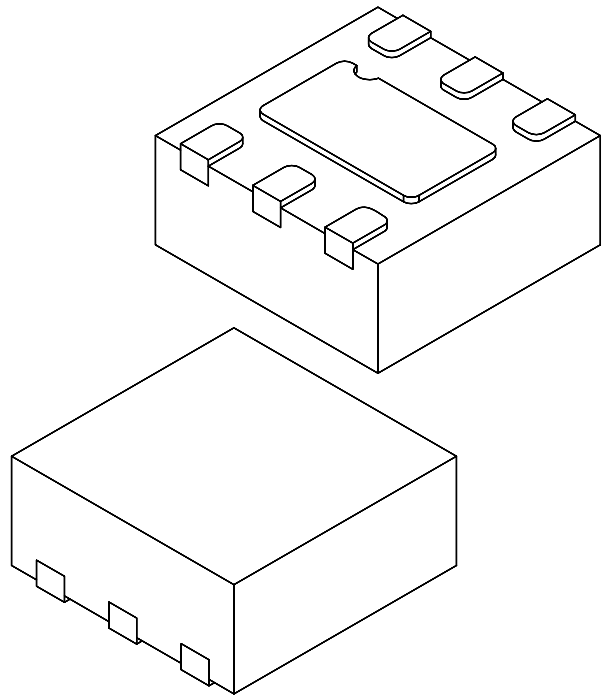
Note:	For the most current package drawings, please see the Microchip Packaging Specification located at http://www.microchip.com/packaging



Microchip Technology Drawing C04-1016A Sheet 1 of 2

6-Lead Very Thin Plastic Dual Flat, No Lead Package (JDA) - 2x2 mm Body [VDFN] Micrel Legacy Package

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		6	
Pitch	e		0.65 BSC	
Overall Height	A	0.80	0.85	0.90
Standoff	A1	0.00	0.02	0.05
Terminal Thickness	A3		0.203 REF	
Overall Length	D		2.00 BSC	
Exposed Pad Length	D2	1.35	1.40	1.45
Overall Width	E		2.00 BSC	
Exposed Pad Width	E2	0.75	0.80	0.85
Terminal Width	b	0.20	0.25	0.30
Terminal Length	L	0.30	0.35	0.40
Terminal-to-Exposed-Pad	K	0.20	-	-

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

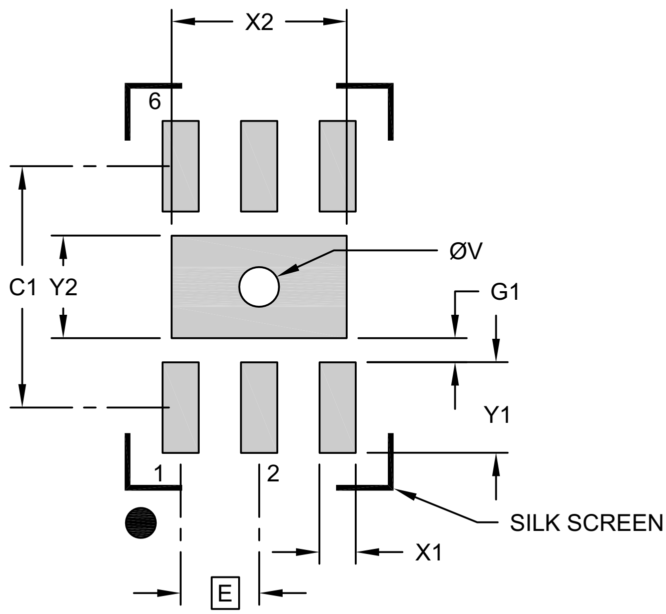
   BSC: Basic Dimension. Theoretically exact value shown without tolerances.

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

Microchip Technology Drawing C04-1016A Sheet 2 of 2

6-Lead Very Thin Plastic Dual Flat, No Lead Package (JDA) - 2x2 mm Body [VDFN] Micrel Legacy Package

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



RECOMMENDED LAND PATTERN

Units		MILLIMETERS		
Dimension Limits		MIN	NOM	MAX
Contact Pitch	E	0.65 BSC		
Optional Center Pad Width	X2			0.85
Optional Center Pad Length	Y2			1.45
Contact Pad Spacing	C1		2.00	
Contact Pad Width (X6)	X1			0.30
Contact Pad Length (X6)	Y1			0.75
Contact Pad to Center Pad (X6)	G1	0.20		
Thermal Via Diameter	V	0.27	0.30	0.33

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 C04-21016A

NOTES:

APPENDIX A: REVISION HISTORY

Revision A (September 2023)

- Converted Micrel document MIC5232 to Microchip data sheet DS20006811A.
- Minor text changes throughout.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

To order or obtain information, e.g., on pricing or delivery, contact your local Microchip representative or sales office.

Part Number	-X.X	X	XX	-XX
Device	Output Voltage	Temperature Range	Package	Media Type

Device:	MIC5232:		10 mA Ultra-Low Quiescent Current µCap LDO
Output Voltage:	1.2	=	1.2V
	1.8	=	1.8V
	2.5	=	2.5V
	2.8	=	2.8V
	3.3	=	3.3V
Temperature Range:	Y	=	–40°C to +125°C
Package:	D5	=	Thin SOT-23-5
	ML	=	6-Lead 2 mm x 2 mm VDFN
Media Type:	TR	=	5,000/Reel (VDFN) or 3,000/Reel (TSOT)
	TX	=	3,000/Reel (Reverse TR, TSOT 1.8V only)

Examples:

a) MIC5232-3.3YD5-TR: MIC5232, 3.3V Output Voltage, –40°C to +125°C Temp. Range, TSOT-23-5, 3,000/Reel

b) MIC5232-2.5YML-TR: MIC5232, 2.5V Output Voltage, –40°C to +125°C Temp. Range, 6-Lead VDFN, 5,000/Reel

c) MIC5232-1.8YD5-TX: MIC5232, 1.8V Output Voltage, –40°C to +125°C Temp. Range, TSOT-23-5, 3,000/Reel (Reverse)

d) MIC5232-1.2YML-TR: MIC5232, 1.2V Output Voltage, –40°C to +125°C Temp. Range, 6-Lead VDFN, 5,000/Reel

Note: Tape and Reel identifier only appears in the catalog part number description. This identifier is used for ordering purposes and is not printed on the device package. Check with your Microchip Sales Office for package availability with the Tape and Reel option.

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