MAQ5281

120V_{IN}, 25 mA, Ultra-Low I_Q, High-PSRR Linear Regulator

Features

- AEC-Q100 Qualified
- Wide Input Voltage Range: 6V to 120V DC
- Ultra-Low Quiescent Current: 6 µA (typ.)
- 25 mA Ensured Output Current
- Adjustable Output Voltage from 1.27V to 5.5V
- Withstands Up to +120V DC at the Input
- Stable with Ceramic Capacitors
- Ultra-High PSRR >90 dB
- Ultra-High Line Transient Rejection (Load Dump)
- High Output Accuracy
  - ±3% Initial Accuracy
- Thermal-Shutdown and Current-Limit Protection
- Thermally Efficient, 8-Lead ePad MSOP Package

Applications

- Automotive
- Remote Keyless Entry Power Supply
- Telecom Applications

General Description

The MAQ5281 high-performance linear regulator offers a very wide input operating voltage range, up to 120V DC, and supplies an output current of up to 25 mA.

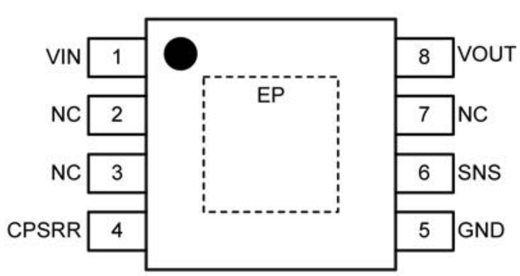
Ideal for high input voltage applications such as automotive, industrial and telecom, the MAQ5281 offers ±3% initial accuracy, extremely high-power supply rejection ratio (>90 dB) and ultra-low quiescent current of 6 µA. The MAQ5281 is optimized for high-voltage line transients, making it ideal for harsh environment applications.

The MAQ5281 is offered in both fixed output voltage (3.3V/5.0V) and adjustable output voltage (1.27V to 5.5V) options.

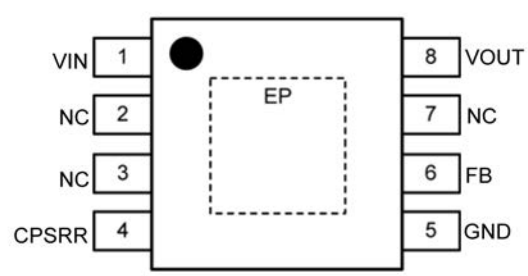
The MAQ5281 operates over a –40°C to +125°C temperature range and is available in lead-free, RoHS-compliant, 8-lead ePad MSOP package. This part is also AEC-Q100 qualified for automotive applications.

Package Types

MAQ5281 (Fixed Version)
8-Lead ePad MSOP (MM)
(Top View)

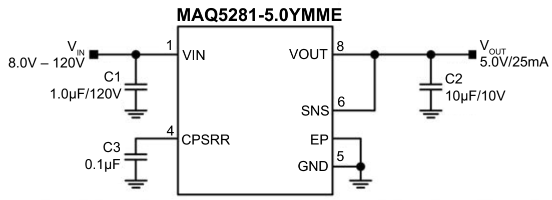


MAQ5281 (Adjustable Version)
8-Lead ePad MSOP (MM)
(Top View)

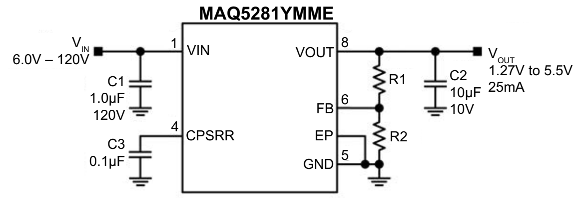


Typical Application Circuits

MAQ5281 (Fixed Version)

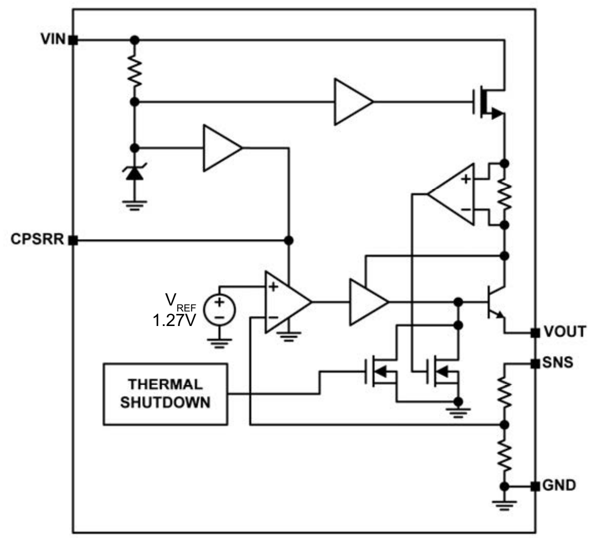


MAQ5281 (Adjustable Version)

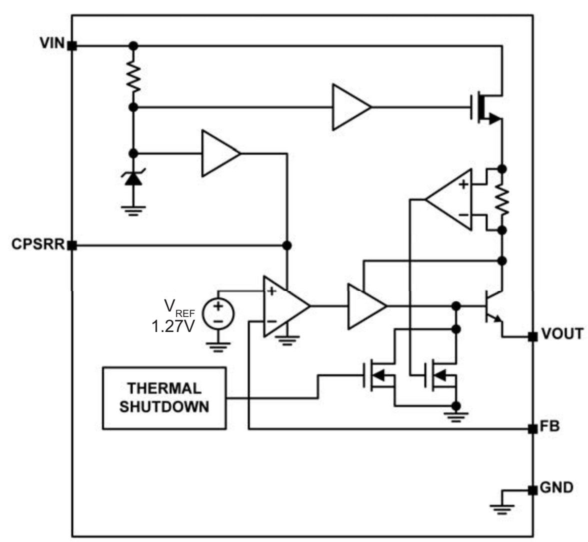


Functional Block Diagrams

MAQ5281 (Fixed Version)



MAQ5281 (Adjustable Version)



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

V_{IN} to GND .... –0.3V to +125V
V_{CPSRR} to GND .... –0.3V to +14V
V_{FB}, V_{SNS}, V_{OUT} to GND .... –0.3V to +6V
Power Dissipation (P_D, Note 1) .... Internally Limited
ESD Ratings (Note 2)
HBM .... 2 kV
MM 200V

Operating Ratings ‡

V_{IN} .... +6V to +120V
V_{OUT} Adjust Range .... +1.27V to +5.5V

† 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 at any T_A (ambient temperature) is $P_{D(MAX)} = (T_{J(MAX)} – T_A)/θ_{JA}$. Exceeding the maximum allowable power dissipation results in excessive die temperature, and causes the regulator to enter thermal shutdown.

2: Devices are ESD sensitive; use proper handling precautions. Human body model, 1.5 kΩ in series with 100 pF.

ELECTRICAL CHARACTERISTICS

Electrical Characteristics: V_{IN} = 12V, C_{IN} = 1.0 µF, C_{PSRR} = 0.1 µF, C_{OUT} = 10 µF, I_{OUT} = 100 µA, T_A = +25°C, **bold** values valid for –40°C ≤ T_J ≤ +125°C, unless noted. (Note 1)

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Power Supply Input						
Input Voltage Range	V_{IN}	6	—	120	V	Note 2
Quiescent Supply Current	I_Q	—	6	**11**	µA	I_{OUT} = 0, Note 3
Output Voltage						
Output Voltage	V_{OUT}	1.27	—	5.5	V	Adjustable version
		3.2	3.3	3.4		Fixed 3.3V version
		3.13	3.3	**3.47**		
		4.85	5.0	5.15		Fixed 5.0 version
		4.75	5.0	**5.25**		
Output Voltage Accuracy	—	–3	—	+3	%	Variation from nominal V_{OUT}
		–5	—	**+5**		
Load Regulation	$ΔV_{OUT}/V_{OUT}$	**–1.0**	0.2	**+1.0**	%	I_{OUT} = 100 µA to 25 mA
Line Regulation	$ΔV_{OUT}/(V_{OUT} \times ΔV_{IN})$	**–0.5**	0.04	**+0.5**	%/V	V_{IN} = 10V to 120V, Note 4
Feedback Input (Adjustable Version)						
Feedback Voltage	V_{FB}	1.232	1.270	1.308	V	—
		1.206	1.270	**1.333**		
Feedback Current	I_{FB}	—	3.2	—	nA	V_{FB} = 1.27V

ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: V_{IN} = 12V, C_{IN} = 1.0 µF, C_{PSRR} = 0.1 µF, C_{OUT} = 10 µF, I_{OUT} = 100 µA, T_A = +25°C, **bold** values valid for –40°C ≤ T_J ≤ +125°C, unless noted. (Note 1)

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Current Limit						
Current Limit	I_{LIM}	**30**	65	**130**	mA	V_{OUT} = 0V
Ripple Rejection						
Power Supply Rejection Ratio	PSRR	—	90	—	dB	f = 20 kHz to 2 MHz
Power Dropout Voltage						
Dropout Voltage	V_{DO}	—	2	**3**	V	I_{OUT} = 25 mA
Thermal Protection						
Thermal Shutdown Temperature	T_{SHDN}	—	157	—	°C	T_J rising
Thermal Shutdown Hysteresis	T_{SD_HYS}	—	15	—	°C	—

Note 1: Specifications are for packaged products only.

2: Ensure that V_{IN} ≥ (V_{OUT} + 3V) and V_{IN} ≥ 6V.

3: Quiescent current is specified for the adjustable option. The fixed options will add approximately 1 µA due to the internal feedback resistors.

4: Line regulation is a percentage of V_{OUT}.

TEMPERATURE SPECIFICATIONS

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Junction Temperature Range	T_J	–40	—	+125	°C	Note 1
Storage Temperature Range	T_S	–65	—	+150	°C	—
Lead Temperature	—	—	—	+260	°C	Soldering, 10s
Package Thermal Resistances						
Thermal Resistance, MSOP 8-LD	θ_{JA}	—	64	—	°C/W	—

Note 1: The maximum allowable power dissipation is a function of ambient temperature, the maximum allowable junction temperature and the thermal resistance from junction to air (i.e., T_A, T_J, θ_{JA}). Exceeding the maximum allowable power dissipation will cause the device operating junction temperature to exceed the maximum +125°C rating. Sustained junction temperatures above +125°C can impact the device reliability.

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.

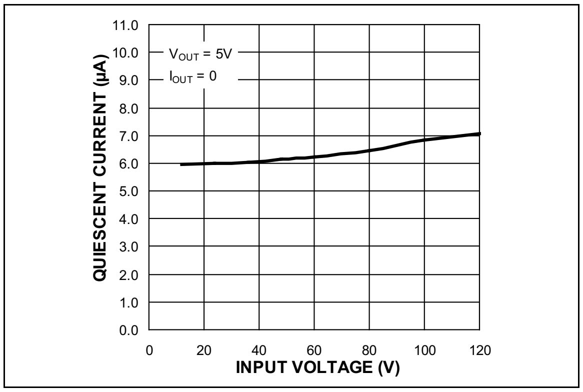


FIGURE 2-1: *Quiescent Supply Current vs. Input Voltage.*

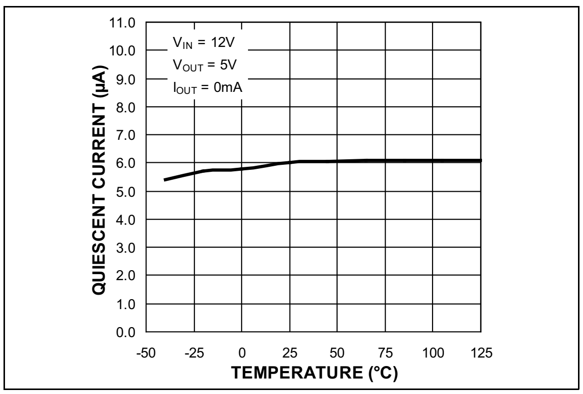


FIGURE 2-2: *Quiescent Supply Current vs. Temperature.*

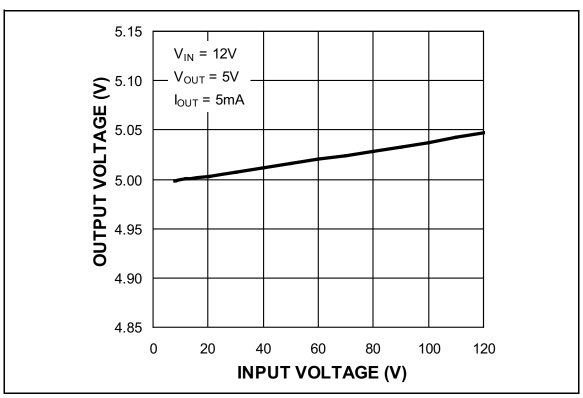


FIGURE 2-3: *Output Voltage vs. Input Voltage.*

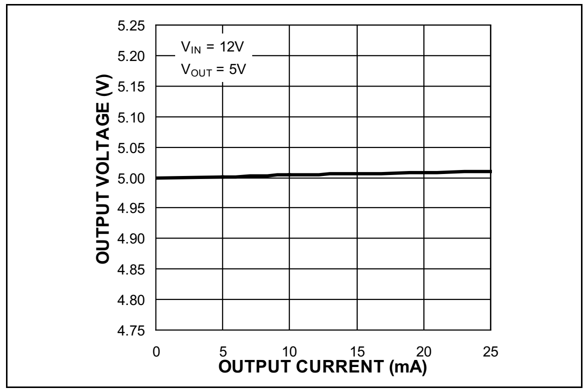


FIGURE 2-4: *Output Voltage vs. Output Current.*

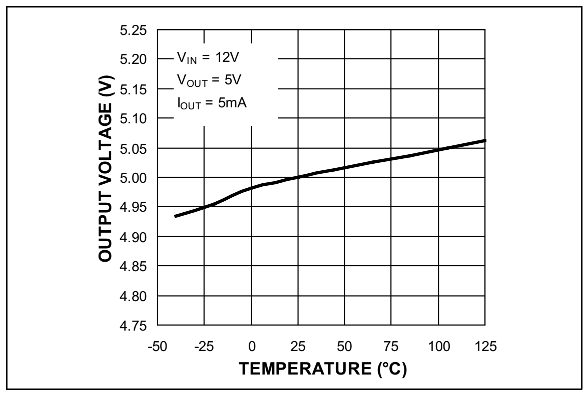


FIGURE 2-5: *Output Voltage vs. Temperature.*

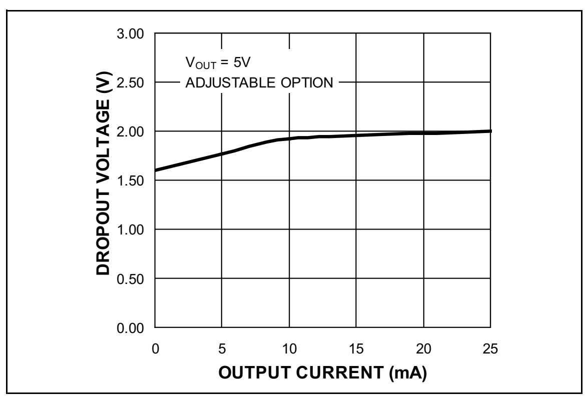


FIGURE 2-6: *Dropout Voltage vs. Output Current.*

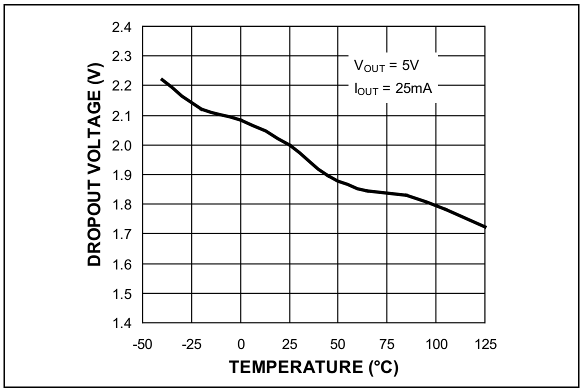


FIGURE 2-7: *Dropout Voltage vs. Temperature.*

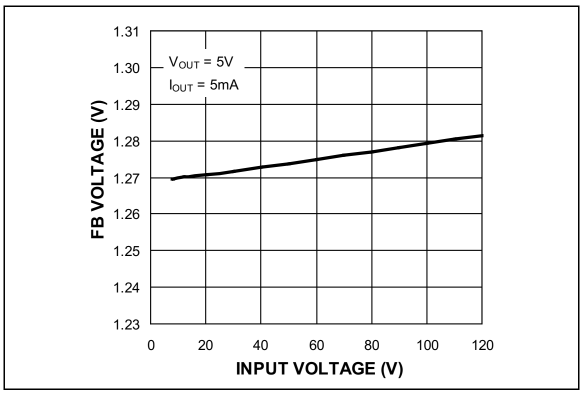


FIGURE 2-8: *Feedback Pin Voltage vs. Input Voltage.*

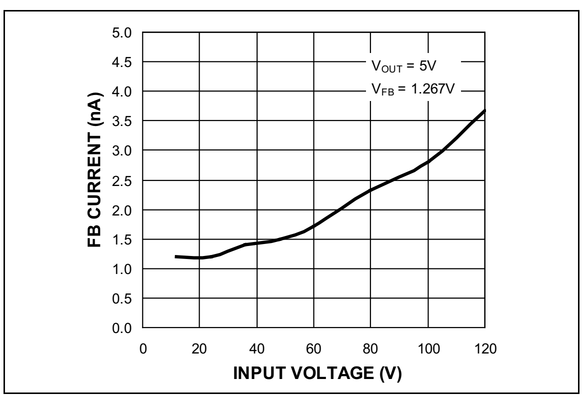


FIGURE 2-9: *Feedback Pin Current vs. Input Voltage.*

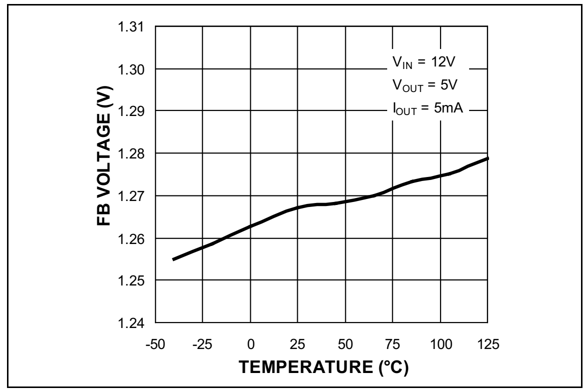


FIGURE 2-10: *Feedback Pin Voltage vs. Temperature.*

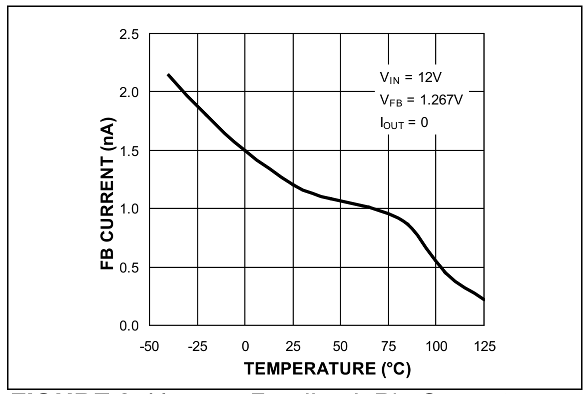


FIGURE 2-11: *Feedback Pin Current vs. Temperature.*

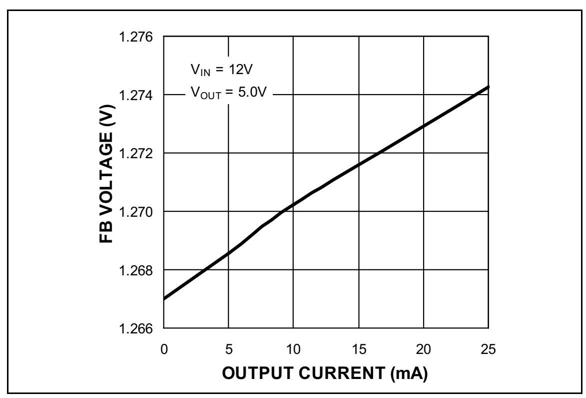


FIGURE 2-12: *Feedback Pin Voltage vs. Output Current.*

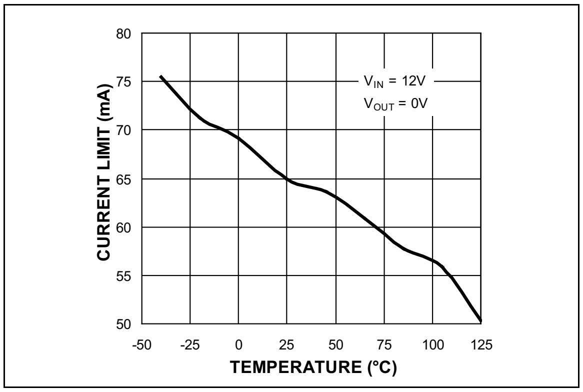


FIGURE 2-13: *Current Limit vs. Temperature.*

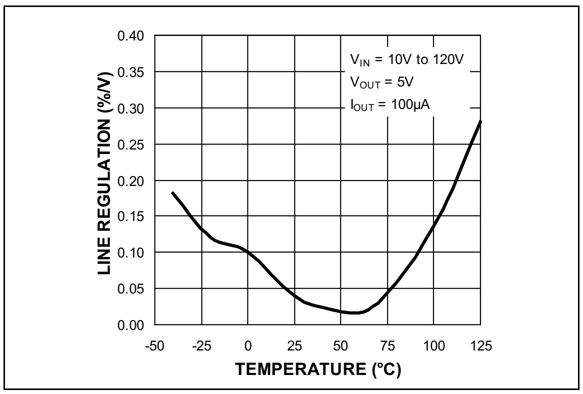


FIGURE 2-14: *Line Regulation vs. Temperature.*

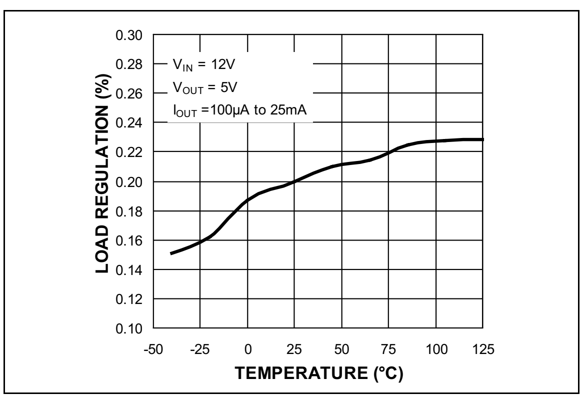


FIGURE 2-15: *Load Regulation vs. Temperature.*

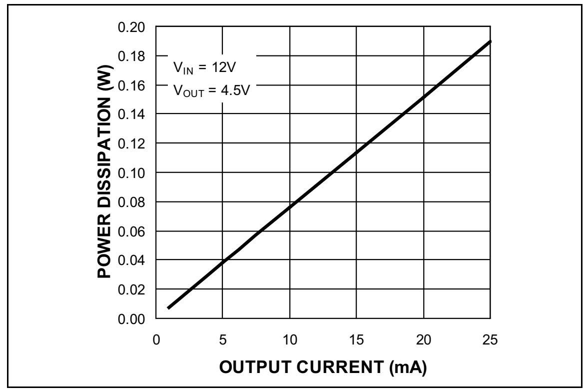


FIGURE 2-16: *Power Dissipation vs. Output Current.*

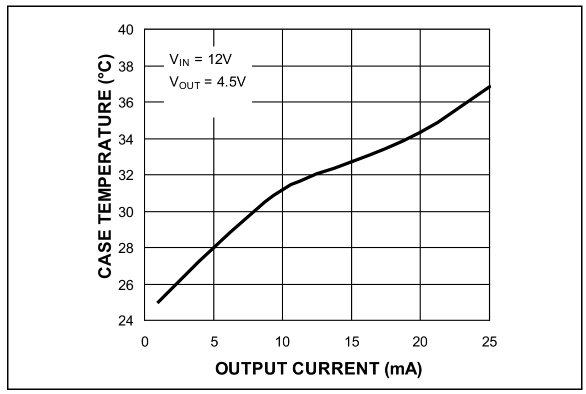


FIGURE 2-17: *Case Temperature* vs. Output Current.*

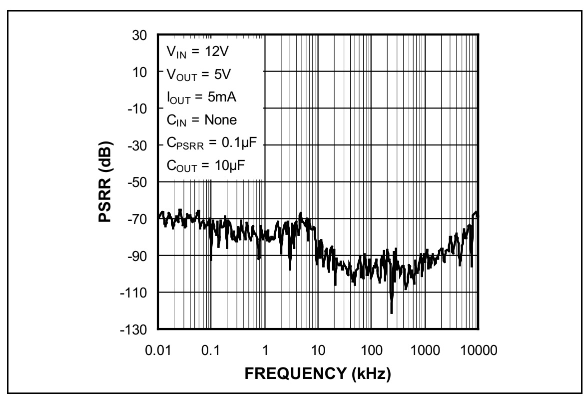


FIGURE 2-18: *PSRR vs. Frequency.*

***** The temperature measurement was taken at the hottest point on the MAQ5282 case mounted on a 2.25 square inch PCB at an ambient temperature of +25°C; see the "Thermal Measurement" section. Actual results will depend upon the size of the PCB, ambient temperature, and proximity to other heat emitting components.

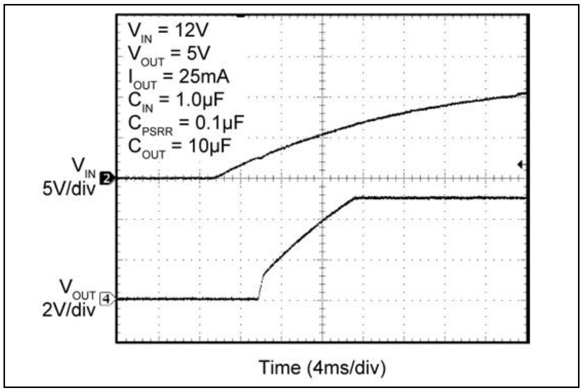


FIGURE 2-19: *Soft Turn-On into Full Load.*

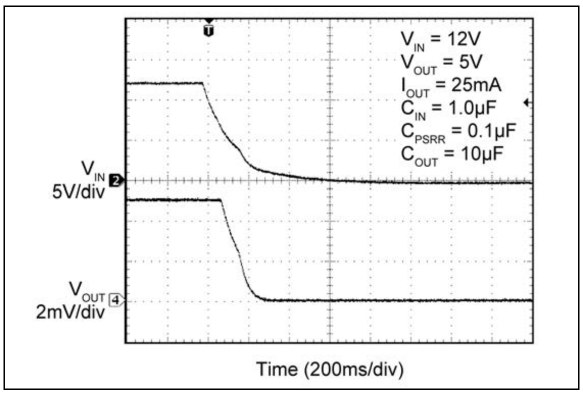


FIGURE 2-20: *Soft Turn-Off.*

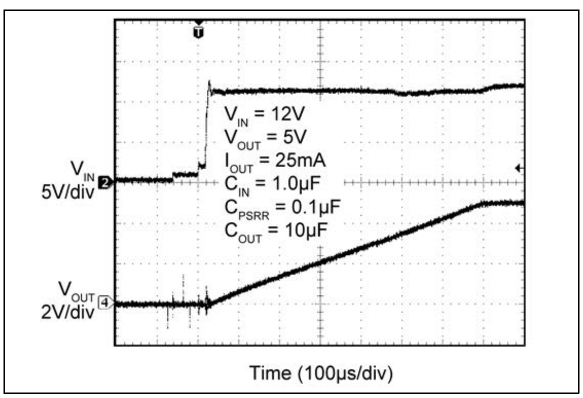


FIGURE 2-21: *Hot Plug.*

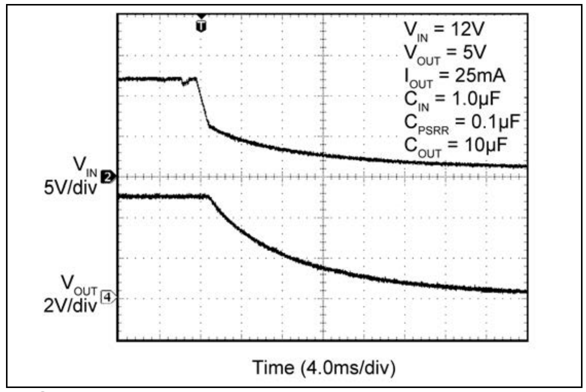


FIGURE 2-22: *Hot Un-Plug.*

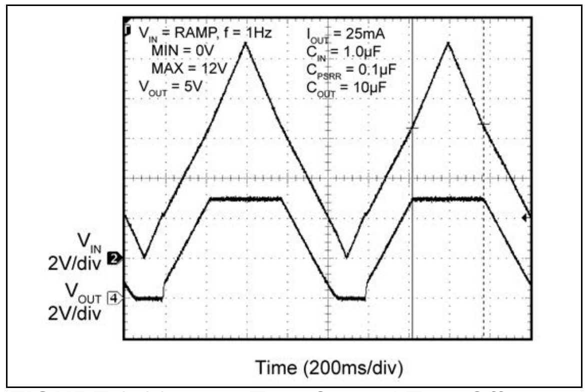


FIGURE 2-23: *Turn-On and Turn-Off.*

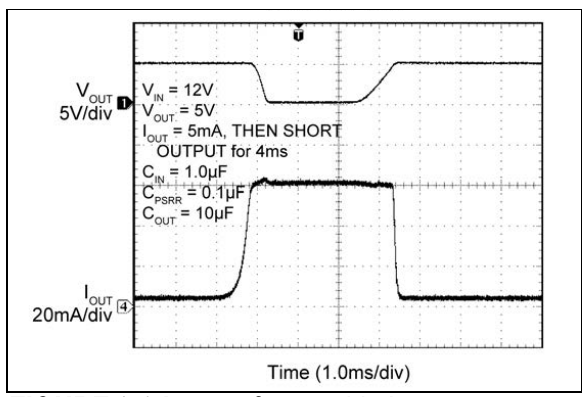


FIGURE 2-24: *Current Limit.*

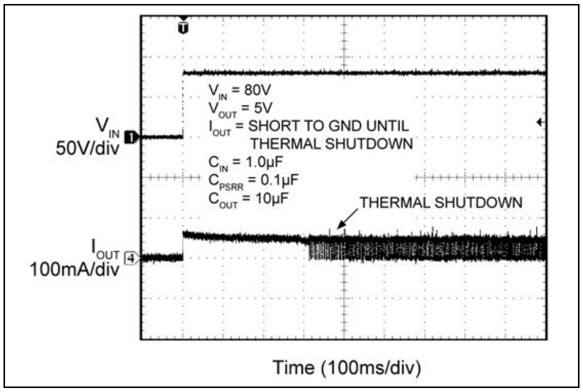


FIGURE 2-25: *Thermal Shutdown, Short Circuit.*

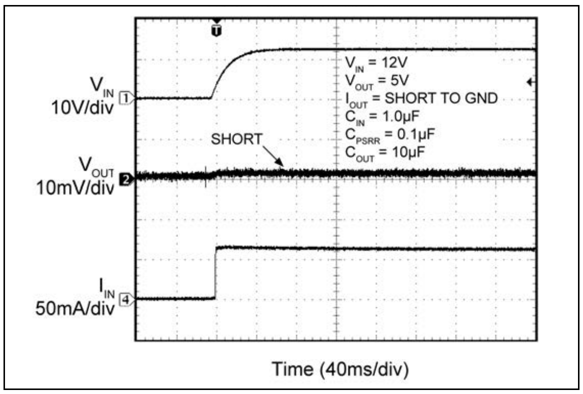


FIGURE 2-26: *Turn-On into Short Circuit.*

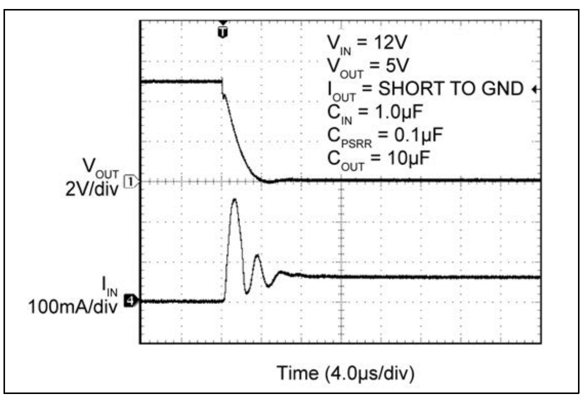


FIGURE 2-27: *Short-Circuit Response.*

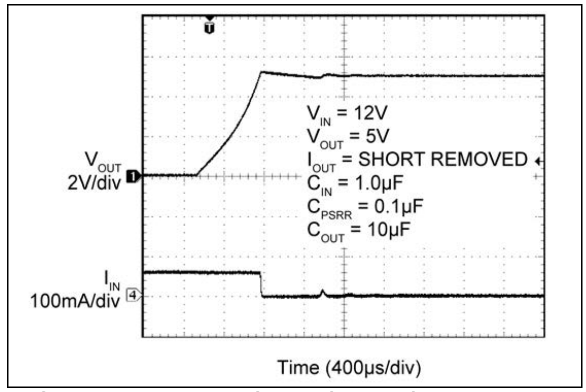


FIGURE 2-28: *Short-Circuit Output Voltage Recovery.*

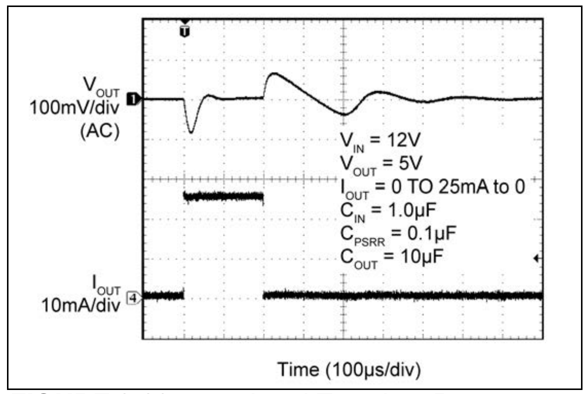


FIGURE 2-29: *Load Transient Response.*

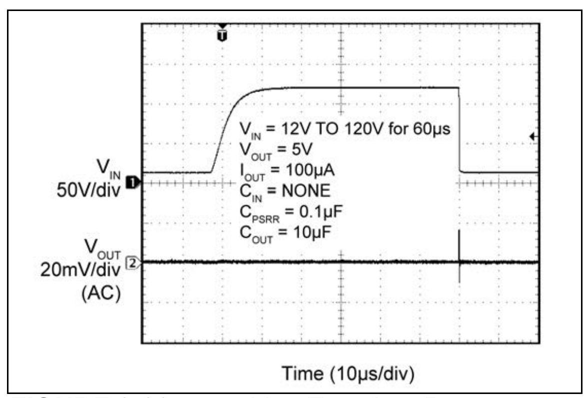


FIGURE 2-30: *Line Transient Response.*

3.0 PIN DESCRIPTIONS

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

TABLE 3-1: PIN FUNCTION TABLE

Pin Number (Adj. Version)	Pin Number (Fixed Version)	Pin Name	Description
1	1	VIN	Supply Voltage Input. Connect 1 µF capacitor from VIN to GND.
2, 3, 7	2, 3, 7	NC	Not internally connected. Connect NC to GND or leave unconnected.
4	4	CPSRR	Bypass Capacitor Connection. Connect 0.1 µF capacitor from CPSRR to GND.
5	5	GND	Ground.
6	—	FB	Feedback Connection. For external resistor divider to set V_{OUT}.
—	6	SNS	Sense input. Connect SNS to VOUT.
8	8	VOUT	Regulator Output. Connect 10 µF capacitor from VOUT to GND.
EP	EP	ePAD	Exposed Pad for Thermal Relief. Connect EP to GND.

4.0 DETAILED DESCRIPTION

The MAQ5281 voltage regulator accepts a 6V to 120V input and has an ultra-low 6 µA typical quiescent current while offering an excellent line transient response and PSRR. These features make it ideal for harsh, noisy environments. All options of the device offer 25 mA of output current. The MAQ5281YMME offers an adjustable output voltage from 1.27V to 5.5V. The MAQ5281-3.3YMME offers fixed 3.3V outputs and the MAQ5281-5.0YMME offers fixed 5.0V outputs. The MME packaged devices feature a heat slug to more effectively remove heat from the die.

5.0 APPLICATIONS INFORMATION

5.1 Thermal Protection

The MAQ5281 has an internal thermal shutdown circuit to protect it from excessive heating of the die. When the junction temperature exceeds approximately +155°C, the output is disabled and the device begins to cool down. The device turns back on when the junction temperature cools by 15°C. This will result in a cycled output during continuous thermal-overload conditions.

5.2 Current Limit

The MAQ5281 features output current-limit protection. The output sustains a continuous short circuit to GND without damage to the device, but thermal shutdown often results.

5.3 Input Capacitor

Connect a 1 µF capacitor from VIN to GND. Microchip recommends the C5750X7R2E105M, 1 µF, 250V capacitor made by TDK. When using a different capacitor, ensure that the voltage rating of the capacitor exceeds any potential transient.

5.4 CPSRR Capacitor

Connect a 0.1 µF capacitor from CPSRR to GND to maintain high power supply rejection. The voltage rating of the capacitor must be at least 14V.

5.5 Output Capacitor

Connect a 10 µF capacitor from VOUT to GND. Ensure that the voltage rating of the capacitor exceeds the designed output voltage of the MAQ5281.

5.6 Output Voltage Setting

For the MAQ5281YMME, V_{OUT} is programmed from 1.27V to 5.5V using:

EQUATION 5-1:

$$V_{OUT} = V_{REF} \times \left(\frac{R1}{R2} + 1\right)$$

Where:

V_{REF} = 1.27V

R1 and R2 are shown in the Typical Application Circuits.

5.7 Thermal Measurements

It is always wise to measure an IC's case temperature to make sure that it is within operating limits, but it is easy to get erroneous results. The standard thermocouple that comes with many voltage meters uses a large wire gauge that behaves like a heat-sink, resulting in artificially low case temperature measurements. Use a thermocouple of 36-gauge wire or smaller, such as the Omega (5SC-TT-K-36-36), to minimize the heat-sinking effect. Also, apply thermal compound to maximize heat transfer between the IC and the thermocouple.

An infrared thermometer is a recommended alternative. The IR thermometer from Optris has a 1 mm spot size, ideal for monitoring small surface mount packages. Also, the optional stand makes it easy to keep the beam on the IC for long periods of time.

6.0 EVALUATION BOARD SCHEMATIC

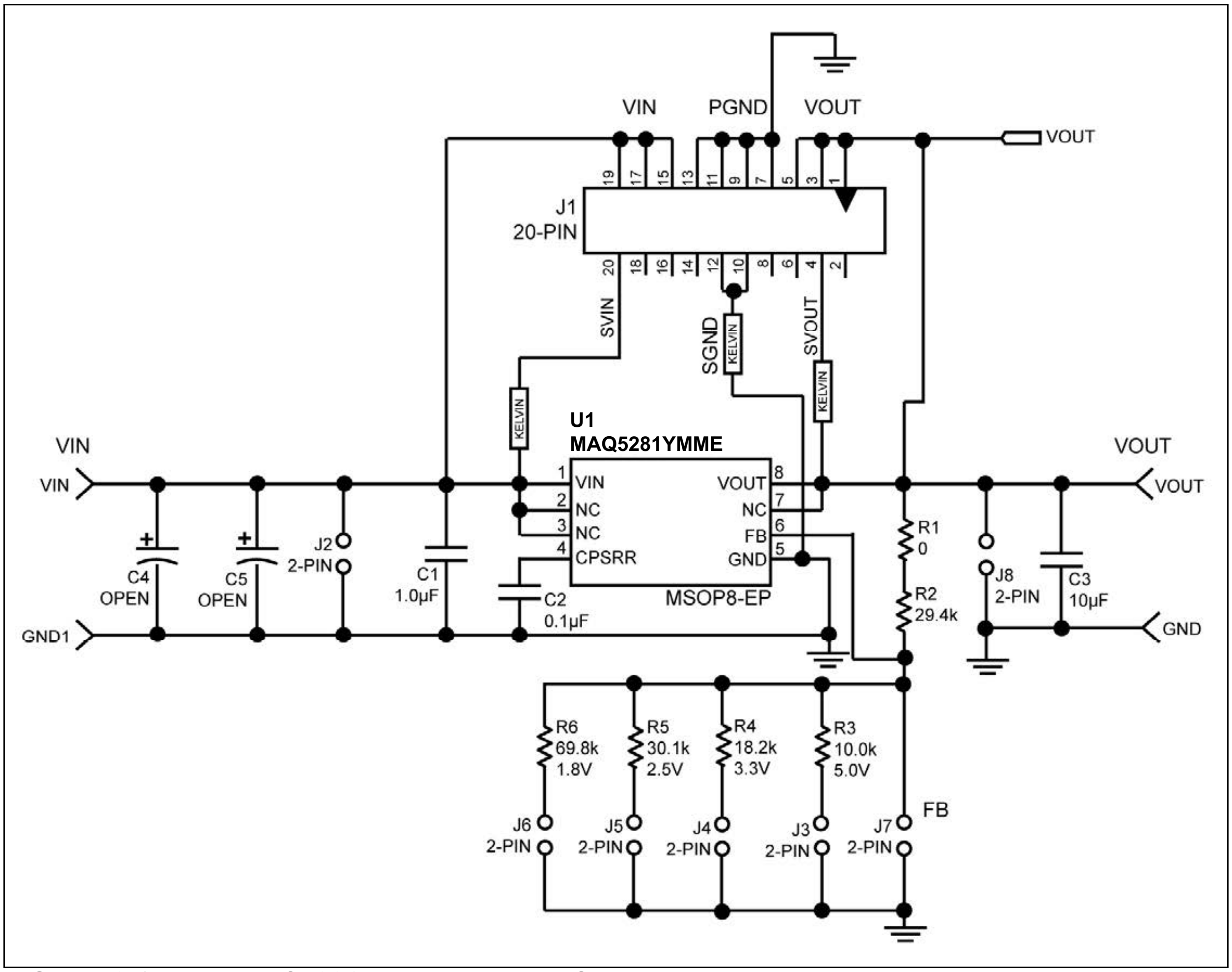


FIGURE 6-1: MAQ5281 Evaluation Board Schematic.

TABLE 6-1: BILL OF MATERIALS

Item	Part Number	Manufacturer	Description	Qty.
C1	C5750X7R2E105M	TDK	1.0 µF, 250V, 20%, X7R capacitor (2220)	1
C2	08053C104KAT2A	AVX	0.1 µF 25V 20%, X7R capacitor (0805)	1
C3	0805ZD106KAT2A	AVX	10 µF, 10V, 20%, X5R, capacitor (0805)	1
C4, C5	OPEN	—	—	0
R1	CRCW06030000F	Vishay/Dale	0Ω, 1% resistor, 0603	1
R2	CRCW06032942F	Vishay/Dale	29.4 kΩ, 1% resistor, 0603	1
R3	CRCW06031002F	Vishay/Dale	10.0 kΩ, 1% resistor, 0603	1
R4	CRCW06031822F	Vishay/Dale	18.2 kΩ, 1%, resistor, 0603	1
R5	CRCW06033012F	Vishay/Dale	30.1 kΩ, 1% resistor chip, 0603	1
R6	CRCW06036982F	Vishay/Dale	69.8 kΩ, 1%, resistor, 0603	1
U1	MAQ5281YMME	Microchip	$120V_{IN}$, 25 mA, Ultra-Low I_Q, High-PSRR Linear Regulator	1

7.0 PCB EVALUATION BOARD LAYOUT

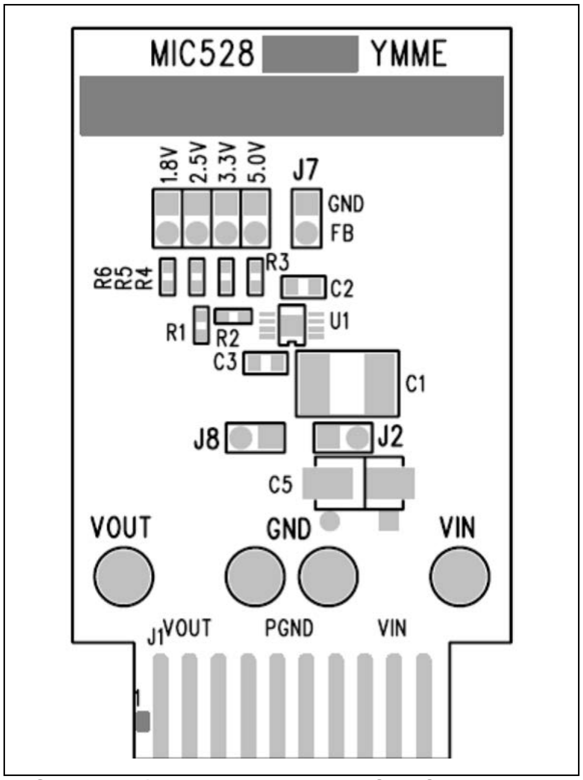


FIGURE 7-1: *Top Layer Silk Screen.*

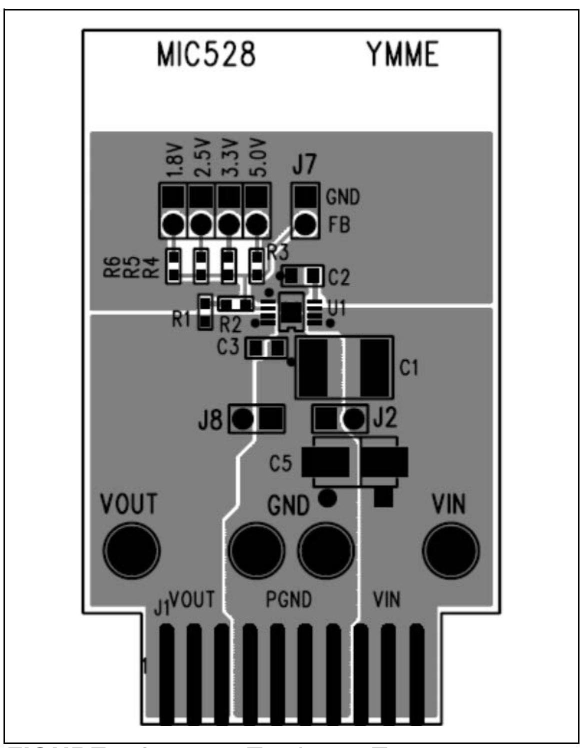


FIGURE 7-2: *Top Layer Traces.*

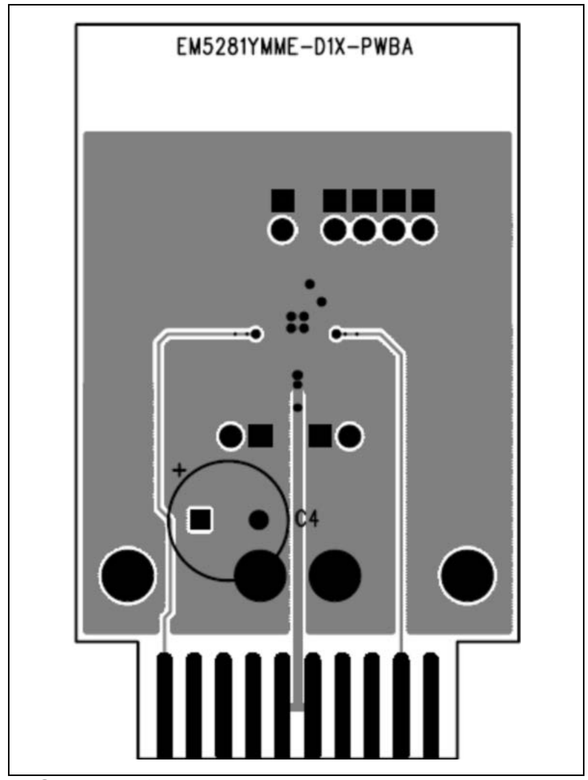


FIGURE 7-3: *Bottom Layer Traces.*

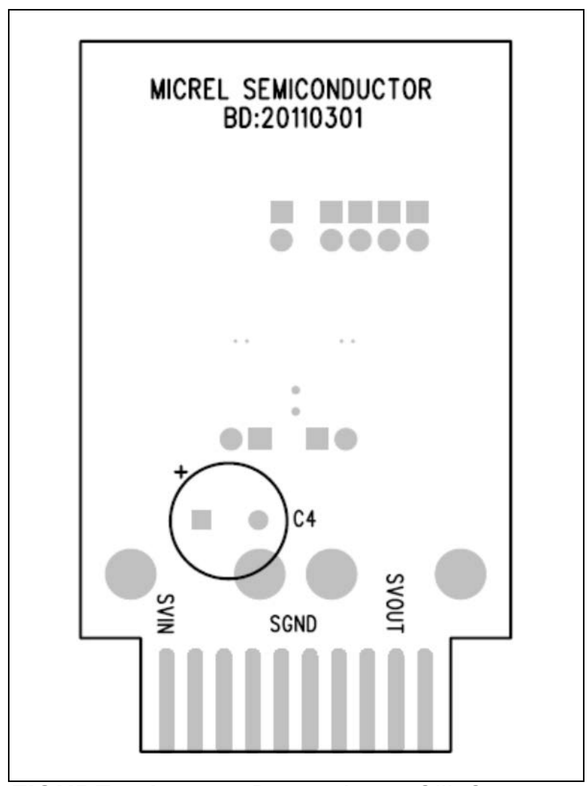


FIGURE 7-4: *Bottom Layer Silk Screen.*

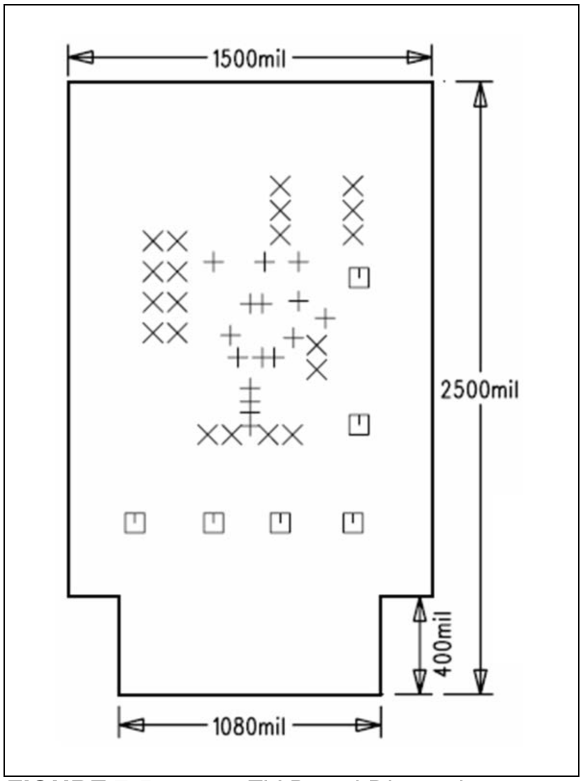
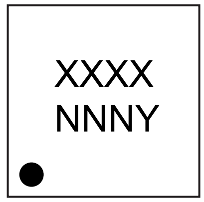


FIGURE 7-5: EV Board Dimensions.

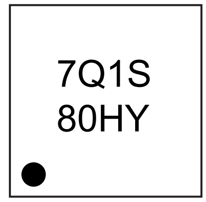
8.0 PACKAGING INFORMATION

8.1 Package Marking Information

8-Lead MSOP*



Example



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.

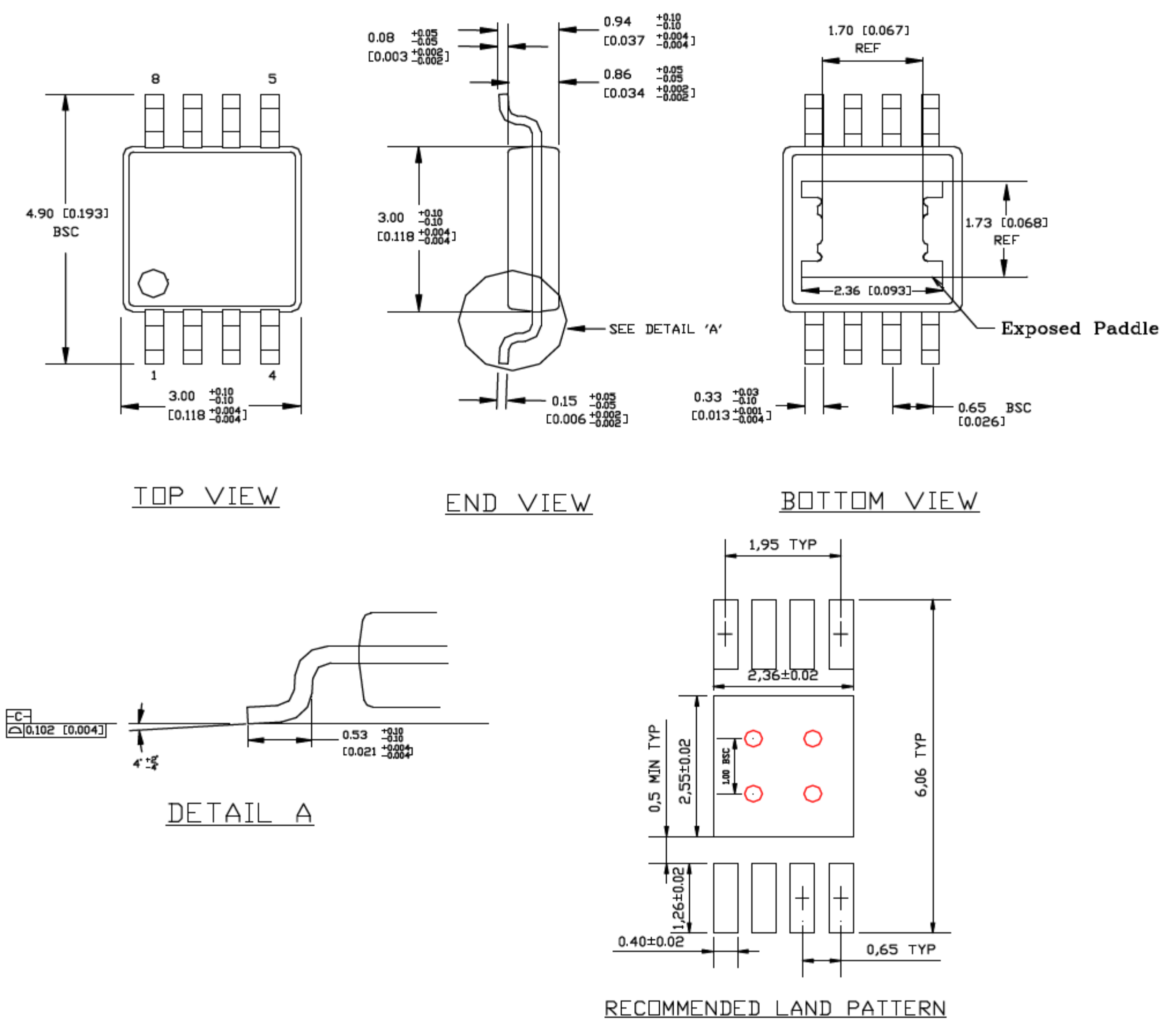
Underbar (_) symbol may not be to scale.

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

8-Lead MSOP ePAD Package Outline and Recommended Land Pattern

TITLE
8 LEAD MSOP EPAD PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	MSOPEP-8LD-PL-1	**UNIT**	MM [INCH]



NOTE:
1. DIMENSION DOES NOT INCLUDE MOLD FLASH OR PROTRUSIONS, EITHER OF WHICH SHALL NOT EXCEED 0.20 [0.008] PER SIDE
2. RED CIRCLES IN LAND PATTERN REPRESENT THERMAL VIAS. RECOMMENDED SIZE IS 0.30-0.35MM IN DIAMETER, 1.00 PITCH AND SHOULD BE CONNECTED TO GND FOR MAXIMUM PERFORMANCE

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

APPENDIX A: REVISION HISTORY

Revision A (October 2022)

- Converted Micrel document MAQ5281 to Microchip data sheet DS20006731A.
- 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	VXX
Device	Output Voltage	Temp. Range	Package	Media Type	Automotive Suffix

Device:	MAQ5281:	$120V_{IN}$, 25 mA, Ultra-Low I_Q, High-PSRR Linear Regulator
Output Voltage:	<blank>= 3.3 = 5.0 =	Adjustable 3.3V 5.0V
Temperature Range:	Y =	–40°C to +125°C
Package:	MME=	8-Lead MSOP
Media Type:	TR = <blank>=	2,500/Reel 100/Tube
Automotive Suffix:	Vxx =	Automotive suffix in which “xx” is assigned by Microchip. VAO is standard automotive option.

Examples:

a) MAQ5281YMME-VAO:	MAQ5281, Adj. Output Voltage, –40°C to +125°C Temp. Range, 8-Lead MSOP, 100/Tube, Automotive Option
b) MAQ5281-3.3YMME-TRVAO:	MAQ5281, 3.3V Output Voltage, –40°C to +125°C Temp. Range, 8-Lead MSOP, 2500/Reel, Automotive Option
c) MAQ5281-5.0YMME-TRVAO:	MAQ5281, 5.0V Output Voltage, –40°C to +125°C Temp. Range, 8-Lead MSOP, 2500/Reel, Automotive Option

Note 1: 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.

NOTES:

Note the following details of the code protection feature on Microchip products:

- Microchip products meet the specifications contained in their particular Microchip Data Sheet.
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- Neither Microchip nor any other semiconductor manufacturer can guarantee the security of its code. Code protection does not mean that we are guaranteeing the product is "unbreakable" Code protection is constantly evolving. Microchip is committed to continuously improving the code protection features of our products.

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