chanhvinh.com

MIC5205

150 mA Low-Noise LDO Regulator

Features

- Ultra-Low Noise Output
- High Output Voltage Accuracy
- Guaranteed 150 mA Output
- Low Quiescent Current
- Low Dropout Voltage
- Extremely Tight Load and Line Regulation
- Very Low Temperature Coefficient
- Current and Thermal Limiting
- Reverse-Battery Protection
- Zero Off-Mode Current
- Logic-Controlled Electronic Enable

Applications

- Cellular Telephones
- Laptop, Notebook, and Palmtop Computers
- Battery-Powered Equipment
- PCMCIA V_{CC} and V_{PP} Regulation/Switching
- Consumer/Personal Electronics
- SMPS Post-Regulator and DC/DC Modules
- High-Efficiency Linear Power Supplies

General Description

The MIC5205 is an efficient linear voltage regulator with ultra low-noise output, very low dropout voltage (typically 17 mV at light loads and 165 mV at 150 mA), and very low ground current (600 µA at 100 mA output). The MIC5205 offers better than 1% initial accuracy.

Designed especially for hand-held, battery-powered devices, the MIC5205 includes a CMOS or TTL compatible enable/shutdown control input. When shut down, power consumption drops nearly to zero. Regulator ground current increases only slightly in dropout, further prolonging battery life.

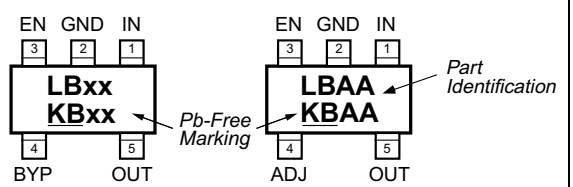
Key MIC5205 features include a reference bypass pin to improve its already excellent low-noise performance, reversed-battery protection, current limiting, and overtemperature shutdown.

The MIC5205 is available in fixed and adjustable output voltage versions in a small SOT-23-5 package.

For low-dropout regulators that are stable with ceramic output capacitors, see the µCap MIC5245/6/7 family.

Package Type

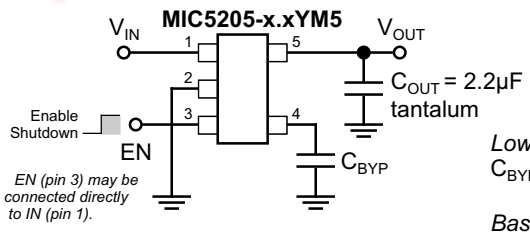
MIC5205
5-Lead SOT-23 (M5)



chanhvinh.com

Typical Application Circuit

MIC5205
5-Lead SOT-23

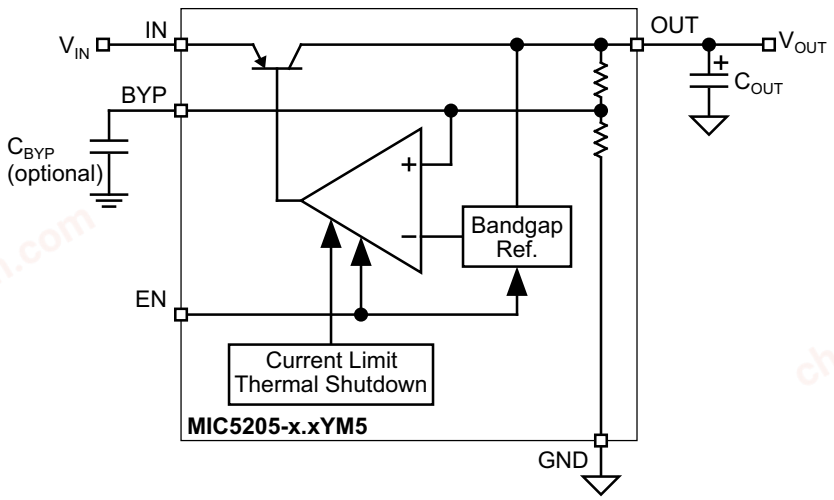


Low-Noise Operation:
C_{BYP} = 470pF, $C_{OUT} \geq$ 2.2µF

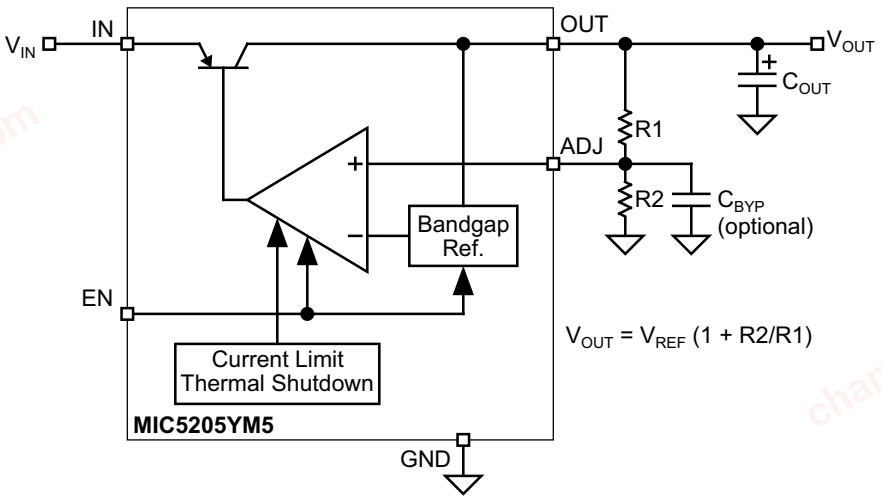
Basic Operation:
C_{BYP} = not used, $C_{OUT} \geq$ 1µF

Functional Block Diagrams

Ultra-Low Noise Fixed Regulator



Ultra-Low Noise Adjustable Regulator



© 2017 - 2022 Microchip Technology Inc. and its subsidiaries

chanhvinh.com

1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Input Voltage (V_{IN}) ..... –20V to +20V
Enable Input Voltage (V_{EN}) ..... –20V to +20V
Power Dissipation (P_D) (Note 1) ..... Internally Limited

Operating Ratings ‡

Supply Input Voltage (V_{IN}) ..... +2.5V to +16V
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 at any T_A (ambient temperature) is $P_{D(max)} = (T_{J(max)} - T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will result in excessive die temperature, and the regulator will go into thermal shutdown. The θ_{JA} of the MIC5205-xxYM5 (all versions) is 220°C/W mounted on a PC board.

ELECTRICAL CHARACTERISTICS

Electrical Characteristics: $V_{IN} = V_{OUT} + 1V$; I_L = 100 µA; C_L = 1.0 µF; $V_{EN} \geq 2.0V$; T_J = +25°C, **bold** values indicate –40°C < T_J < +125°C, unless noted.

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Output Voltage Accuracy	V_O	–1	—	1	%	Variation from specified V_{OUT}
		–2	—	**2**		
Output Voltage Temperature Coefficient	$\Delta V_O/\Delta T$	—	40	—	ppm/°C	Note 1
Line Regulation	$\Delta V_O/V_O$	—	0.004	0.012	%/V	$V_{IN} = V_{OUT}$ + 1V to 16V
		—	—	**0.05**		
Load Regulation	$\Delta V_O/V_O$	—	0.02	0.2	%	I_L = 0.1 mA to 150 mA, Note 2
		—	—	**0.5**		
Dropout Voltage, Note 3	$V_{IN} - V_O$	—	10	50	mV	I_L = 100 µA
		—	—	**70**	mV	
		—	110	150	mV	I_L = 50 mA
		—	—	**230**	mV	
		—	140	250	mV	I_L = 100 mA
		—	—	**300**	mV	
		—	165	275	mV	I_L = 150 mA
		—	—	**350**	mV	
Quiescent Current	I_{GND}	—	0.01	1	µA	$V_{EN} \leq 0.4V$ (shutdown)
		—	—	**5**	µA	$V_{EN} \leq 0.18V$ (shutdown)

© 2017 - 2022 Microchip Technology Inc. and its subsidiaries

chanhvinh.com

ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: V_{IN} = V_{OUT} +1V; I_L = 100 µA; C_L = 1.0 µF; V_{EN} ≥ 2.0V; T_J = +25°C, **bold** values indicate –40°C < T_J < +125°C, unless noted.

Parameter	Symbol	Min.	Typ.	Max.	Units	Conditions
Ground Pin Current, Note 4	I_{GND}	—	80	125	µA	V_{EN} ≥ 2.0V, I_L = 100 µA
		—	—	**150**	µA	
		—	350	600	µA	I_L = 50 mA
		—	—	**800**	µA	
		—	600	1000	µA	I_L = 100 mA
		—	—	**1500**	µA	
		—	1300	1900	µA	I_L = 150 mA
		—	—	**2500**	µA	
Ripple Rejection	PSRR	—	75	—	dB	Frequency = 100 Hz, I_L = 100 µA
Current Limit	I_{LIMIT}	—	320	500	mA	V_{OUT} = 0V
Thermal Regulation	$\Delta V_O/\Delta_{PD}$	—	0.05	—	%/W	Note 5
Output Noise	e_{NO}	—	260	—	nV/√Hz	I_L = 50 mA, C_L = 2.2 µF, 470 pF from BYP to GND
ENABLE Input						
Enable Input Logic-Low Voltage	V_{IL}	—	—	0.4	V	Regulator shutdown
		—	—	**0.18**		
Enable Input Logic-High Voltage	V_{IH}	**2.0**	—	—	V	Regulator enabled
Enable Input Current	I_{IL}	—	0.01	–1	µA	V_{IL} ≤ 0.4V
		—	—	**–2**		V_{IL} ≤ 0.18V
	I_{IH}	2	5	20		V_{IL} = 2.0V
		—	—	**25**		V_{IL} = 2.0V

Note 1: Output voltage temperature coefficient is defined as the worst case voltage change divided by the total temperature range.

2: Regulation is measured at constant junction temperature using low duty cycle pulse testing. Parts are tested for load regulation in the load range from 0.1 mA to 150 mA. Changes in output voltage due to heating effects are covered by the thermal regulation specification.

3: Dropout Voltage is defined as the input to output differential at which the output voltage drops 2% below its nominal value measured at 1V differential.

4: Ground pin current is the regulator quiescent current plus pass transistor base current. The total current drawn from the supply is the sum of the load current plus the ground pin current.

5: Thermal regulation is defined as the change in output voltage at a time “t” after a change in power dissipation is applied, excluding load or line regulation effects. Specifications are for a 150 mA load pulse at V_{IN} = 16V for t = 10 ms.

© 2017 - 2022 Microchip Technology Inc. and its subsidiaries

chanhvinh.com

TEMPERATURE SPECIFICATIONS (Note 1)

Parameters	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Junction Operating Temperature Range	T_J	–40	—	+125	°C	—
Storage Temperature Range	T_S	–65	—	+150	°C	—
Lead Temperature	—	—	—	+260	°C	Soldering, 5s
Package Thermal Resistances						
Thermal Resistance SOT-23-5	θ_{JA}	—	220	—	°C/W	Note 2
	θ_{JC}	—	130	—	°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: The maximum allowable power dissipation at any T_A (ambient temperature) is $P_{D(max)} = (T_{J(max)} - T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will result in excessive die temperature, and the regulator will go into thermal shutdown. The θ_{JA} of the MIC5205-xxYM5 (all versions) is 220°C/W mounted on a PC board.

© 2017 - 2022 Microchip Technology Inc. and its subsidiaries

chanhvinh.com

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.

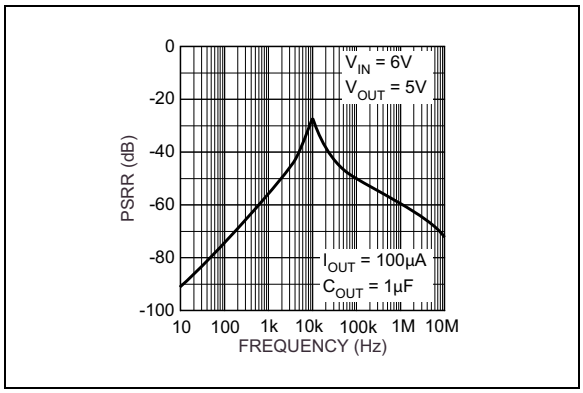


FIGURE 2-1: *Power Supply Rejection Ratio.*

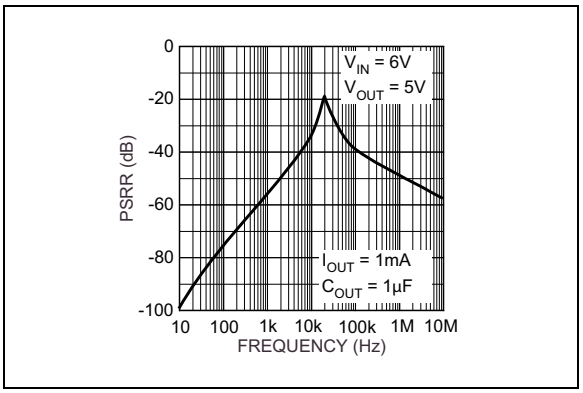


FIGURE 2-4: *Power Supply Rejection Ratio.*

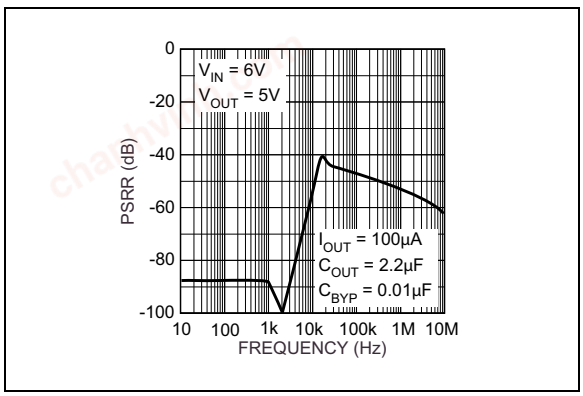


FIGURE 2-2: *Power Supply Rejection Ratio.*

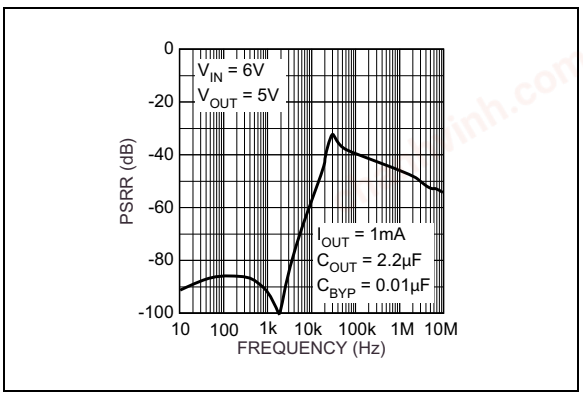


FIGURE 2-5: *Power Supply Rejection Ratio.*

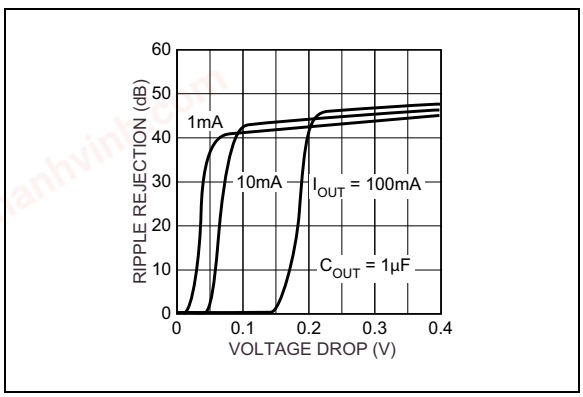


FIGURE 2-3: *Power Supply Ripple Rejection vs. Voltage Drop.*

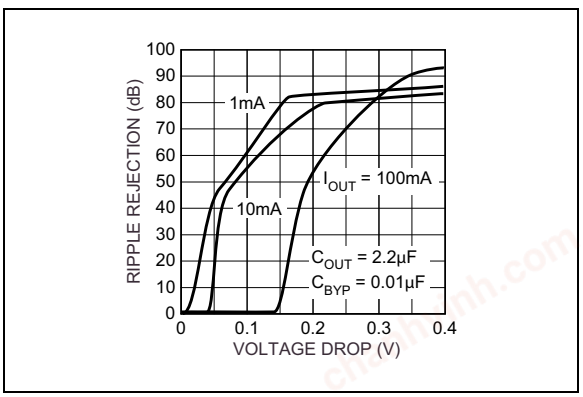


FIGURE 2-6: *Power Supply Ripple Rejection vs. Voltage Drop.*

© 2017 - 2022 Microchip Technology Inc. and its subsidiaries

chanhvinh.com

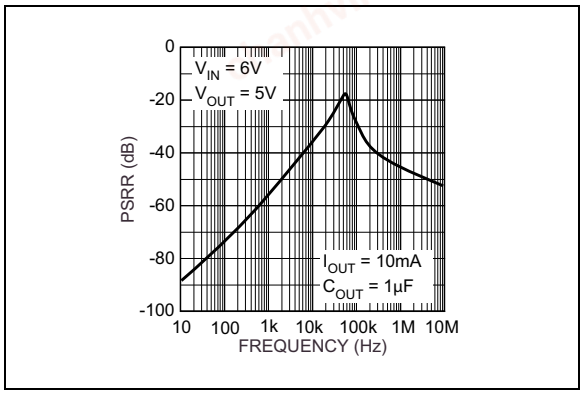


FIGURE 2-7: *Power Supply Rejection Ratio.*

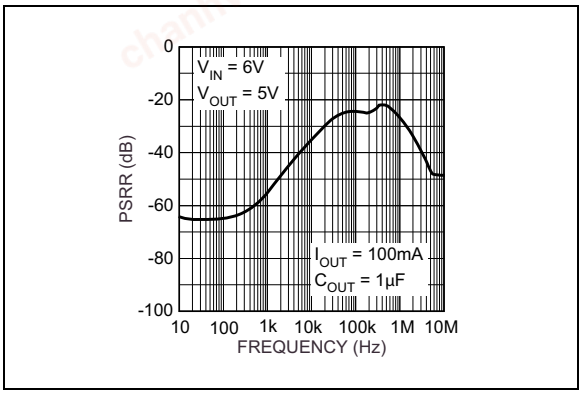


FIGURE 2-10: *Power Supply Rejection Ratio.*

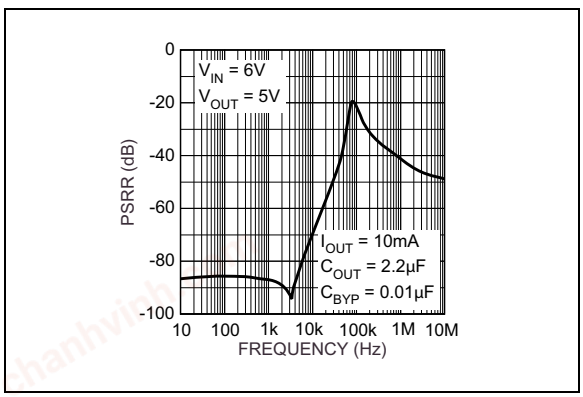


FIGURE 2-8: *Power Supply Rejection Ratio.*

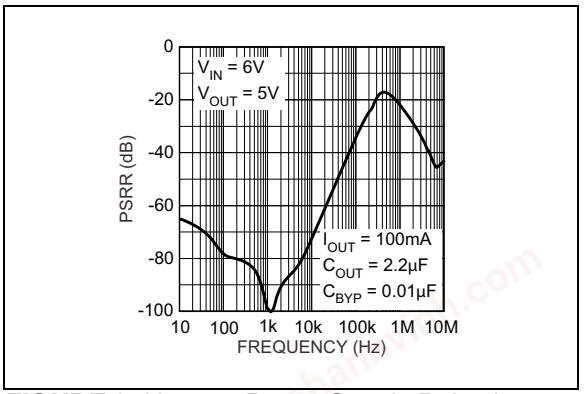


FIGURE 2-11: *Power Supply Rejection Ratio.*

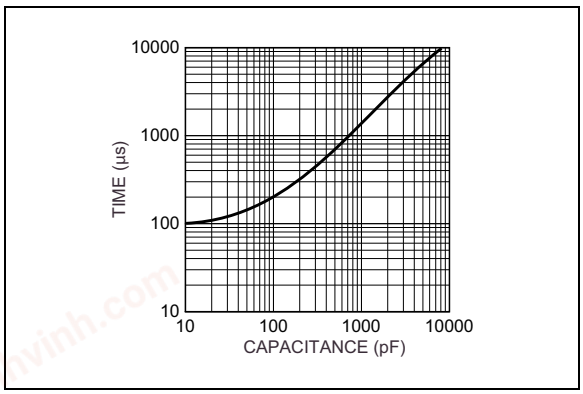


FIGURE 2-9: *Turn-On Time vs. Bypass Capacitance.*

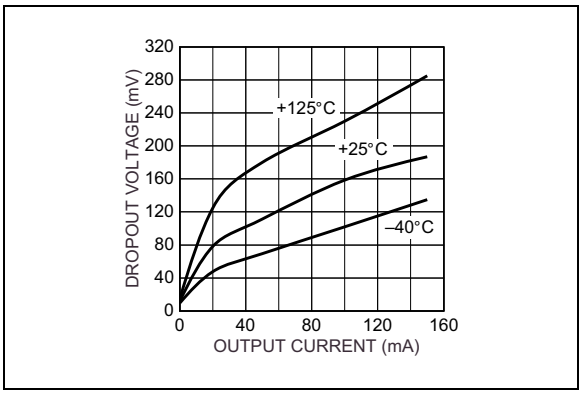


FIGURE 2-12: *Dropout Voltage vs. Output Current.*

chanhvinh.com

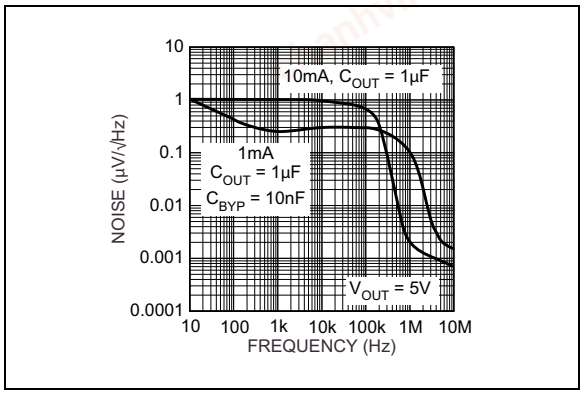


FIGURE 2-13: *Noise Performance.*

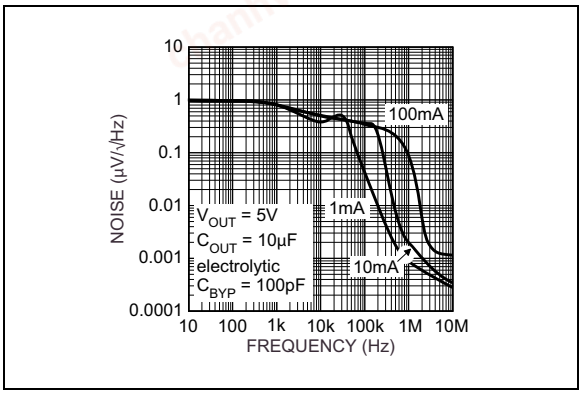


FIGURE 2-16: *Noise Performance.*

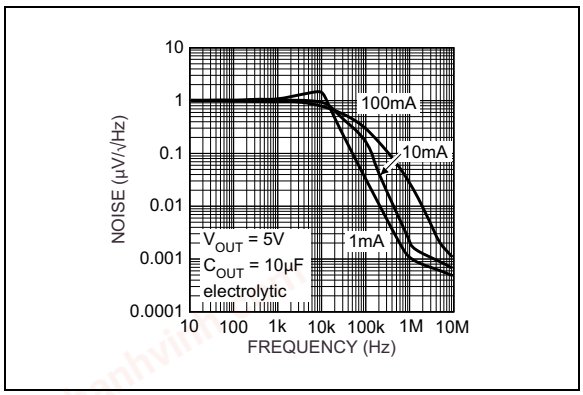


FIGURE 2-14: *Noise Performance.*

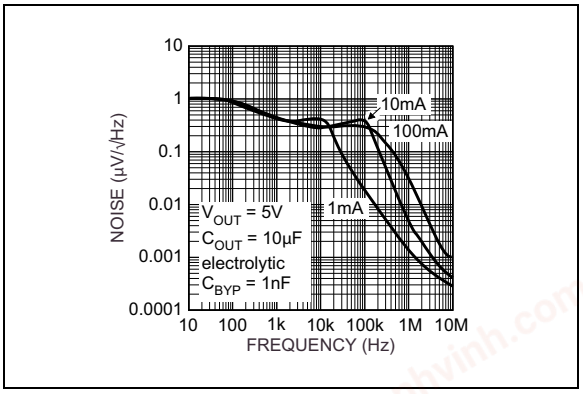


FIGURE 2-17: *Noise Performance.*

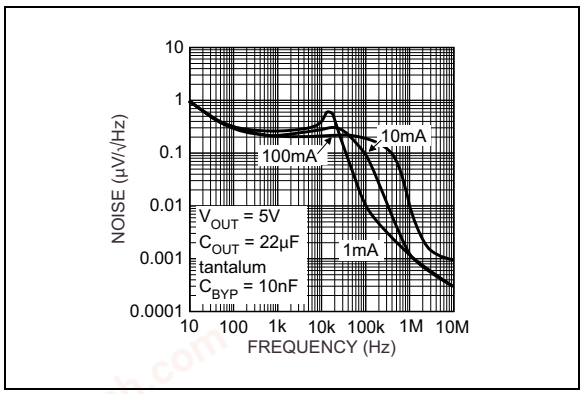


FIGURE 2-15: *Noise Performance.*

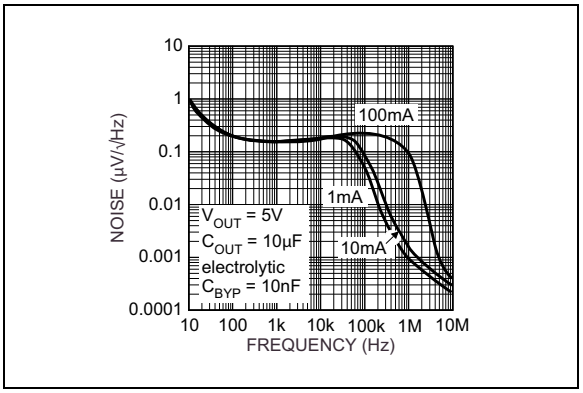


FIGURE 2-18: *Noise Performance.*

© 2017 - 2022 Microchip Technology Inc. and its subsidiaries

chanhvinh.com

3.0 PIN DESCRIPTIONS

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

TABLE 3-1: PIN FUNCTION TABLE

Pin Number Fixed Version	Pin Number Adj. Version	Pin Name	Description
1	1	IN	Supply Input
2	2	GND	Ground
3	3	EN	Enable/Shutdown (Input): CMOS compatible input. Logic-high = enable, logic-low or open = shutdown
4	—	BYP	Reference Bypass: Connect external 470 pF capacitor to GND to reduce output noise. May be left open.
—	4	ADJ	Adjust (Input): Adjustable regulator feedback input. Connect to resistor voltage divider.
5	5	OUT	Regulator Output

© 2017 - 2022 Microchip Technology Inc. and its subsidiaries

chanhvinh.com

4.0 APPLICATION INFORMATION

4.1 Enable/Shutdown

Forcing EN (enable/shutdown) high (greater than 2V) enables the regulator. EN is compatible with CMOS logic gates.

If the enable/shutdown feature is not required, connect EN (pin 3) to IN (supply input, pin 1). See Figure 4-1.

4.2 Input Capacitor

A 1 µF capacitor should be placed from IN to GND if there are more than 10 inches of wire between the input and the AC filter capacitor or if a battery is used as the input.

4.3 Reference Bypass Capacitor

BYP (reference bypass) is connected to the internal voltage reference. A 470 pF capacitor (C_{BYP}) connected from BYP to GND quiets this reference, providing a significant reduction in output noise. C_{BYP} reduces the regulator phase margin; when using C_{BYP}, output capacitors of 2.2 µF or greater are generally required to maintain stability.

The start-up speed of the MIC5205 is inversely proportional to the size of the reference bypass capacitor. Applications requiring a slow ramp-up of output voltage should consider larger values of C_{BYP}. Likewise, if rapid turn-on is necessary, consider omitting C_{BYP}.

If output noise is not a major concern, omit C_{BYP} and leave BYP open.

4.4 Output Capacitor

An output capacitor is required between OUT and GND to prevent oscillation. The minimum size of the output capacitor is dependent upon whether a reference bypass capacitor is used. 1.0 µF minimum is recommended when C_{BYP} is not used (see Figure 4-2). 2.2 µF minimum is recommended when C_{BYP} is 470 pF (see Figure 4-1). Larger values improve the regulator's transient response. The output capacitor value may be increased without limit.

The output capacitor should have an ESR (effective series resistance) of about 5Ω or less and a resonant frequency above 1 MHz. Ultra-low-ESR capacitors can cause a low amplitude oscillation on the output and/or underdamped transient response. Most tantalum or aluminum electrolytic capacitors are adequate; film types will work, but are more expensive. Because many aluminum electrolytics have electrolytes that freeze at about –30°C, solid tantalums are recommended for operation below –25°C.

At lower values of output current, less output capacitance is required for output stability. The capacitor can be reduced to 0.47 µF for current below 10 mA or 0.33 µF for currents below 1 mA.

4.5 No-Load Stability

The MIC5205 will remain stable and in regulation with no load (other than the internal voltage divider) unlike many other voltage regulators. This is especially important in CMOS RAM keep-alive applications.

4.6 Thermal Considerations

The MIC5205 is designed to provide 150 mA of continuous current in a very small package. Maximum power dissipation can be calculated based on the output current and the voltage drop across the part. To determine the maximum power dissipation of the package, use the junction-to-ambient thermal resistance of the device and the following basic equation:

EQUATION 4-1:

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

$T_{J(MAX)}$ is the maximum junction temperature of the die, 125°C, and T_A is the ambient operating temperature. θ_{JA} is layout dependent; Table 4-1 shows examples of junction-to-ambient thermal resistance for the MIC5205.

TABLE 4-1: SOT-23-5 THERMAL RESISTANCE

Package	θ_{JA} Rec. Min. Footprint	θ_{JA} Square Copper Clad	θ_{JC}
SOT-23-5 (M5)	220°C/W	170°C/W	130°C/W

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

EQUATION 4-2:

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

Substituting $P_{D(MAX)}$ for P_D and solving for the operating conditions that are critical to the application will give the maximum operating conditions for the

© 2017 - 2022 Microchip Technology Inc. and its subsidiaries

chanhvinh.com

regulator circuit. For example, when operating the MIC5205-3.3YM5 at room temperature with a minimum footprint layout, the maximum input voltage for a set output current can be determined as follows:

EQUATION 4-3:

$$P_{D(MAX)} = \frac{(125°C - 25°C)}{220°C/W} = 455mW$$

The junction-to-ambient thermal resistance for the minimum footprint is 220°C/W, from Table 4-1. The maximum power dissipation must not be exceeded for proper operation. Using the output voltage of 3.3V and an output current of 150 mA, the maximum input voltage can be determined. From the Electrical Characteristics table, the maximum ground current for 150 mA output current is 2500 µA or 2.5 mA.

EQUATION 4-4:

$$455mW = (V_{IN} - 3.3V) \times 150mA + V_{IN} \times 2.5mA$$

EQUATION 4-5:

$$455mW = V_{IN} \times 150mA - 495mW + V_{IN} \times 2.5mA$$

EQUATION 4-6:

$$950mW = V_{IN} \times 152.5mA$$

$V_{IN(MAX)}$ then equates out to 6.23V. Therefore, a 3.3V application at 150 mA of output current can accept a maximum input voltage of 6.2V in a SOT-23-5 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.

4.7 Fixed Regulator Applications

Figure 4-1 includes a 470 pF capacitor for low-noise operation and shows EN (pin 3) connected to IN (pin 1) for an application where enable/shutdown is not required. C_{OUT} = 2.2 µF minimum.

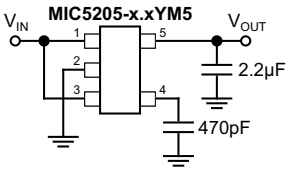


FIGURE 4-1: *Ultra-Low Noise Fixed Voltage Application.*

Figure 4-2 is an example of a low-noise configuration where C_{BYP} is not required. C_{OUT} = 1 µF minimum.

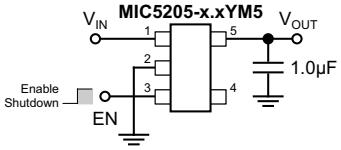


FIGURE 4-2: *Low Noise Fixed Voltage Application.*

4.8 Adjustable Regulator Applications

The MIC5205YM5 can be adjusted to a specific output voltage by using two external resistors (Figure 4-3). The resistors set the output voltage based on the following equation:

EQUATION 4-7:

$$V_{OUT} = 1.242V \times \left(\frac{R2}{R1} + 1\right)$$

This equation is correct due to the configuration of the bandgap reference. The bandgap voltage is relative to the output, as seen in the block diagram. Traditional regulators normally have the reference voltage relative to ground and have a different V_{OUT} equation.

Resistor values are not critical because ADJ (adjust) has a high input impedance, but for best results use resistors of 470 kΩ or less. A capacitor from ADJ to ground provides greatly improved noise performance.

© 2017 - 2022 Microchip Technology Inc. and its subsidiaries

chanhvinh.com

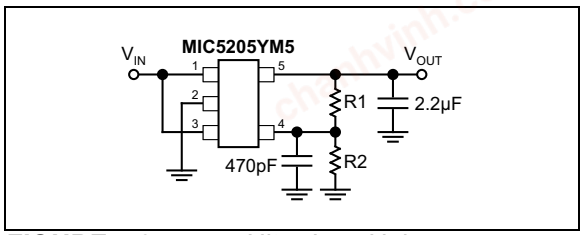


FIGURE 4-3: *Ultra-Low Noise.*

4.9 Adjustable Voltage Application

Figure 4-3 includes the optional 470 pF noise bypass capacitor from ADJ to GND to reduce output noise.

4.10 Dual-Supply Operation

When used in dual supply systems where the regulator load is returned to a negative supply, the output voltage must be diode clamped to ground.

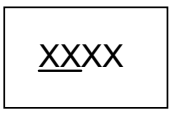
© 2017 - 2022 Microchip Technology Inc. and its subsidiaries

chanhvinh.com

5.0 PACKAGING INFORMATION

5.1 Package Marking Information

5-Lead SOT-23* (Fixed, Front)



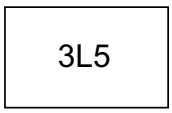
Example



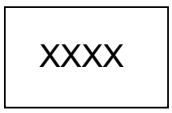
5-Lead SOT-23* (Fixed, Back)



Example



5-Lead SOT-23* (Adj., Front)



Example



5-Lead SOT-23* (Adj., Back)



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 (_) 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

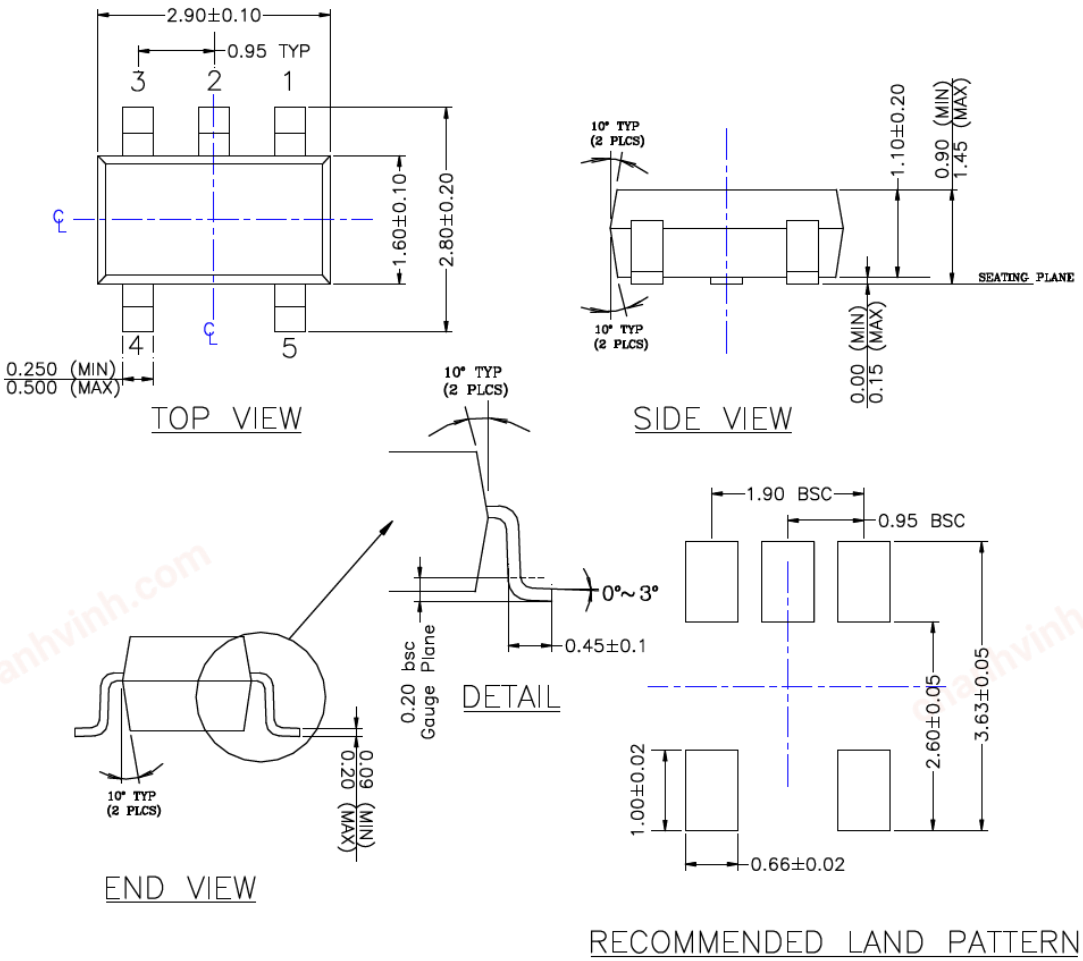
© 2017 - 2022 Microchip Technology Inc. and its subsidiaries

chanhvinh.com

5-Lead SOT-23 Package Outline and Recommended Land Pattern

TITLE
5 LEAD SOT23 PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	SOT23-5LD-PL-1	UNIT	MM



NOTE:
1. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & BURR.
2. PACKAGE OUTLINE INCLUSIVE OF SOLER PLATING.
3. DIMENSION AND TOLERANCE PER ANSI Y14.5M, 1982.
4. FOOT LENGTH MEASUREMENT BASED ON GAUGE PLANE METHOD.
5. DIE FACES UP FOR MOLD, AND FACES DOWN FOR TRIM/FORM.
6. ALL DIMENSIONS ARE IN MILLIMETERS.

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

© 2017 - 2022 Microchip Technology Inc. and its subsidiaries

chanhvinh.com

APPENDIX A: REVISION HISTORY

Revision A (May 2017)

- Converted Micrel document MIC5205 to Microchip data sheet DS20005785A.
- Minor text changes throughout.

Revision B (February 2022)

- Updated the Package Marking Information drawing to reflect the most current marking information.

Revision C (March 2022)

- Corrected the 2.7V code in the Voltage section of the Product Identification System section.

chanhvinh.com

chanhvinh.com

NOTES:

© 2017 - 2022 Microchip Technology Inc. and its subsidiaries

chanhvinh.com

PRODUCT IDENTIFICATION SYSTEM

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

PART NO.	–X.X	X	XX	–XX
Device	Voltage	Temperature	Package	Media Type

Device:	MIC5205:	150 mA Low-Noise LDO Regulator
Voltage:	<blank>=	Adjustable
	2.5 =	2.5V
	2.7 =	2.7V
	2.8 =	2.8V
	2.85 =	2.85V
	2.9 =	2.9V
	3.0 =	3.0V
	3.1 =	3.1V
	3.2 =	3.2V
	3.3 =	3.3V
	3.6 =	3.6V
	3.8 =	3.8V
	4.0 =	4.0V
	5.0 =	5.0V
Temperature:	Y =	–40°C to +125°C
Package:	M5 =	5-Lead SOT-23
Media Type:	TX =	3,000/Reel (Reverse Pin 1)
	TR =	3,000/Reel

Examples:

a) MIC5205YM5-TX: 150 mA Low-Noise LDO Regulator, Adjustable Voltage, –40°C to +125°C, 5-Lead SOT-23, 3k/Reel (Rev. Pin 1)

b) MIC5205-3.0YM5-TR: 150 mA Low-Noise LDO Regulator, 3.0V, –40°C to +125°C, 5-Lead SOT-23, 3k/Reel

c) MIC5205-2.8YM5-TX: 150 mA Low-Noise LDO Regulator, 2.8V, –40°C to +125°C, 5-Lead SOT-23, 3k/Reel (Rev. Pin 1)

d) MIC5205-4.0YM5-TR: 150 mA Low-Noise LDO Regulator, 4.0V, –40°C to +125°C, 5-Lead SOT-23, 3k/Reel

e) MIC5205-2.5YM5-TX: 150 mA Low-Noise LDO Regulator, 2.5V, –40°C to +125°C, 5-Lead SOT-23, 3k/Reel (Rev. Pin 1)

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.

chanhvinh.com

chanhvinh.com

NOTES:

chanhvinh.com

© 2017 - 2022 Microchip Technology Inc.

chanhvinh.com

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

- Microchip products meet the specifications contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is secure when used in the intended manner, within operating specifications, and under normal conditions.
- Microchip values and aggressively protects its intellectual property rights. Attempts to breach the code protection features of Microchip product is strictly prohibited and may violate the Digital Millennium Copyright Act.
- 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.

This publication and the information herein may be used only with Microchip products, including to design, test, and integrate Microchip products with your application. Use of this information in any other manner violates these terms. Information regarding device applications is provided only for your convenience and may be superseded by updates. It is your responsibility to ensure that your application meets with your specifications. Contact your local Microchip sales office for additional support or, obtain additional support at https://www.microchip.com/en-us/support/design-help/client-support-services.

THIS INFORMATION IS PROVIDED BY MICROCHIP "AS IS". MICROCHIP MAKES NO REPRESENTATIONS OR WARRANTIES OF ANY KIND WHETHER EXPRESS OR IMPLIED, WRITTEN OR ORAL, STATUTORY OR OTHERWISE, RELATED TO THE INFORMATION INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTIES OF NON-INFRINGEMENT, MERCHANTABILITY, AND FITNESS FOR A PARTICULAR PURPOSE, OR WARRANTIES RELATED TO ITS CONDITION, QUALITY, OR PERFORMANCE.

IN NO EVENT WILL MICROCHIP BE LIABLE FOR ANY INDIRECT, SPECIAL, PUNITIVE, INCIDENTAL, OR CONSEQUENTIAL LOSS, DAMAGE, COST, OR EXPENSE OF ANY KIND WHATSOEVER RELATED TO THE INFORMATION OR ITS USE, HOWEVER CAUSED, EVEN IF MICROCHIP HAS BEEN ADVISED OF THE POSSIBILITY OR THE DAMAGES ARE FORESEEABLE. TO THE FULLEST EXTENT ALLOWED BY LAW, MICROCHIP'S TOTAL LIABILITY ON ALL CLAIMS IN ANY WAY RELATED TO THE INFORMATION OR ITS USE WILL NOT EXCEED THE AMOUNT OF FEES, IF ANY, THAT YOU HAVE PAID DIRECTLY TO MICROCHIP FOR THE INFORMATION.

Use of Microchip devices in life support and/or safety applications is entirely at the buyer's risk, and the buyer agrees to defend, indemnify and hold harmless Microchip from any and all damages, claims, suits, or expenses resulting from such use. No licenses are conveyed, implicitly or otherwise, under any Microchip intellectual property rights unless otherwise stated.

For information regarding Microchip’s Quality Management Systems, please visit www.microchip.com/quality.

Trademarks

The Microchip name and logo, the Microchip logo, Adaptec, AnyRate, AVR, AVR logo, AVR Freaks, BesTime, BitCloud, CryptoMemory, CryptoRF, dsPIC, flexPWR, HELDO, IGLOO, JukeBlox, KeeLoq, Kleer, LANCheck, LinkMD, maXStylus, maXTouch, MediaLB, megaAVR, Microsemi, Microsemi logo, MOST, MOST logo, MPLAB, OptoLyzer, PIC, picoPower, PICSTART, PIC32 logo, PolarFire, Prochip Designer, QTouch, SAM-BA, SenGenuity, SpyNIC, SST, SST Logo, SuperFlash, Symmetricom, SyncServer, Tachyon, TimeSource, tinyAVR, UNI/O, Vectron, and XMEGA are registered trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

AgileSwitch, APT, ClockWorks, The Embedded Control Solutions Company, EtherSynch, Flashtec, Hyper Speed Control, HyperLight Load, IntelliMOS, Libero, motorBench, mTouch, Powermite 3, Precision Edge, ProASIC, ProASIC Plus, ProASIC Plus logo, Quiet-Wire, SmartFusion, SyncWorld, Temux, TimeCesium, TimeHub, TimePictra, TimeProvider, TrueTime, WinPath, and ZL are registered trademarks of Microchip Technology Incorporated in the U.S.A.

Adjacent Key Suppression, AKS, Analog-for-the-Digital Age, Any Capacitor, AnyIn, AnyOut, Augmented Switching, BlueSky, BodyCom, CodeGuard, CryptoAuthentication, CryptoAutomotive, CryptoCompanion, CryptoController, dsPICDEM, dsPICDEM.net, Dynamic Average Matching, DAM, ECAN, Espresso T1S, EtherGREEN, GridTime, IdealBridge, In-Circuit Serial Programming, ICSP, INICnet, Intelligent Paralleling, Inter-Chip Connectivity, JitterBlocker, Knob-on-Display, maxCrypto, maxView, memBrain, Mindi, MiWi, MPASM, MPF, MPLAB Certified logo, MPLIB, MPLINK, MultiTRAK, NetDetach, NVM Express, NVMe, Omniscient Code Generation, PICDEM, PICDEM.net, PICkit, PICtail, PowerSmart, PureSilicon, QMatrix, REAL ICE, Ripple Blocker, RTAX, RTG4, SAM-ICE, Serial Quad I/O, simpleMAP, SimpliPHY, SmartBuffer, SmartHLS, SMART-I.S., storClad, SQI, SuperSwitcher, SuperSwitcher II, Switchtec, SynchroPHY, Total Endurance, TSHARC, USBCheck, VariSense, VectorBlox, VeriPHY, ViewSpan, WiperLock, XpressConnect, and ZENA are trademarks of Microchip Technology Incorporated in the U.S.A. and other countries.

SQTP is a service mark of Microchip Technology Incorporated in the U.S.A.

The Adaptec logo, Frequency on Demand, Silicon Storage Technology, Symmcom, and Trusted Time are registered trademarks of Microchip Technology Inc. in other countries.

GestIC is a registered trademark of Microchip Technology Germany II GmbH & Co. KG, a subsidiary of Microchip Technology Inc., in other countries.

All other trademarks mentioned herein are property of their respective companies.

© 2017 - 2022, Microchip Technology Incorporated and its subsidiaries.

All Rights Reserved.

ISBN: 978-1-5224-9931-2

chanhvinh.com

Worldwide Sales and Service

AMERICAS

Corporate Office
2355 West Chandler Blvd.
Chandler, AZ 85224-6199
Tel: 480-792-7200
Fax: 480-792-7277
Technical Support:
http://www.microchip.com/support
Web Address:
www.microchip.com

Atlanta
Duluth, GA
Tel: 678-957-9614
Fax: 678-957-1455

Austin, TX
Tel: 512-257-3370

Boston
Westborough, MA
Tel: 774-760-0087
Fax: 774-760-0088

Chicago
Itasca, IL
Tel: 630-285-0071
Fax: 630-285-0075

Dallas
Addison, TX
Tel: 972-818-7423
Fax: 972-818-2924

Detroit
Novi, MI
Tel: 248-848-4000

Houston, TX
Tel: 281-894-5983

Indianapolis
Noblesville, IN
Tel: 317-773-8323
Fax: 317-773-5453
Tel: 317-536-2380

Los Angeles
Mission Viejo, CA
Tel: 949-462-9523
Fax: 949-462-9608
Tel: 951-273-7800

Raleigh, NC
Tel: 919-844-7510

New York, NY
Tel: 631-435-6000

San Jose, CA
Tel: 408-735-9110
Tel: 408-436-4270

Canada - Toronto
Tel: 905-695-1980
Fax: 905-695-2078

ASIA/PACIFIC

Australia - Sydney
Tel: 61-2-9868-6733

China - Beijing
Tel: 86-10-8569-7000

China - Chengdu
Tel: 86-28-8665-5511

China - Chongqing
Tel: 86-23-8980-9588

China - Dongguan
Tel: 86-769-8702-9880

China - Guangzhou
Tel: 86-20-8755-8029

China - Hangzhou
Tel: 86-571-8792-8115

China - Hong Kong SAR
Tel: 852-2943-5100

China - Nanjing
Tel: 86-25-8473-2460

China - Qingdao
Tel: 86-532-8502-7355

China - Shanghai
Tel: 86-21-3326-8000

China - Shenyang
Tel: 86-24-2334-2829

China - Shenzhen
Tel: 86-755-8864-2200

China - Suzhou
Tel: 86-186-6233-1526

China - Wuhan
Tel: 86-27-5980-5300

China - Xian
Tel: 86-29-8833-7252

China - Xiamen
Tel: 86-592-2388138

China - Zhuhai
Tel: 86-756-3210040

ASIA/PACIFIC

India - Bangalore
Tel: 91-80-3090-4444

India - New Delhi
Tel: 91-11-4160-8631

India - Pune
Tel: 91-20-4121-0141

Japan - Osaka
Tel: 81-6-6152-7160

Japan - Tokyo
Tel: 81-3-6880- 3770

Korea - Daegu
Tel: 82-53-744-4301

Korea - Seoul
Tel: 82-2-554-7200

Malaysia - Kuala Lumpur
Tel: 60-3-7651-7906

Malaysia - Penang
Tel: 60-4-227-8870

Philippines - Manila
Tel: 63-2-634-9065

Singapore
Tel: 65-6334-8870

Taiwan - Hsin Chu
Tel: 886-3-577-8366

Taiwan - Kaohsiung
Tel: 886-7-213-7830

Taiwan - Taipei
Tel: 886-2-2508-8600

Thailand - Bangkok
Tel: 66-2-694-1351

Vietnam - Ho Chi Minh
Tel: 84-28-5448-2100

EUROPE

Austria - Wels
Tel: 43-7242-2244-39
Fax: 43-7242-2244-393

Denmark - Copenhagen
Tel: 45-4485-5910
Fax: 45-4485-2829

Finland - Espoo
Tel: 358-9-4520-820

France - Paris
Tel: 33-1-69-53-63-20
Fax: 33-1-69-30-90-79

Germany - Garching
Tel: 49-8931-9700

Germany - Haan
Tel: 49-2129-3766400

Germany - Heilbronn
Tel: 49-7131-72400

Germany - Karlsruhe
Tel: 49-721-625370

Germany - Munich
Tel: 49-89-627-144-0
Fax: 49-89-627-144-44

Germany - Rosenheim
Tel: 49-8031-354-560

Israel - Ra'anana
Tel: 972-9-744-7705

Italy - Milan
Tel: 39-0331-742611
Fax: 39-0331-466781

Italy - Padova
Tel: 39-049-7625286

Netherlands - Drunen
Tel: 31-416-690399
Fax: 31-416-690340

Norway - Trondheim
Tel: 47-7288-4388

Poland - Warsaw
Tel: 48-22-3325737

Romania - Bucharest
Tel: 40-21-407-87-50

Spain - Madrid
Tel: 34-91-708-08-90
Fax: 34-91-708-08-91

Sweden - Gothenberg
Tel: 46-31-704-60-40

Sweden - Stockholm
Tel: 46-8-5090-4654

UK - Wokingham
Tel: 44-118-921-5800
Fax: 44-118-921-5820

© 2017 - 2022 Microchip Technology Inc. and its subsidiaries