MIC4576

200 kHz Simple 3A Buck Regulator

Features

- Fixed 200 kHz Operation
- 3.3V, 5V, and Adjustable Output Versions
- Voltage Over Specified Line and Load Conditions:
  - Fixed version: ±3% maximum output voltage
  - Adjustable version: ±2% maximum feedback voltage
- Guaranteed 3A Switch Current
- Wide 4V to 36V Input Voltage Range
- Wide 1.23V to 33V Output Voltage Range
- Requires Minimum External Components
- <200 µA Typical Shutdown Mode
- 75% Efficiency (Adjustable Version > 75% Typical)
- Standard Inductors are 25% of Typical LM2576 Inductor Values
- Thermal Shutdown
- Overcurrent Protection
- 100% Electrical Thermal Limit Burn-In

Applications

- Simple High-Efficiency Step-Down (Buck) Regulator
- Efficient Preregulator for Linear Regulators
- On-Card Switching Regulators
- Positive-to-Negative Converter (Inverting Buck-Boost)
- Battery Charger
- Negative Boost Converter
- Step-Down to 3.3V for Intel Pentium™ and Similar Microprocessors

General Description

The MIC4576 is a series of easy-to-use fixed and adjustable BiCMOS step-down (buck) switch-mode voltage regulators. The 200 kHz MIC4576 duplicates the pinout and function of the 52 kHz LM2576. The higher switching frequency may allow up to a 2:1 reduction in output filter inductor size.

The MIC4576 is available in 3.3V, and 5V fixed output versions or a 1.23V to 33V adjustable output version. Both versions are capable of driving a 3A load with excellent line and load regulation.

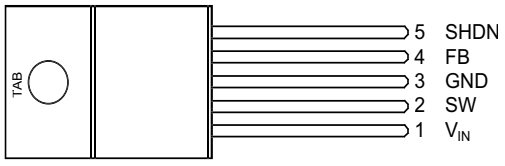
The feedback voltage is guaranteed to ±2% tolerance for adjustable versions, and the output voltage is guaranteed to ±3% for fixed versions, within specified voltages and load conditions. The oscillator frequency is guaranteed to ±10%.

In Shutdown mode, the regulator draws less than 200 µA shutdown current. The regulator performs cycle-by-cycle current limiting and thermal shutdown for protection under fault conditions.

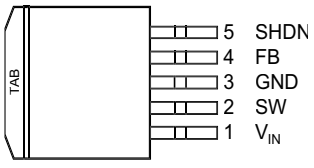
This series of simple switch-mode regulators requires a minimum number of external components and can operate using a standard series of inductors. Frequency compensation is provided internally.

The MIC4576 is available in TO-220 (T) and TO-263 (U) packages for the industrial temperature range.

Package Types



5-Pin TO-220 (T)

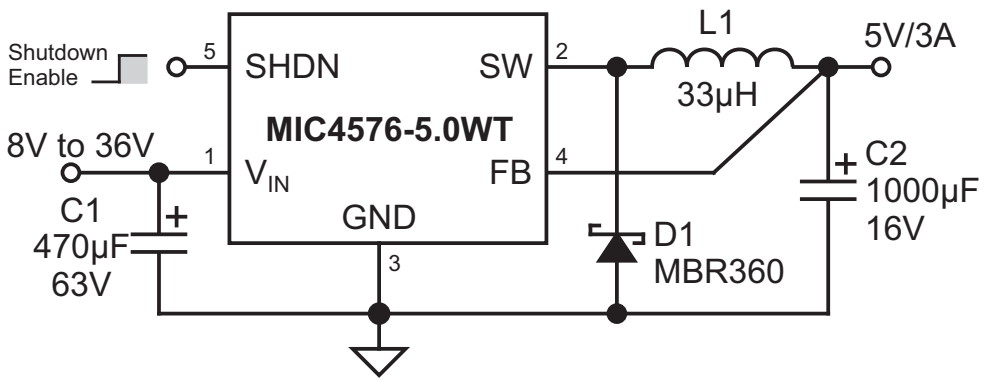


5-Pin TO-263 (U)

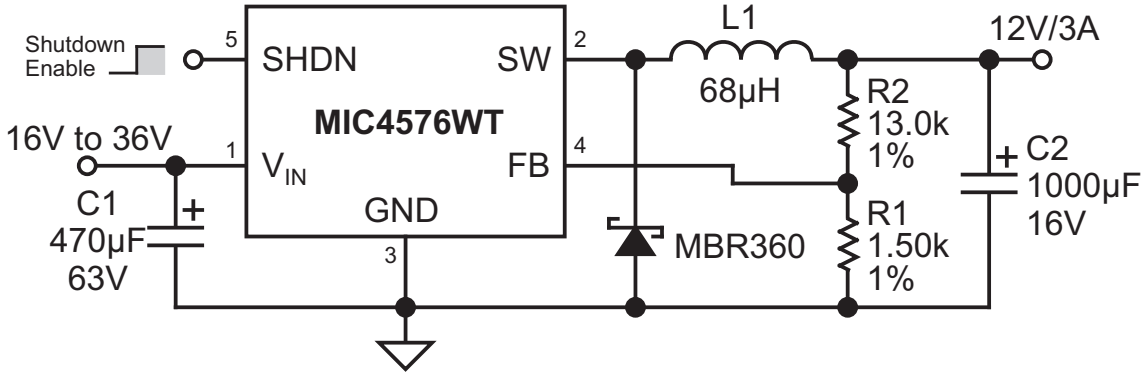
See Table 2-1 for pin information.

Typical Application Circuit

Fixed Regulator

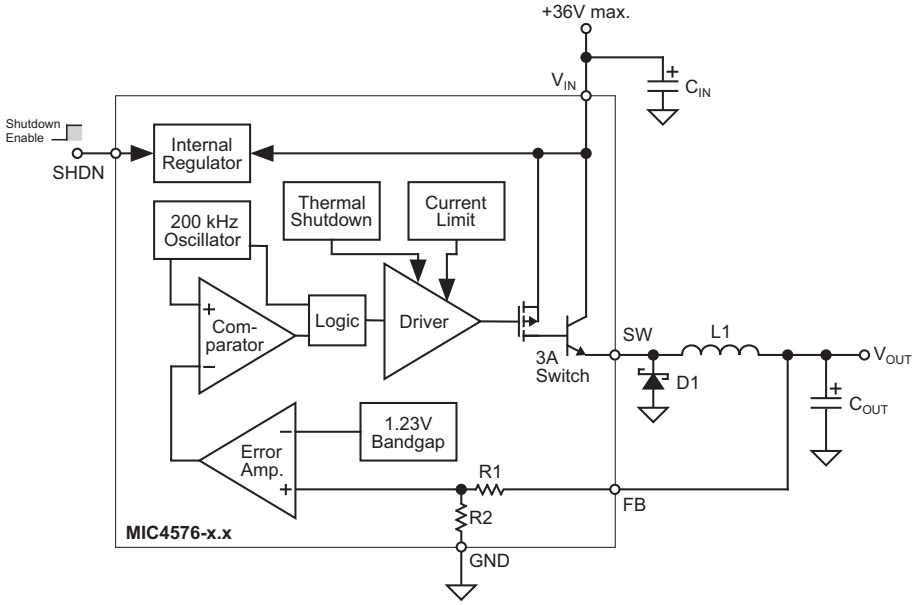


Adjustable Regulator

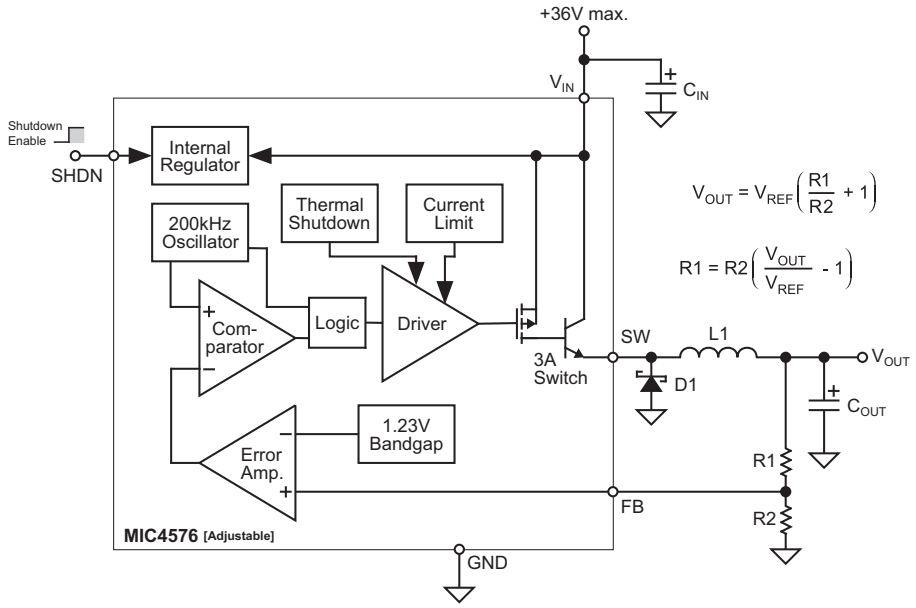


Functional Block Diagram

Block Diagram with External Components
Fixed Step-Down Regulator



Block Diagram with External Components
Adjustable Step-Down Regulator



1.0 ELECTRICAL CHARACTERISTICS

Absolute Maximum Ratings †

Supply Voltage (V_{IN}) ..... +40V
Shutdown Voltage (V_{SHDN}) ..... –0.3V to +36V
Output Switch (V_{SW}), Steady State ..... –1V
Feedback Voltage (V_{FB}) [Adjustable] ..... +3.8V
Storage Temperature (T_S) ..... –65°C to +150°C
Junction Temperature (T_J) ..... +150°C

Operating Ratings ††

Supply Voltage (V_{IN}) ..... +36V
Junction Temperature (T_J) ..... –40°C to +85°C
Package Thermal Resistance
TO-220, TO-263 (θ_{JA}) ..... 65°C/W
TO-220, TO-263 (θ_{JC}) ..... 2°C/W

† 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 $P_{D(MAX)} = (T_{J(MAX)} – T_A)/\theta_{JA}$. Exceeding the maximum allowable power dissipation will result in excessive die temperature, and the regulator will go into thermal shutdown.

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

ELECTRICAL CHARACTERISTICS

Electrical Characteristics: V_{IN} = 12V; I_{LOAD} = 500 mA; T_J = +25°C, **bold** values indicate –40°C ≤ T_J ≤ +85°C, unless noted.

Parameter	Sym.	Min.	Typ.	Max.	Units	Conditions
MIC4576 (Adjustable)						
Feedback Voltage	V_{FB}	1.217	1.230	1.243	V	
Feedback Voltage	V_{FB}	1.193	1.230	1.267	V	8V ≤ V_{IN} ≤ 36V, 0.5A ≤ I_{LOAD} ≤ 3A
		1.180	—	**1.280**	V	
Efficiency	η	—	77	—	%	I_{LOAD} = 3A, Note 1
Maximum Duty Cycle (On)	D_{MAX}	90	95	—	%	V_{FB} = 1.0V
SW Leakage Current	I_{SW_LK}	—	0	2	mA	V_{IN} = 36V, V_{FB} = 1.5V, V_{SW} = 0V
		—	7.5	35	mA	V_{IN} = 36V, V_{FB} = 1.5V, V_{SW} = –1V
Quiescent Current	I_Q	—	5	10	mA	V_{FB} = 1.5V
Feedback Bias Current	I_{FB}	—	50	100	nA	
		—	—	**500**	nA	
MIC4576-3.3						
Output Voltage	V_{OUT}	3.234	3.3	3.366	V	
Output Voltage	V_{OUT}	3.168	3.3	3.432	V	6V ≤ V_{IN} ≤ 36V, 0.5A ≤ I_{LOAD} ≤ 3A
		3.135	—	**3.465**	V	
Efficiency	η	—	72	—	%	I_{LOAD} = 3A
Maximum Duty Cycle (On)	D_{MAX}	90	95	—	%	V_{FB} = 2.5V
SW Leakage Current	I_{SW_LK}	—	0	2	mA	V_{IN} = 36V, V_{FB} = 4V, V_{SW} = 0V
		—	7.5	35	mA	V_{IN} = 36V, V_{FB} = 4V, V_{SW} = –1V
Quiescent Current	I_Q	—	5	10	mA	V_{FB} = 4.0V
MIC4576-5.0						
Output Voltage	V_{OUT}	4.900	5.0	5.100	V	
Output Voltage	V_{OUT}	4.800	5.0	5.200	V	8V ≤ V_{IN} ≤ 36V, 0.5A ≤ I_{LOAD} ≤ 3A
		4.750	—	**5.250**	V	
Efficiency	η	—	77	—	%	I_{LOAD} = 3A
Maximum Duty Cycle (On)	D_{MAX}	90	95	—	%	V_{FB} = 4.0V
SW Leakage Current	I_{SW_LK}	—	0	2	mA	V_{IN} = 36V, V_{FB} = 6V, V_{SW} = 0V
		—	7.5	35	mA	V_{IN} = 36V, V_{FB} = 6V, V_{SW} = –1V
Quiescent Current	I_Q	—	5	10	mA	V_{FB} = 6.0V
MIC4576/-3.3/-5.0						
Oscillator Frequency	f_{SW}	180	200	220	kHz	
Saturation Voltage	V_{SAT}	—	1.7	2.3	V	I_{OUT} = 3A
		—	—	**2.5**	V	
Current Limit	I_{CLIM}	4.2	5.2	7.9	A	Peak current, t_{ON} ≤ 3 µs; V_{FB} = 0V
		3.5	—	**8.5**	A	
Shutdown Current	I_{SD}	—	50	200	µA	V_{SHDN} = 5V (regulator off), V_{FB} = 0V

Note 1: V_{OUT} = 5V.

ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: V_{IN} = 12V; I_{LOAD} = 500 mA; T_J = +25°C, **bold** values indicate –40°C ≤ T_J ≤ +85°C, unless noted.

Parameter	Sym.	Min.	Typ.	Max.	Units	Conditions
SHDN Turn-off Threshold	V_{SDTH_OFF}	—	1.4	—	V	Regulator turns off
SHDN Turn-on Threshold	V_{SDTH_ON}	—	1.2	—	V	Regulator turns on
SHDN Input Logic Level	V_{IH}	**2.4**	—	—	V	V_{OUT} = 0V (regulator off)
	V_{IL}	—	—	**0.8**	V	V_{OUT} = 3.3V or 5V (regulator on)
SHDN Input Current	I_{IH}	—	4	30	µA	V_{SHDN} = 5V (regulator off)
	I_{IL}	-10	0.01	10	µA	V_{SHDN} = 0V (regulator on)

Note 1: V_{OUT} = 5V.

TEMPERATURE SPECIFICATIONS

Parameter	Sym.	Min.	Typ.	Max.	Units	Conditions
Temperature Ranges						
Operating Junction Temperature	T_J	–40	—	+85	°C	
Maximum Junction Temperature	$T_{J(ABSMAX)}$	—	—	+150	°C	
Storage Temperature	T_S	–65	—	+150	°C	
Package Thermal Resistances						
Thermal Resistance, TO-220	θ_{JA}	—	65	—	°C/W	Junction to air
Thermal Resistance, TO-220	θ_{JC}	—	2	—	°C/W	Junction to case
Thermal Resistance, TO-263	θ_{JA}	—	65	—	°C/W	Junction to air
Thermal Resistance, TO-263	θ_{JC}	—	2	—	°C/W	Junction to case

2.0 PIN DESCRIPTION

The description of the pins are listed in Table 2-1.

TABLE 2-1: PIN FUNCTION TABLE

Pin Number	Pin Name	Description
1	VIN	Supply Voltage (Input): Unregulated +4V to +36V supply voltage.
2	SW	Switch (Output): Emitter of NPN output switch. Connect to external storage inductor and Shottky diode.
3, TAB	GND	Ground.
4	FB	Feedback (Input): Output voltage feedback to regulator. Connect to output of regular application circuit for fixed versions. Connect to 1.23V tap of resistive divider for adjustable versions.
5	SHDN	Shutdown (Input): Logic low enables regulator. Logic high (> 2.4V) shuts down regulator.

3.0 FUNCTIONAL DESCRIPTION

The MIC4576 is a variable duty cycle switch-mode regulator with an internal power switch. Refer to the **"Functional Block Diagram"**.

3.1 Supply Voltage

The MIC4576 operates from a +4V to +36V unregulated input. Highest efficiency operation is from a supply voltage around +15V.

3.2 Enable/Shutdown

The shutdown (SHDN) input is TTL compatible. Ground the input if unused. A logic low enables the regulator. A logic high shuts down the regulator which reduces the device current consumption to typically 50 µA.

3.3 Feedback

Fixed versions of the regulator have an internal resistive divider from the feedback (FB) pin. Connect the FB pin directly to the output line.

Adjustable versions require an external resistive voltage divider from the output voltage to ground, connected from the 1.23V tap to the FB pin.

3.4 Duty Cycle Control

A fixed-gain error amplifier compares the feedback signal with a 1.23V bandgap voltage reference. The resulting error amplifier output voltage is compared to a 200 kHz sawtooth waveform to produce a voltage controlled variable duty cycle output.

A higher feedback voltage increases the error amplifier output voltage. A higher error amplifier voltage (comparator inverting input) causes the comparator to detect only the peaks of the sawtooth, reducing the duty cycle of the comparator output. A lower feedback voltage increases the duty cycle.

3.5 Output Switching

When the internal switch is on, an increasing current flows from the supply V_{IN}, through external storage inductor L1, to output capacitor C_{OUT} and the load. Energy is stored in the inductor as the current increases with time.

When the internal switch is turned off, the collapse of the magnetic field in L1 forces current to flow through fast recovery diode D1, charging C_{OUT}.

3.6 Output Capacitor

External output capacitor C_{OUT} provides stabilization and reduces ripple.

3.7 Return Paths

During the on portion of the cycle, the output capacitor and load currents return to the supply ground. During the off portion of the cycle, current is being supplied to the output capacitor and load by storage inductor L1, which means that D1 is part of the high-current return path.

4.0 APPLICATION INFORMATION

The applications circuit that follow have been constructed and tested. For additional information, refer to the MIC4576 product webpage from the Microchip website at www.microchip.com for the following Application Notes:

- For information on efficiency graphs, addresses and telephone numbers of the manufacturer for most circuits, refer to the "*Practical Switching Regulator Circuits*" (AN15).
- For a mathematical approach to component selection and circuit design, refer to the "*200kHz MIC4574/5/6 Family Design Guide*" (AN14).

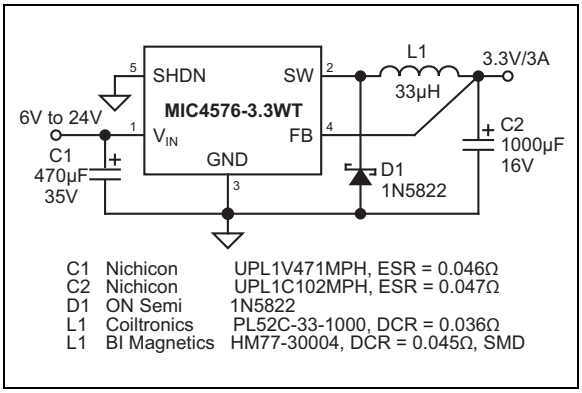


FIGURE 4-1: *6V-24V to 3.3V/3A Buck Converter Through Hole.*

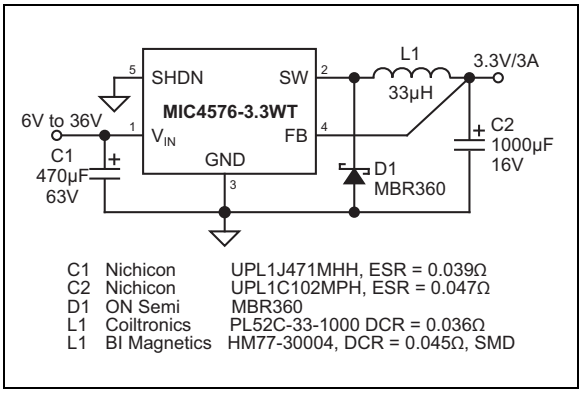


FIGURE 4-2: *6V-36V to 3.3V/3A Buck Converter Through Hole.*

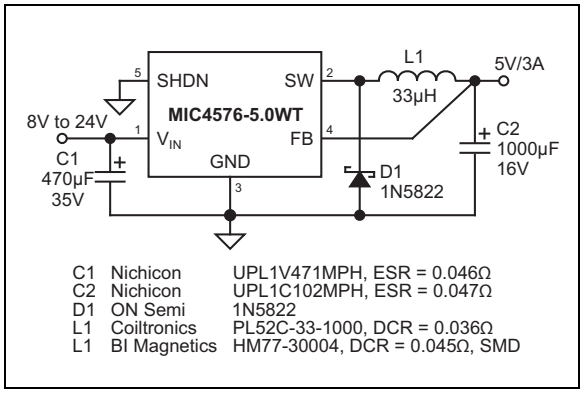


FIGURE 4-3: *8V-24V to 5V/3A Buck Converter Through Hole.*

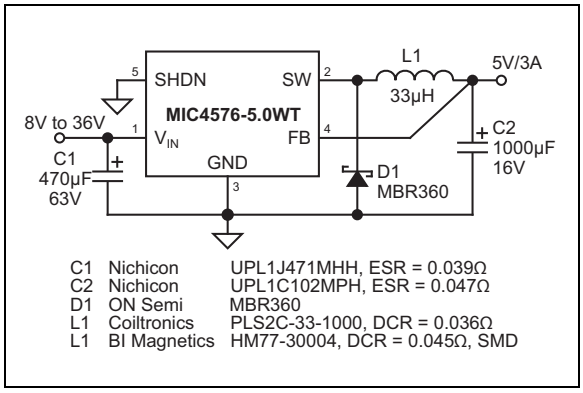
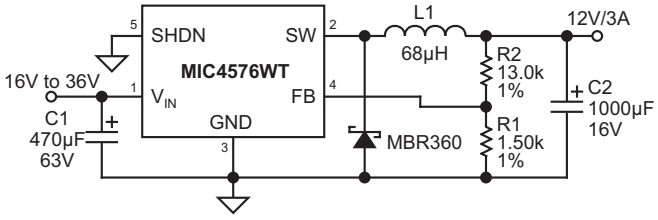
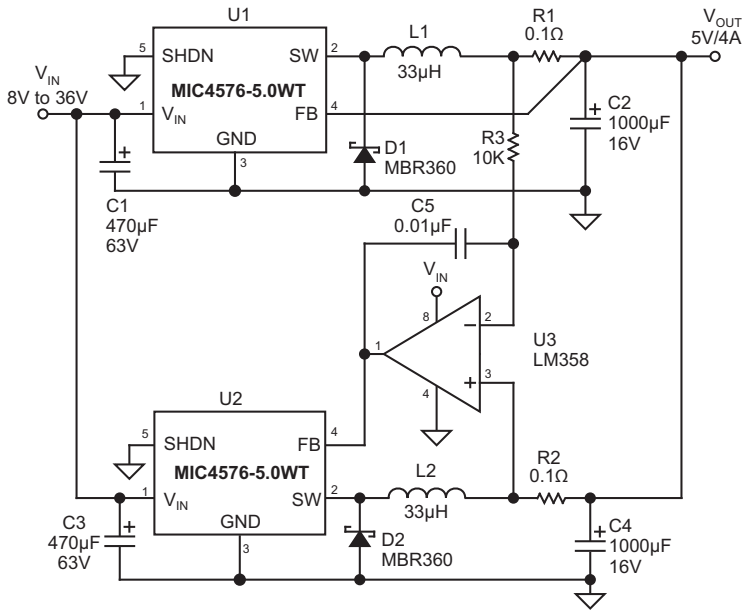


FIGURE 4-4: *8V-36V to 5V/3A Buck Converter Through Hole.*



C1	Nichicon	UPL1J471MHH, ESR = 0.039Ω
C2	Nichicon	UPL1C102MPH, ESR = 0.047Ω
D1	ON Semi	MBR360
L1	BI Magnetics	HM77-29006, DCR = 0.08Ω, SMD

FIGURE 4-5: *16V-36V to 12V/3A Buck Converter Through Hole.*



C1, C3	Nichicon	UPL1J471MHH, ESR = 0.039Ω
C2, C4	Nichicon	UPL1C102MPH, ESR = 0.047Ω
D1, D2	ON Semi	MBR360
L1, L2	Coiltronics	PL52C-33-1000, DCR = 0.036Ω
R1, R2	KRL	SP-1-A1-0R100J
U3	TI	LM358

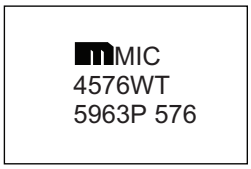
FIGURE 4-6: *Parallel Switching Regulators.*

5.0 PACKAGING INFORMATION

5.1 Package Marking Information

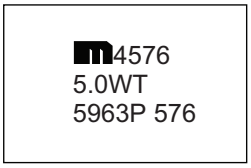
5-Lead TO-220
Adjustable Output

Example



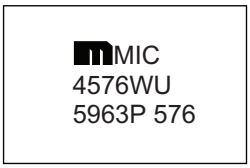
5-Lead TO-220
Fixed Output

Example



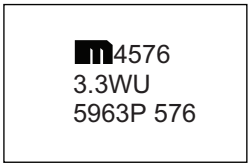
5-Lead TO-263
Adjustable Output

Example



5-Lead TO-263
FIxed Output

Example

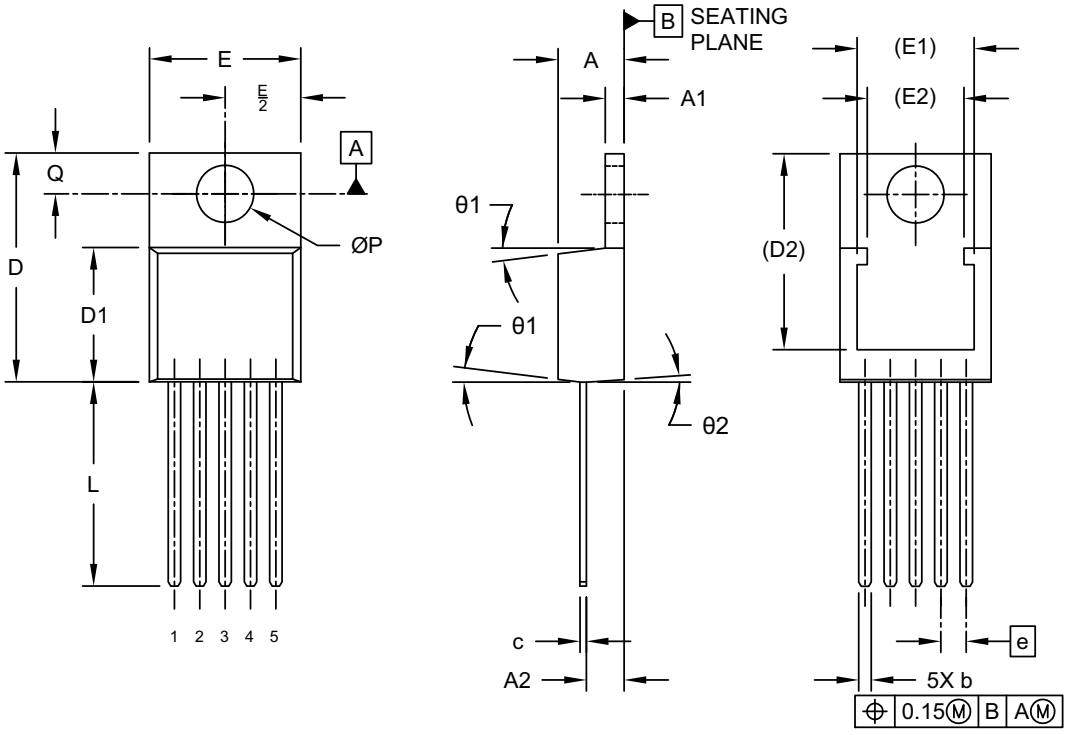


Legend:	XX...X	Product code or customer-specific information
	Y	Year code (last digit of calendar year)
	YY	Year code (last 2 digits of calendar year)
	WW	Week code (week of January 1 is week ‘01’)
	NNN	Alphanumeric traceability code
	(e3)	Pb-free JEDEC® designator for Matte Tin (Sn)
	*	This package 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.	

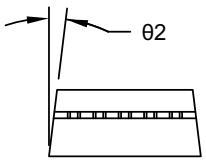
5.2 Package Outline Drawing

5-Lead Transistor Outline Type LB03 (B8X) - [TO-220]
Micrel Legacy Package TO220-LB03-5LD-PL-1

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



TOP VIEW SIDE VIEW BOTTOM VIEW

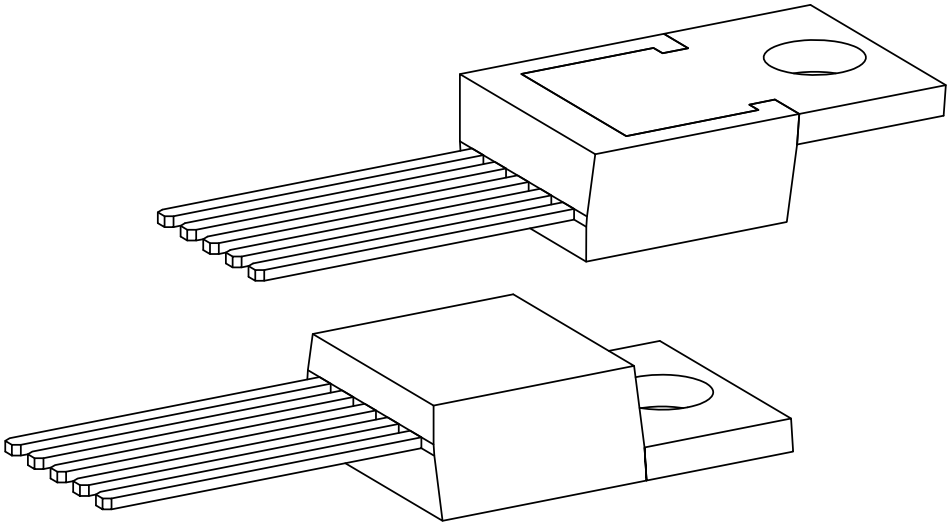


END VIEW

Microchip Technology Drawing C04-036 Rev D Sheet 1 of 2

5-Lead Transistor Outline Type LB03 (B8X) - [TO-220]
Micrel Legacy Package TO220-LB03-5LD-PL-1

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



		INCHES		
Dimension Limits		Min	Nom	Max
Number of Leads	N		5	
Pitch	e		.067 BSC	
Overall Height	A	.160	.175	.190
Tab Height	A1	.045	.050	.055
Seating Plane to Lead	A2	.080	.098	.115
Lead Width	b	.025	.033	.040
Lead Thickness	c	.012	.016	.020
Lead Length	L	.500	.540	.580
Total Body Length Including Tab	D	.542	.580	.619
Molded Body Length	D1	.348	.354	.360
Total Width	E	.380	.400	.420
Pad Width	E1		0.256 REF	
Pad Length	D2		0.486 REF	
Hole Diameter	ØP	.146	.151	.156
Hole Center to Tab Edge	Q	.103	.108	.113
Molded Body Draft Angle	θ1	3	7	10
Molded Body Draft Angle	θ2	1	4	7

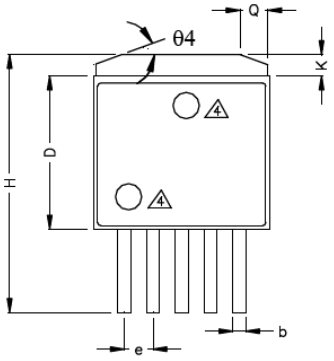
Notes:

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

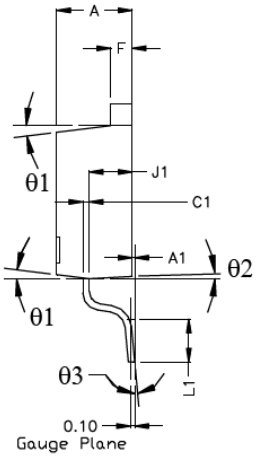
Microchip Technology Drawing C04-036 Rev D Sheet 2 of 2

TITLE
5 LEAD T0263 PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

DRAWING #	T0263-5LD-PL-1	**UNIT**	INCH/MM

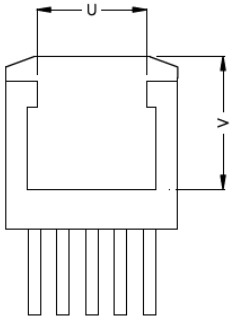


TOP VIEW

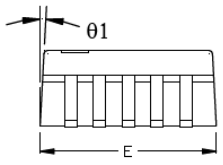


SIDE VIEW 1

PΩS	INCH		MM	
	MIN	MAX	MIN	MAX
A	0.170	0.181	4.318	4.597
A1	0.000	0.012	0.000	0.305
b	0.026	0.036	0.660	0.914
C1	0.012	0.023	0.305	0.584
D	0.330	0.361	8.392	9.169
E	0.396	0.420	10.058	10.668
e	0.062	0.072	1.575	1.829
F	0.045	0.055	1.143	1.397
H	0.575	0.625	14.605	15.875
J1	0.080	0.120	2.032	3.048
K	0.045	0.066	1.143	1.676
L1	0.090	0.110	2.286	2.794
θ1	3°	10°	3°	10°
θ2	1°	7°	1°	7°
θ3	0°	8°	0°	8°
θ4	18°	22°	18°	22°
Q	0.055	0.075	1.397	1.905
U	0.256 Ref.		6.502 Ref.	
V	0.305 Ref.		7.747 Ref.	

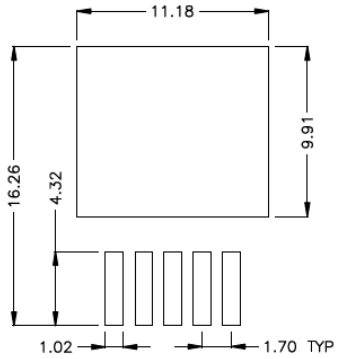


BOTTOM VIEW



SIDE VIEW 2

NOTE:
1. PACKAGE OUTLINE EXCLUSIVE OF MOLD FLASH & METAL BURR.
2. PACKAGE OUTLINE INCLUSIVE OF PLATING THICKNESS.
3. FOOT LENGTH USING GAUGE PLANE METHOD MEASUREMENT 0.010"
4. PACKAGE TOP MARK MAY BE IN TOP CENTER OR LOWER LEFT CORNER
5. ALL DIMENSIONS ARE IN INCHES/MILLIMETERS.



RECOMMENDED LAND PATTERN
(UNIT : mm)

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 (December 2019)

- Converted Micrel document MIC4576 to Microchip data sheet DS20006158A.
- Changed the package marking format.
- Made minor text changes throughout the document.

NOTES:

PRODUCT IDENTIFICATION SYSTEM

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

Device	–	X.X	X	X	–	XX
Part No.		Output Voltage	Temperature Range	Package		Media Type

Device:	MIC4576:	200 kHz 3A Step-Down Regulator
Output Voltage:	3.3	= 3.3V Fixed
	5.0	= 5.0V Fixed
	<blank>	= Adjustable
Temperature Range:	W	= –40°C to +85°C, Industrial, RoHS-Compliant
Package:	T	= 5-Lead TO-220*
	U	= 5-Lead TO-263 (DDPAK)
Media Type:	<blank>	= 50/Tube (T, TO-220 & U, DDPAK)
	TR	= 750/Reel (U, DDPAK)

Note: Tube ship media type is available for TO-220, DDPAK packages

* Contact MCHP Sales for bent or staggered lead options.

Examples:

a) MIC4576WT:	200 kHz 3A Step-Down Regulator, Adjustable Output Voltage, –40°C to +85°C Temperature Range, 5-Lead TO-220 Package, 50/Tube
b) MIC4576-3.3WU:	200 kHz 3A Step-Down Regulator, 3.3V Fixed Output Voltage, –40°C to +85°C Temperature Range, 5-Lead DDPAK Package, 50/Tube
c) MIC4576-3.3WU-TR:	200 kHz 3A Step-Down Regulator, 3.3V Fixed Output Voltage, –40°C to +85°C Temperature Range, 5-Lead DDPAK Package, 750/Reel
d) MIC4576-5.0WT:	200 kHz 3A Step-Down Regulator, 5.0V Fixed Output Voltage, –40°C to +85°C Temperature Range, 5-Lead TO-220 Package, 50/Tube
e) MIC4576WU-TR:	200 kHz 3A Step-Down Regulator, Adjustable Output Voltage, –40°C to +85°C Temperature Range, 5-Lead DDPAK Package, 750/Reel

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 devices:

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
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