

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: $\pm 3\%$ maximum output voltage
 - Adjustable version: $\pm 2\%$ 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
- $< 200 \mu\text{A}$ 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.

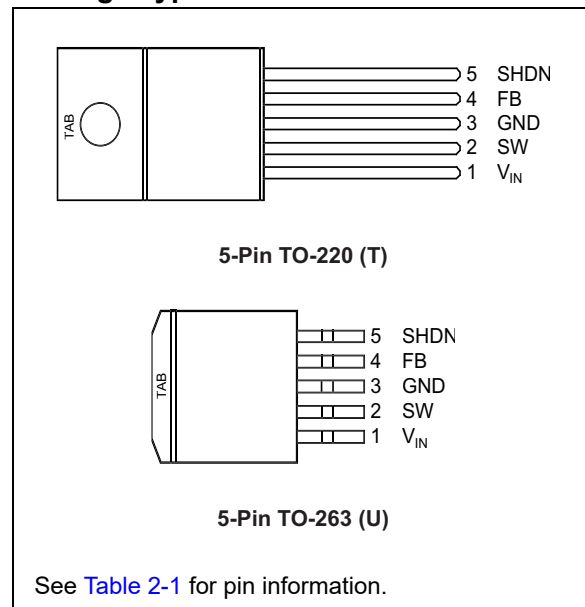
The feedback voltage is guaranteed to $\pm 2\%$ tolerance for adjustable versions, and the output voltage is guaranteed to $\pm 3\%$ for fixed versions, within specified voltages and load conditions. The oscillator frequency is guaranteed to $\pm 10\%$.

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.

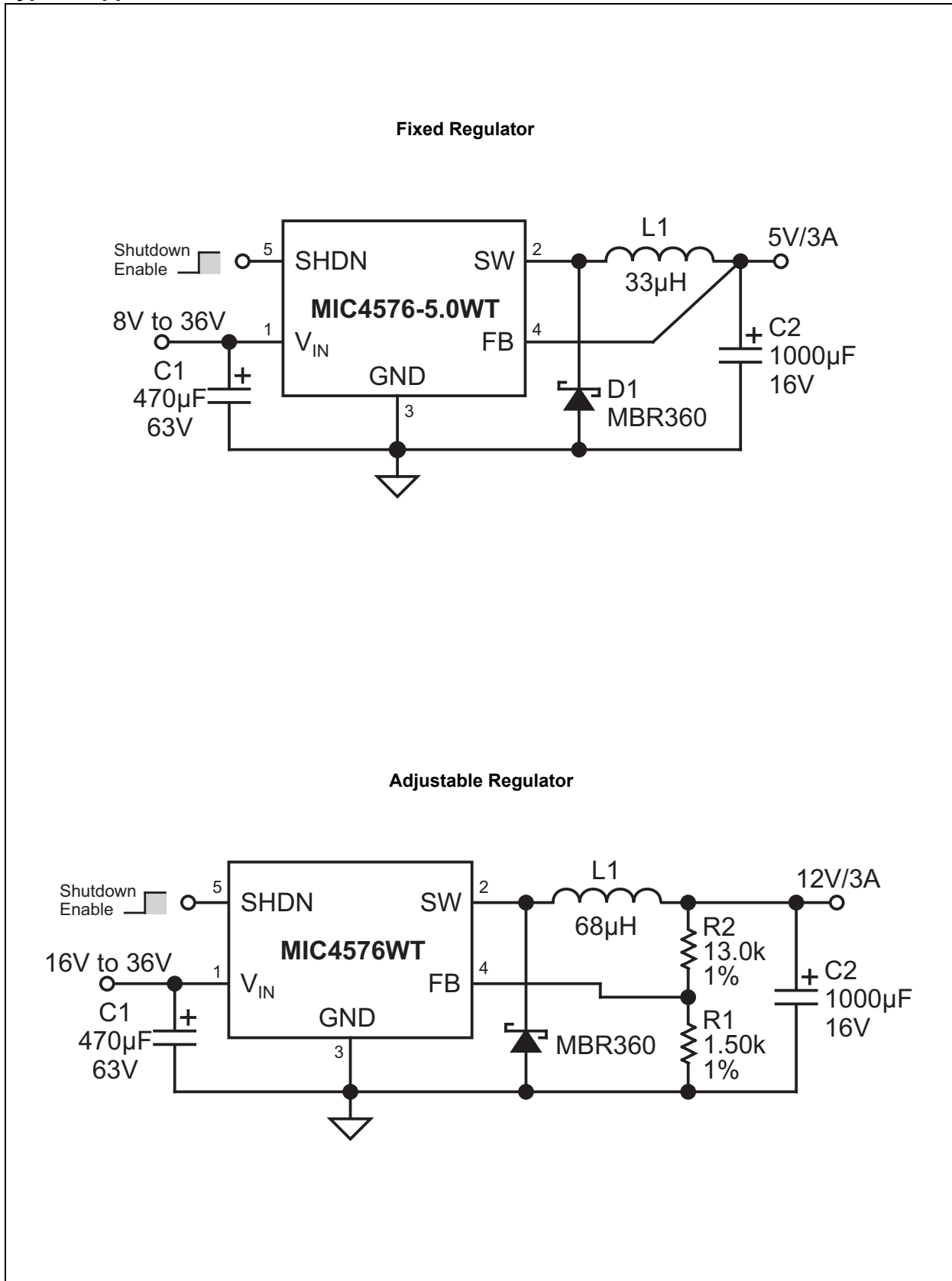
The MIC4576 is available in TO-220 (T) and TO-263 (U) packages for the industrial temperature range.

Package Types

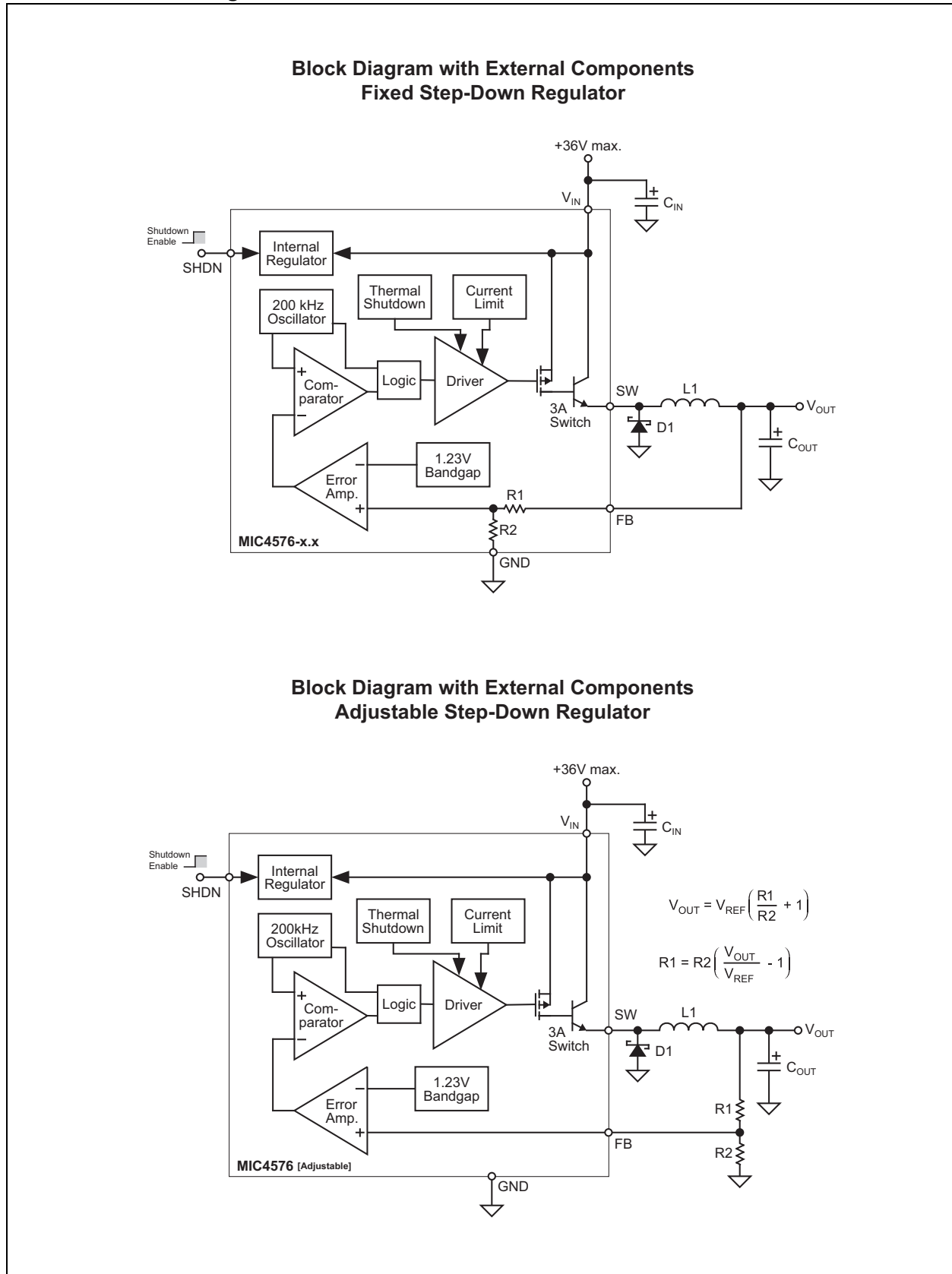


MIC4576

Typical Application Circuit



Functional Block Diagram



MIC4576

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 k Ω in series with 100pF.

ELECTRICAL CHARACTERISTICS

Electrical Characteristics: $V_{IN} = 12V$; $I_{LOAD} = 500\text{ mA}$; $T_J = +25^\circ\text{C}$, **bold** values indicate $-40^\circ\text{C} \leq T_J \leq +85^\circ\text{C}$, 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 | $8V \leq V_{IN} \leq 36V, 0.5A \leq I_{LOAD} \leq 3A$ |
| | | 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 | $6V \leq V_{IN} \leq 36V, 0.5A \leq I_{LOAD} \leq 3A$ |
| | | 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 | $8V \leq V_{IN} \leq 36V, 0.5A \leq I_{LOAD} \leq 3A$ |
| | | 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, $t_{ON} \leq 3\text{ }\mu\text{s}$; $V_{FB} = 0V$ |
| | | 3.5 | — | 8.5 | A | |
| Shutdown Current | I_{SD} | — | 50 | 200 | μA | $V_{SHDN} = 5V$ (regulator off), $V_{FB} = 0V$ |

Note 1: $V_{OUT} = 5V$.

MIC4576

ELECTRICAL CHARACTERISTICS (CONTINUED)

Electrical Characteristics: $V_{IN} = 12V$; $I_{LOAD} = 500\text{ mA}$; $T_J = +25^\circ\text{C}$, **bold** values indicate $-40^\circ\text{C} \leq T_J \leq +85^\circ\text{C}$, 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 | $^\circ\text{C}$ | |
| Maximum Junction Temperature | $T_{J(ABSMAX)}$ | — | — | +150 | $^\circ\text{C}$ | |
| Storage Temperature | T_S | -65 | — | +150 | $^\circ\text{C}$ | |
| Package Thermal Resistances | | | | | | |
| Thermal Resistance, TO-220 | θ_{JA} | — | 65 | — | $^\circ\text{C}/\text{W}$ | Junction to air |
| Thermal Resistance, TO-220 | θ_{JC} | — | 2 | — | $^\circ\text{C}/\text{W}$ | Junction to case |
| Thermal Resistance, TO-263 | θ_{JA} | — | 65 | — | $^\circ\text{C}/\text{W}$ | Junction to air |
| Thermal Resistance, TO-263 | θ_{JC} | — | 2 | — | $^\circ\text{C}/\text{W}$ | 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 Schottky 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. |

MIC4576

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 μ A.

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).

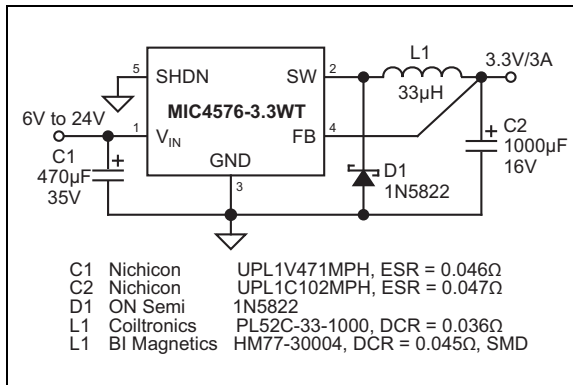


FIGURE 4-1: 6V-24V to 3.3V/3A Buck Converter Through Hole.

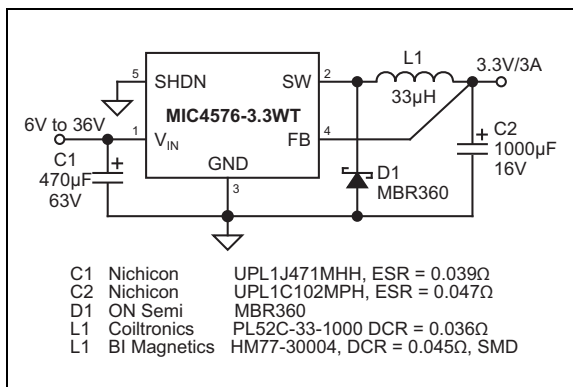


FIGURE 4-2: 6V-36V to 3.3V/3A Buck Converter Through Hole.

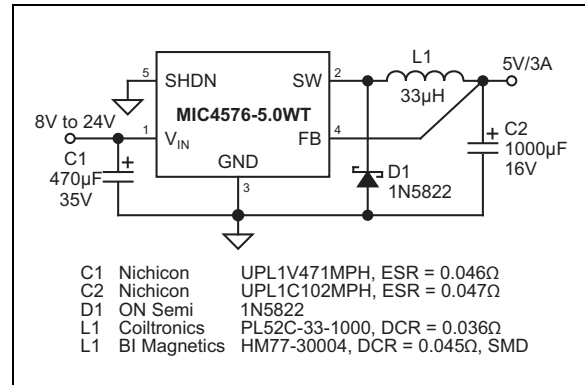


FIGURE 4-3: 8V-24V to 5V/3A Buck Converter Through Hole.

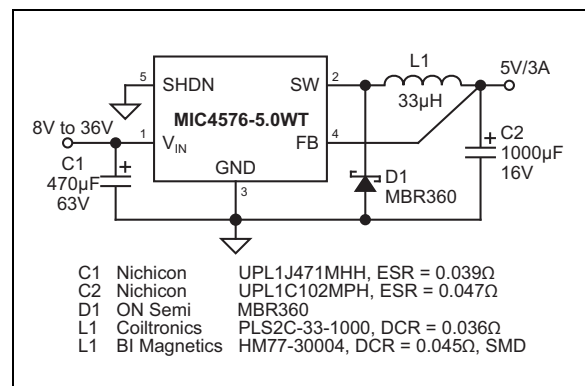


FIGURE 4-4: 8V-36V to 5V/3A Buck Converter Through Hole.

MIC4576

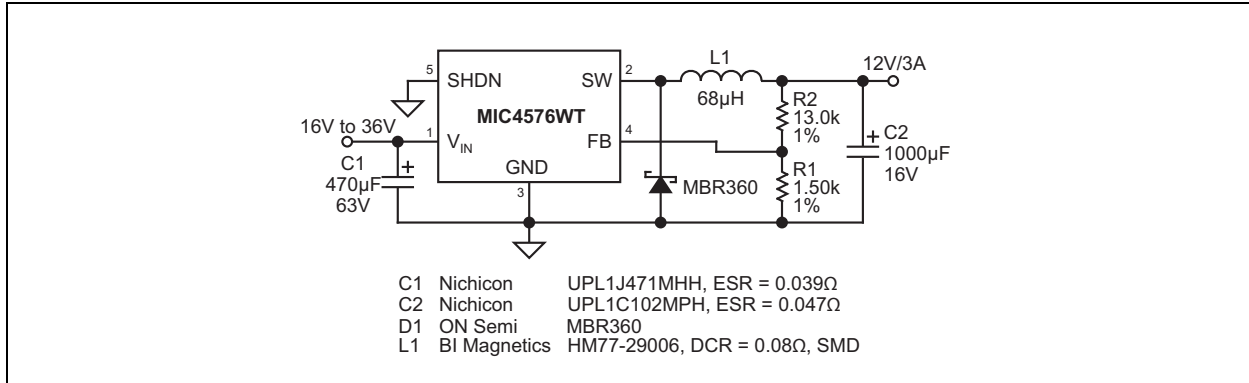


FIGURE 4-5: 16V-36V to 12V/3A Buck Converter Through Hole.

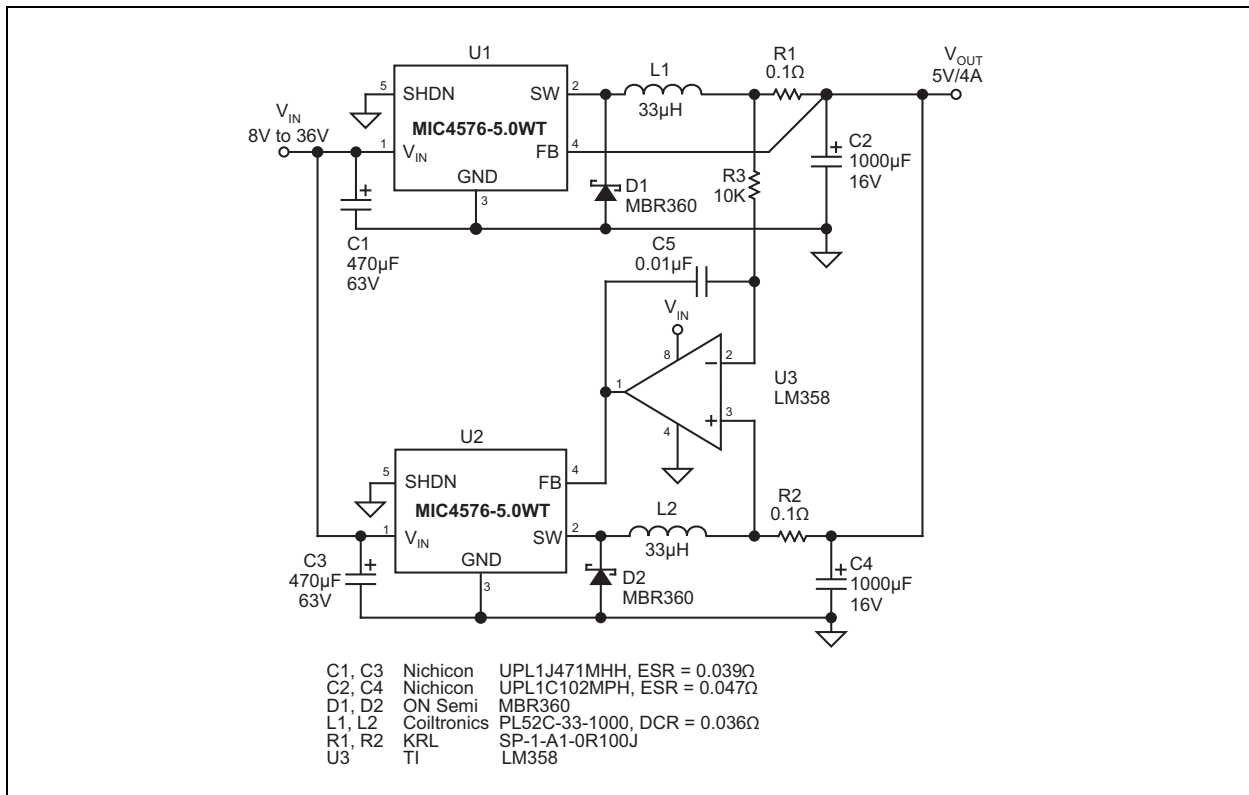


FIGURE 4-6: Parallel Switching Regulators.

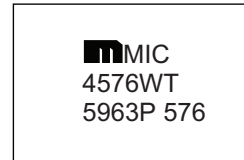
5.0 PACKAGING INFORMATION

5.1 Package Marking Information

5-Lead TO-220
Adjustable Output



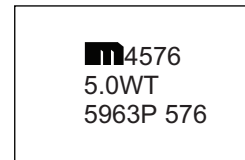
Example



5-Lead TO-220
Fixed Output



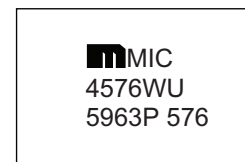
Example



5-Lead TO-263
Adjustable Output



Example



5-Lead TO-263
Fixed Output



Example



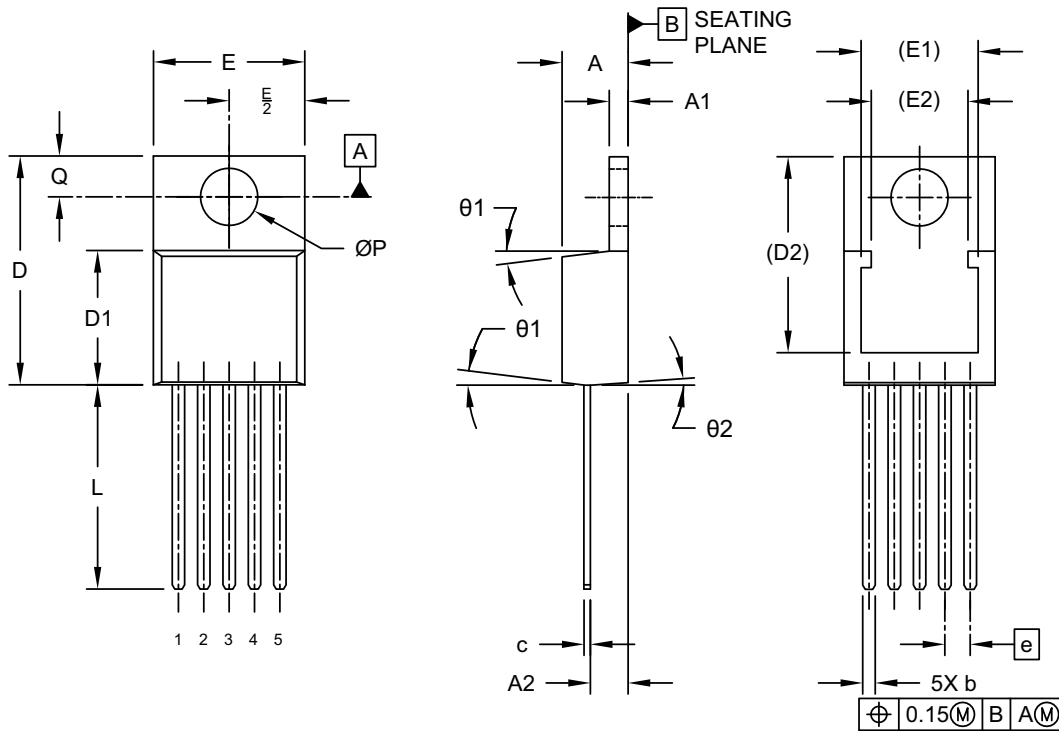
| | | |
|----------------|--|--|
| Legend: | XX...X | Product code or customer-specific information |
| | Y | Year code (last digit of calendar year) |
| | YY | Year code (last 2 digits of calendar year) |
| | WW | Week code (week of January 1 is week '01') |
| | NNN | Alphanumeric traceability code |
| | (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. | |

MIC4576

5.2 Package Outline Drawing

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

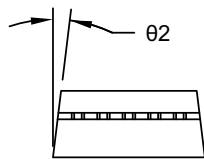
Note: For the most current package drawings, please see the Microchip Packaging Specification located at <http://www.microchip.com/packaging>



TOP VIEW

SIDE VIEW

BOTTOM VIEW

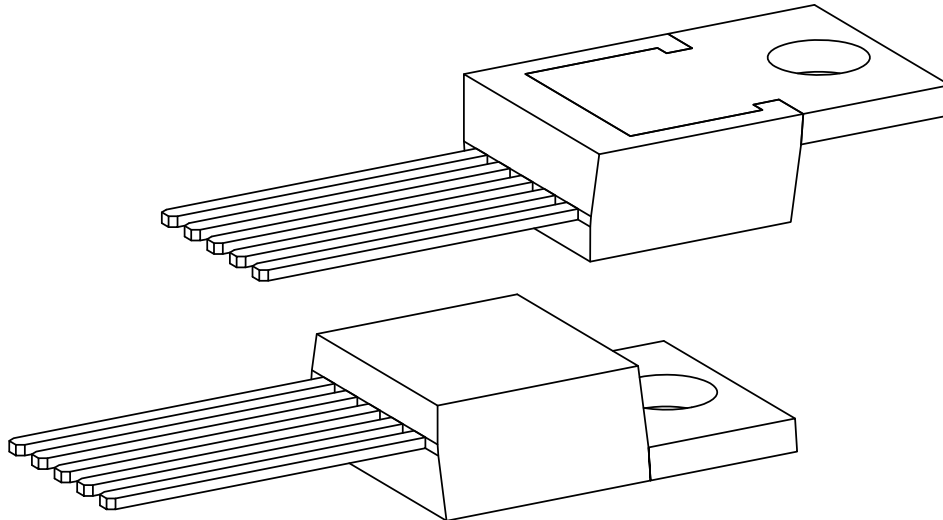


END VIEW

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>



| Dimension Limits | | INCHES | | |
|---------------------------------|----|-----------|------|------|
| | | 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:

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

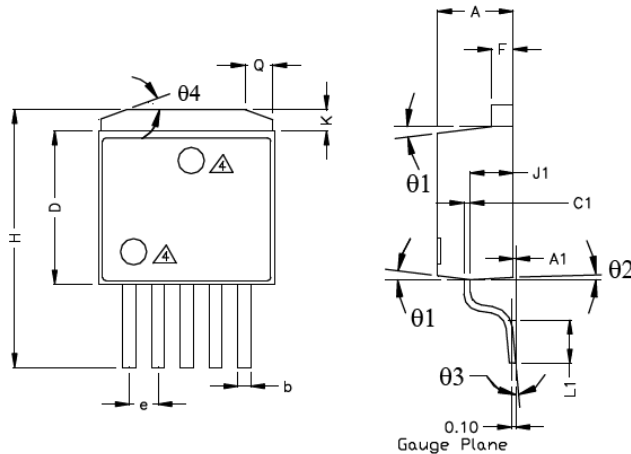
Microchip Technology Drawing C04-036 Rev D Sheet 2 of 2

MIC4576

TITLE

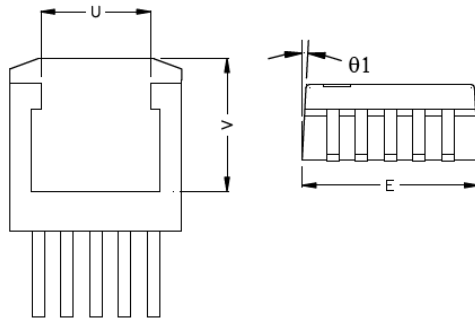
5 LEAD T0263 PACKAGE OUTLINE & RECOMMENDED LAND PATTERN

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



TOP VIEW

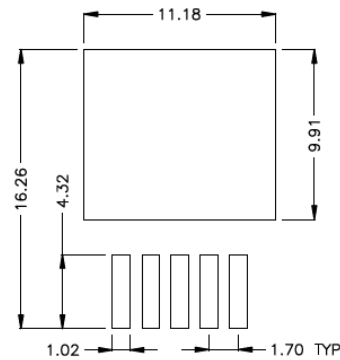
SIDE VIEW 1



BOTTOM VIEW

SIDE VIEW 2

| POS | 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 |
| theta 1 | 3° | 10° | 3° | 10° |
| theta 2 | 1° | 7° | 1° | 7° |
| theta 3 | 0° | 8° | 0° | 8° |
| theta 4 | 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. |



RECOMMENDED LAND PATTERN
(UNIT : mm)

- 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.

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.

MIC4576

NOTES:

PRODUCT IDENTIFICATION SYSTEM

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

| Device | - | <u>X.X</u> | <u>X</u> | <u>X</u> | - | <u>XX</u> |
|---------------------------|--|----------------|--------------------------------|--|---|------------|
| 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. | | | | | |

MIC4576

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