MIC4690 Evaluation Board

SuperSwitcher™ SOIC-8 Buck Switching Regulator (500kHz 4V to 30V/1A)

General Description

The MIC4690 SuperSwitcher™ is an easy-to-use fixed or adjustable output voltage step-down (buck) switch-mode voltage regulator. The 500kHz MIC4690 achieves up to 1.3A of continuous output current over a wide input range in an 8-pin SOIC.

The MIC4690 has an input voltage range of 4V to 30V, with excellent line, load, and transient response. The regulator performs cycle-by-cycle current limiting and thermal shutdown for protection under fault conditions. In shutdown mode, the regulator draws less than 1.5µA of standby current.

The MIC4690 SuperSwitcher™ regulator requires a minimum number of external components and can operate using a standard series of inductors and capacitors. Frequency compensation is provided internally for fast transient response and ease of use.

The MIC4690 is available in the 8-pin SOIC with a –40°C to + 125°C junction temperature range.

Describe significant voltage/current/other versions or capabilities. Do not include applications information or theory of operation in this general description.

Requirements

The MIC4690 evaluation board requires a power supply capable of at least 1.7A at up to 30V. The load should be capable delivering 1.3A under normal operation or 3A incurrent limit.

Operation

Figure 1 shows the schematic of the evaluation board circuit. When the internal high-side switch turns on, one side of the inductor is fed from the input voltage, charging the inductor (+) and (–). During this period, current flows from the input, through the internal switch, output inductor and load. When the output switch turns off, the inductor polarity switches to (–) and (+), the SW pin voltage drops until the freewheeling diode is forward biased. During this portion of the cycle, current flows through the diode, inductor and load. Figure 2 shows the 5V output efficiency versus input voltage and output current.

Precautions

MIC4690 has no protection from reversed polarity being applied to its input. Any momentary reversal of the dc power supply connections can cause permanent damage to the circuit. Use extreme care with these connections. The safest way to power up the MIC4690 evaluation board is to set the power supply to zero volts, and then gradually increase the supply voltage. Monitor the input supply current while increasing the input voltage. If the circuit draws excessive current with no load applied (greater than 100mA) then there is probably a problem with the set-up. Immediately shut off the main power supply and check for proper power supply connections. This simple procedure can avoid most catastrophic failures.

Warning: Tantalum capacitors may explode if improperly connected. Always wear safety glasses when operating the evaluation board

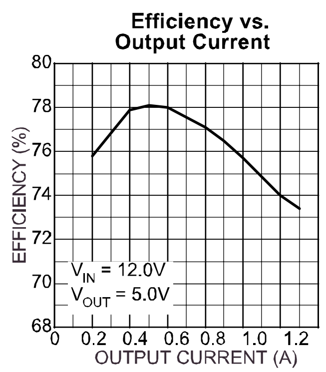


Figure 2.

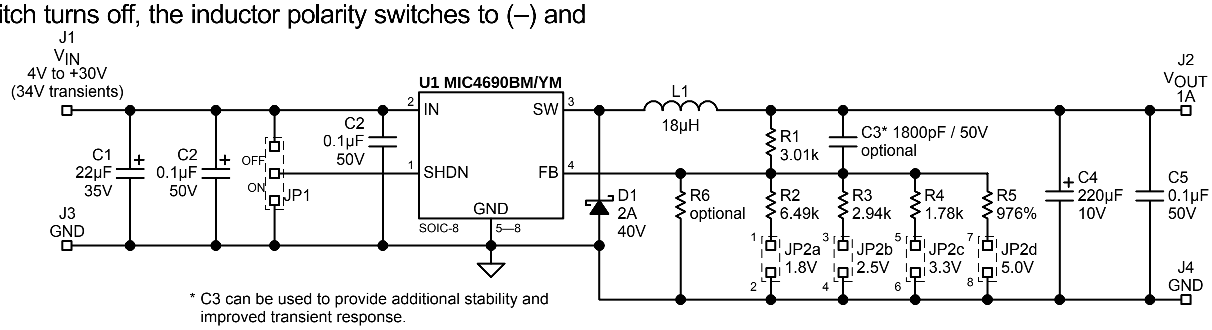


Figure 1. Evaluation Board Schematic

Functional Characteristics

The MIC4690 is a variable duty cycle switch-mode regulator with an internal power switch.

Supply Voltage

The MIC4690 operates from a +4V to +30V unregulated input. Highest efficiency operation is from a supply voltage around +12V. See Figure 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 internal regulator which reduces the current to typically 1.5µA when $V_{SHDN} = V_{IN} = 12V$ and 30µA when $V_{SHDN} = 5V$.

Feedback

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

Adjustable versions require an external resistive voltage divider from the output voltage to ground, center tapped to the FB pin. See Table 1 for recommended resistor values.

Duty Cycle Control

A fixed-gain error amplifier compares the feedback signal with a 1.23V band gap voltage reference. The resulting error amplifier output voltage is compared to a 500kHz 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. The MIC4690 uses voltage mode control architecture.

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}.

Output Capacitor

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

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. See Figure 3.

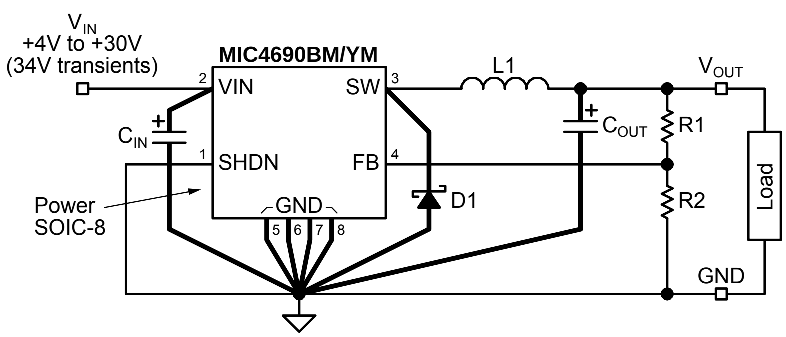
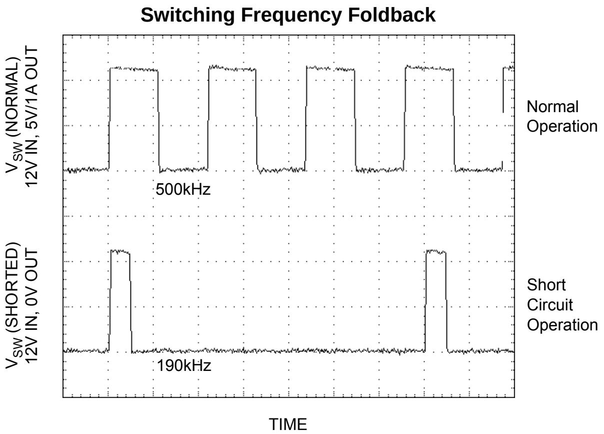
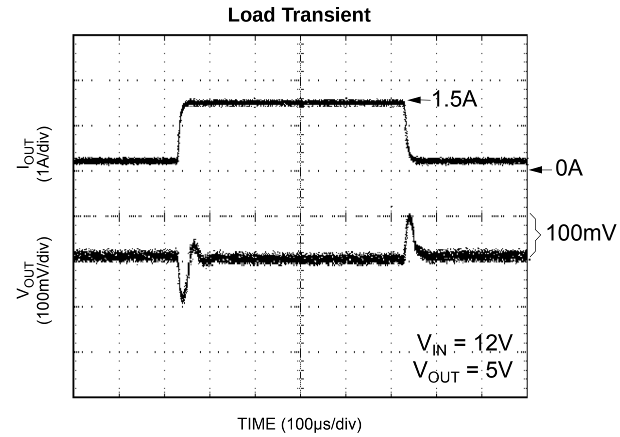


Figure 3. Critical Traces for Layout

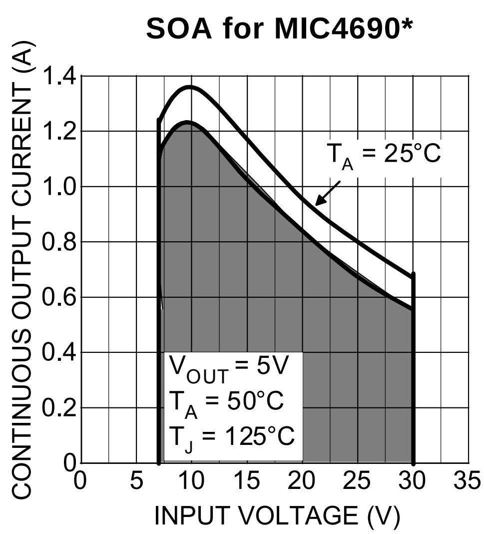
Functional Characteristics





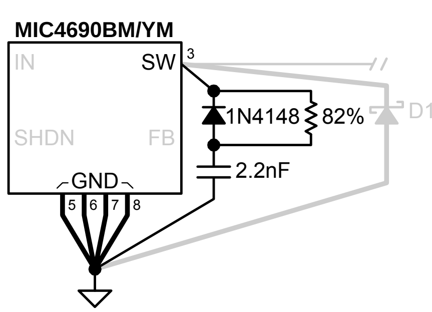
Frequency Foldback

The MIC4690 folds the switching frequency back during a hard short-circuit condition to reduce the energy per cycle and protect the device.



* SOA measured on the MIC4690 evaluation board

For higher currents (> 1A) at input voltages above 15V, use the snubber circuit shown below. For higher currents with out the snubber circuit, refer to the MIC4684.



Snubber Circuit

Application Information

Adjustable Regulators

Adjustable regulators require a 1.23V feedback signal. Recommended voltage-divider resistor values for common output voltages are included in Table 1.

For other voltages, the resistor values can be determined using the following formulas:

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

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

V_{REF} = 1.23V

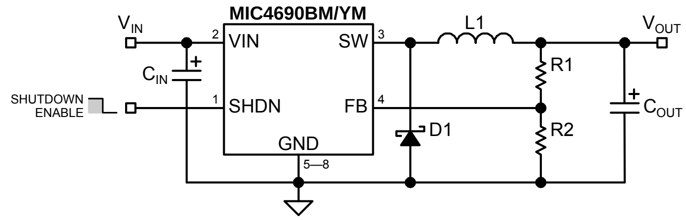


Figure 4. Adjustable Regulator Circuit

Bill of Materials Matrix

V_{OUT}	R1[1]	R2[1]	V_{IN}	C_{IN}	D1	L1	C_{OUT}	I_{OUT}
5.0V	3.01k	976Ω	6.8V–30V	22µF, 35V Vishay-Dale 595D226X0035D2T Micro Commercial	2A, 40V Schotty SS24	18µH Sumida CDRH6D38-180ML	220µF, 10V Vishay-Dale 594D227X0010D2T	see SOA
5.0V	3.01k	976Ω	6.8V–14V	47µF, 20V Vishay-Dale 595D476X0020C2T Micro Commercial	2A, 20V Schotty SS22	18µH Sumida CDRH6D38-180ML	100µF, 6.3V Vishay-Dale 595D107X06R3C2T	1.0A
3.3V	3.01k	1.78k	4.9V–14V	47µF, 20V Vishay-Dale 595D476X0020C2T Micro Commercial	2A, 20V Schotty SS22	15µH Sumida CDRH6D38-150ML	120µF, 4.0V Vishay-Dale 595D127X0004C2T	1.0A
2.5V	3.01k	2.94k	4.25V–14V	47µF, 20V Vishay-Dale 595D476X0020C2T Micro Commercial	2A, 20V Schotty SS22	10µH Sumida CDRH6D38-100ML	120µF, 4.0V Vishay-Dale 595D127X0004C2T	1.0A
1.8V	3.01k	6.49k	4.0V–14V	47µF, 20V Vishay-Dale 595D476X0020C2T Micro Commercial	2A, 20V Schotty SS22	10µH Sumida CDRH6D38-100ML	120µF, 4.0V Vishay-Dale 595D127X0004C2T	1.0A

Note 1. All resistors 1%

Table 1. Recommended Components for Common Output Voltages

Thermal Considerations

The MIC4690 SuperSwitcher features the power-SOIC-8. This package has a standard 8-pin small-outline package profile but with much higher power dissipation than a standard SOIC-8. The MIC4690 SuperSwitcher is the first dc-to-dc converter to take full advantage of this package.

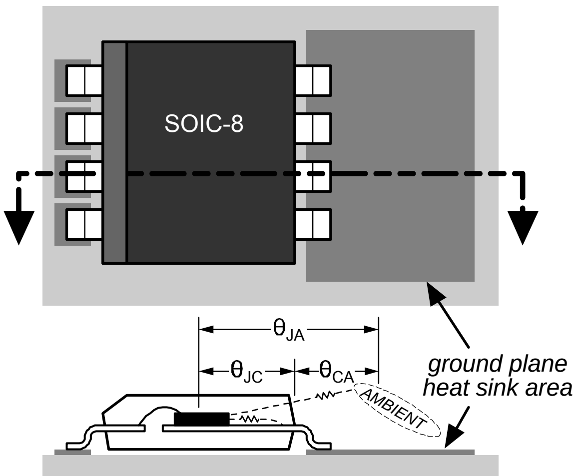


Figure 5. Power SOIC-8 Cross Section

The power SOIC-8 has higher power dissipation (lower thermal resistance) because pins 5 though 8 and the die-attach paddle are a single piece of metal. The die is attached to the paddle with thermally conductive adhesive. This provides a low thermal resistance path from the junction of the die to the ground pins. This design significantly improves package power dissipation by allowing excellent heat transfer through the ground leads to the printed circuit board.

One of the limitation to the maximum output current on any MIC4690 design is the junction-to-ambient thermal resistance (θ_{JA}) of the design (package and ground plane).

Examining θ_{JA} in more detail:

$$\theta_{JA} = (\theta_{JC} + \theta_{CA})$$

where:

θ_{JC} = junction-to-case thermal resistance

θ_{CA} = case-to-ambient thermal resistance

θ_{JC} is a relatively constant 20°C/W for a power SOIC-8.

θ_{CA} is dependent on layout and is primarily governed by the connection of pins 5 though 8 to the ground plane. The purpose of the ground plane is to function as a heat sink.

θ_{JA} is ideally 63°C/W but will vary depending on the size of the ground plane to which the power SOIC-8 is attached.

Determining Ground-Plane Heat-Sink Area

There are two methods of determining the minimum ground plane area required by the MIC4690.

Quick Method

Make sure that MIC4690 pins 5 though 8 are connected to a ground plane with a minimum area of $6cm^2$. This ground plane should be as close to the MIC4690 as possible. The area maybe distributed in any shape around the package or on any pcb layer as long as there is good thermal contact to pins 5 though 8. This ground plane area is more than sufficient for most designs.

When designing with the MIC4690, it is a good practice to connect pins 5 through 8 to the largest ground plane that is practical for the specific design.

Checking the Maximum Junction Temperature

For this example, with an output power (P_{OUT}) of 5W, (5V output at 1A maximum with V_{IN} = 12V) and 50°C maximum ambient temperature, what is the maximum junction temperature?

Referring to the "Figure 2, 5V Output Efficiency" graph, read the efficiency (η) for 1A output current at V_{IN} = 12V or perform you own measurement.

$$\eta = 75\%$$

The efficiency is used to determine how much of the output power (P_{OUT}) is dissipated in the regulator circuit (P_D).

$$P_D = \frac{P_{OUT}}{\eta} - P_{OUT}$$

$$P_D = \frac{5W}{0.75} - 5W$$

$$P_D = 1.67W$$

A worst-case rule of thumb is to assume that 80% of the total output power dissipation is in the MIC4690 ($P_{D(IC)}$) and 20% is in the diode-inductor-capacitor circuit.

$$P_{D(IC)} = 0.8\ P_D$$

$$P_{D(IC)} = 0.8 \times 1.67W$$

$$P_{D(IC)} = 1.336W$$

Calculate the worst-case junction temperature:

$$T_J = P_{D(IC)}\ \theta_{JC} + (T_C - T_A) + T_{A(max)}$$

where:

T_J = MIC4690 junction temperature

$P_{D(IC)}$ = MIC4690 power dissipation

θ_{JC} = junction-to-case thermal resistance.

The θ_{JC} for the MIC4690's power-SOIC-8 is approximately 20°C/W. (Also see Figure 5.)

T_C = "pin" temperature measurement taken at the entry point of pins 6 or 7 into the plastic package at the ambient temperature (T_A) at which T_C is measured.

T_A = ambient temperature at which T_C is measured.

$T_{A(max)}$ = maximum ambient operating temperature for the specific design.

Calculating the maximum junction temperature given a maximum ambient temperature of 65°C:

T_J = 1.336 × 20°C/W + (63°C – 25°C) + 50°C

T_J = 114.72°C

This value is within the allowable maximum operating junction temperature of 125°C as listed in "Operating Ratings." Typical thermal shutdown is 160°C and is listed in "Electrical Characteristics."

Layout Considerations

Layout is very important when designing any switching regulator. Rapidly changing switching currents through the printed circuit board traces and stray inductance can generate voltage transients which can cause problems.

To minimize stray inductance and ground loops, keep trace lengths, indicated by the heavy lines in Figure 6, as short as possible. For example, keep D1 close to pin 3 and pins 5 through 8, keep L1 away from sensitive node FB, and keep C_{IN} close to pin 2 and pins 5 though 8.

The feedback pin trace from the output back to the IC should be kept as far way from the switching elements (usually L1and D1) as possible.

Circuits with sample layouts are provided. See Figure 6a though 6c.

Printed Circuit Board Layouts

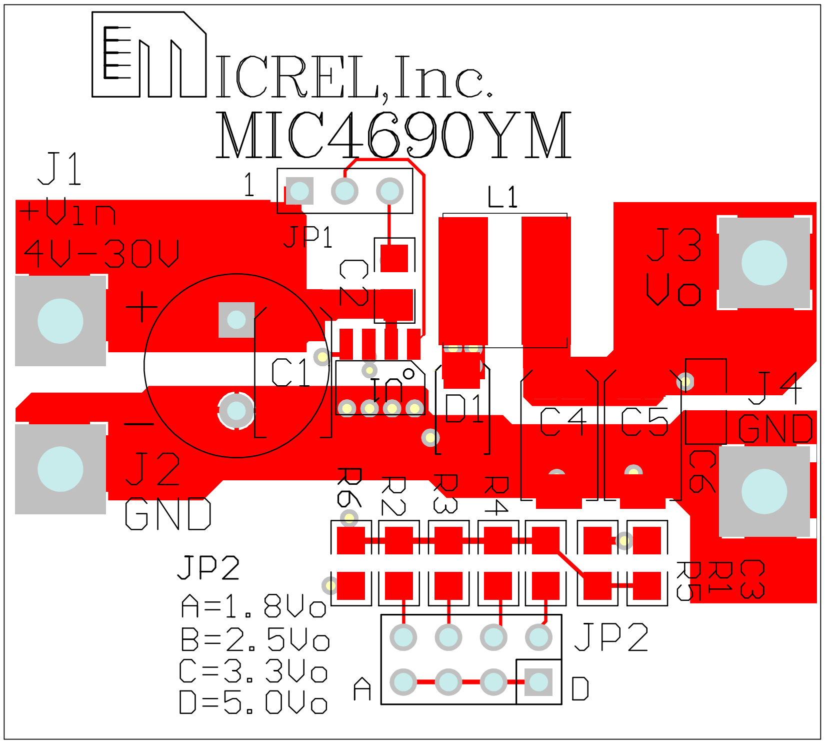


Figure 6a. Top-Side Layer

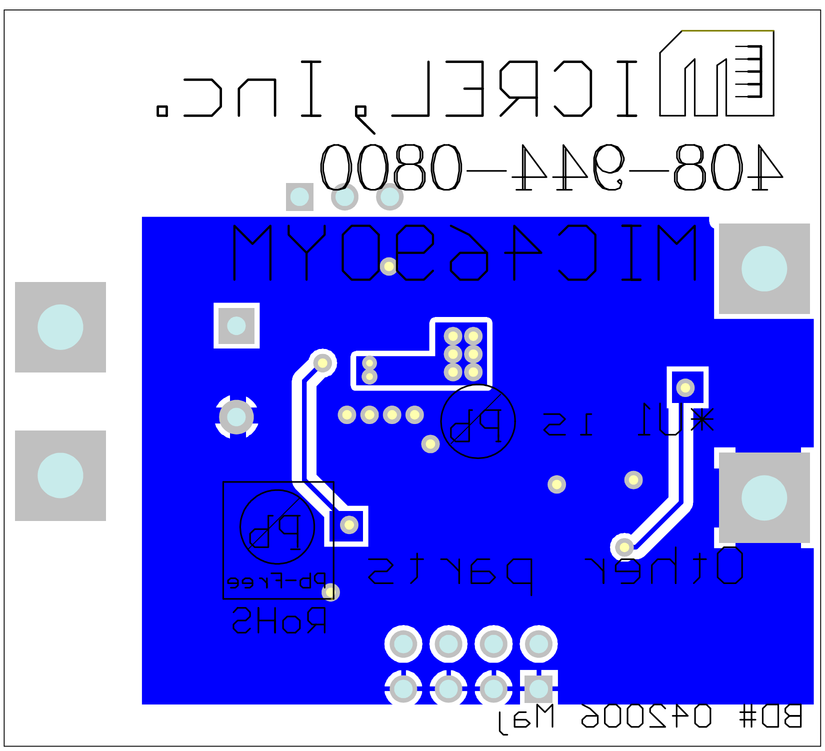


Figure 6b. Bottom-Side Layer

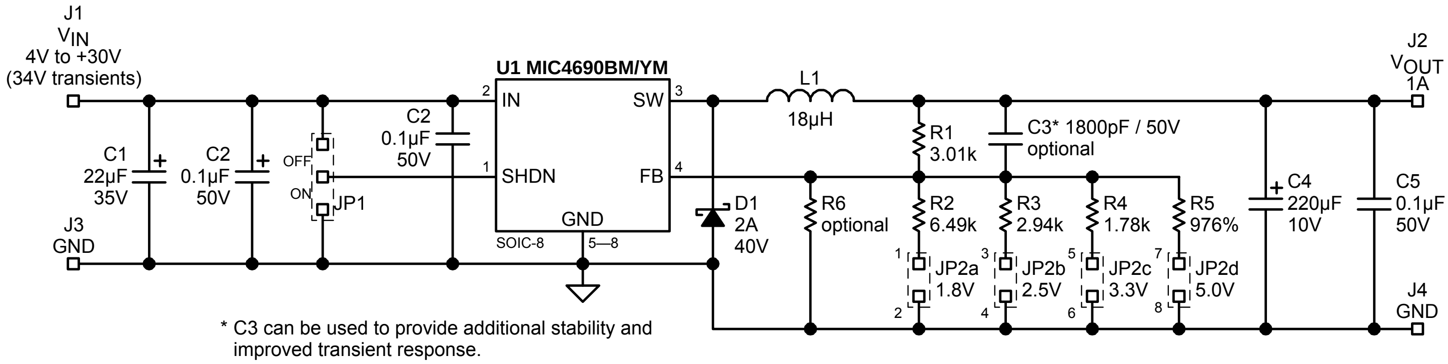


Figure 6c. Evaluation Board Schematic

Bill of Material

Reference	Part Number	Manufacturer	Description	Qty
C1	595D226X0035D2T	Vishay Sprague[1]	22µF, 35V	1
	ECE-A1HFS470	Panasonic	47µF 50V, 8mm x 11.5mm	
	TPSD226M035R0300	AVX[2]	22µF, 35V	
C2, C6	VJ0805Y104KXAMB	Vishay Vitramon[1]	0.1µF 50V	1
C3			option	
C4	594D227X0010D2T	Vishay Sprague[1]	220µF 10V	1
C5			option	
D1	SS24	Micro Commercial Corp.[3]	2A/40V Schottky	1
	B240A	Diodes Inc.[4]		
J1–J4	2551-2-00-01-00-00-07-0	MillMax	turret pins	4
JP1	S1012-02-ND	Sullins	straight single-row male header	1
JP2	S2012-04-ND	Sullins	straight dual-row male header	1
JP3 (Note 1)	SNT-100-BL-G	Samtec	jumper header female	
R1			3.01k 1/10W 1%, size 0805	1
R2			6.49k 1/10W 1%, size 0805	1
R3			2.94k 1/10W 1%, size 0805	1
R4			1.78k 1/10W 1%, size 0805	1
R5			976Ω 1/10W 1%, size 0805	1
R6			optional, size 0805	
L1	CDRH6D38-180MC	Sumida[5]	18µH, 1.5A I_{SAT}	1
U1	**MIC4690BM/YM**	**Micrel, Inc.[6]**	**1A 200kHz power-SOIC-8 buck regulator**	**1**

Note 1. Voltage selector.

1. Vishay Inc.: www.vishay.com
2. AVX: www.avxcorp.com
3. Micro Commercial Corp.: www.mccsemi.com
4. Diodes Inc.: www.diodes.com
5. Sumida: www.sumida.com
6. Micrel, Inc.: www.micrel.com

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