AMS4154

2A, 32V Step-Down Converter

General Description

The AMS4154 is a 2A, 330KHz, high voltage step-down converter in a single thermally enhanced exposed paddle SO-8 package. Its wide 6V to 32V input voltage range is ideal for a wide range of applications. These applications include automotive battery requirements where the part achieves 2A of continuous output current for fast charge capability.

The AMS4154 is a current mode control part which provides low ESR ceramic output capacitor stability and fast transient response. Fault protection includes a "hiccup" current limit and thermal protection with hysteresis to protect the device from excessive die temperatures.

With an external V_{REF} and using only minimum number of readily available external components to compensate, AMS4154 is very flexible for a wide range of applications that requires a 2A step-down DC/DC solution.

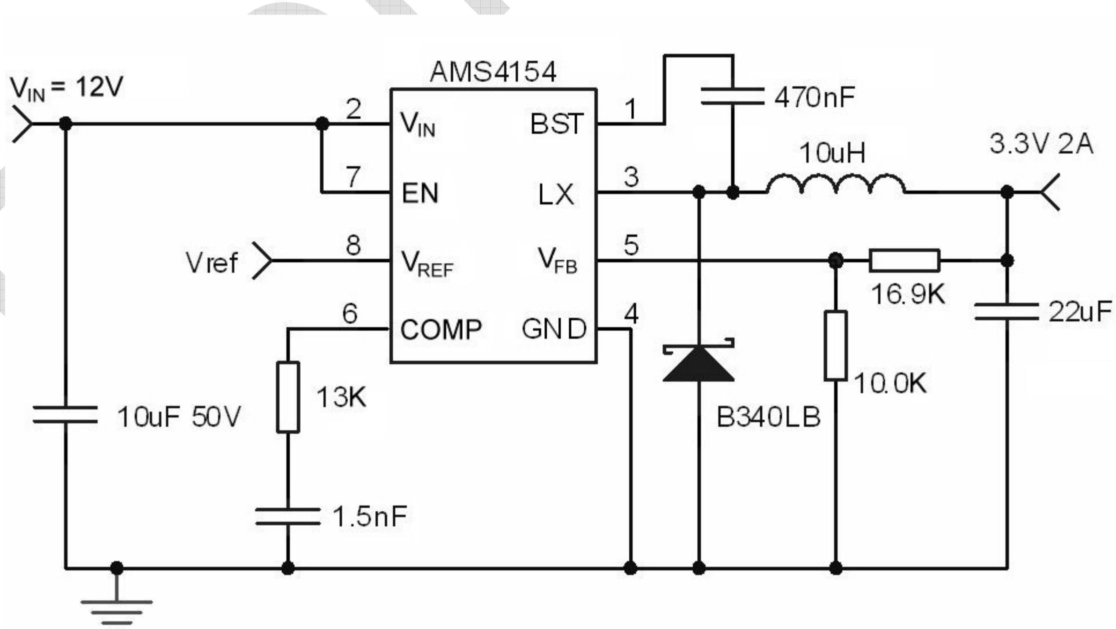
Features

- Wide 6V to 32V Input Operating Range
- 34V Absolute Maximum Input
- Up to 2A Output Current
- Low ESR Ceramic Output Capacitor Stable
- Up to 90% Efficiency
- Less than 2µA Shutdown Mode
- 330 KHz Switching Frequency
- Hiccup Mode Over Current Protection
- Output Adjustable From 1.23V to 32V
- Reference Voltage Output
- Thermal Shutdown
- Operating Temperature -40℃ to 125℃
- Available in SOIC 8-Pin EDP

Applications

- Automotive Power Adapters
- Automotive Infotainment
- Audio Power Amplifiers
- Portable (Notebook) Computers
- Point of Regulation for High Performance Electronics
- Consumer Electronics
- DVD, Blue-ray DVD writers
- LCD TVs and LCD monitors
- Distributed Power Systems
- Battery Chargers
- Pre-Regulator for Linear Regulation

Typical Application

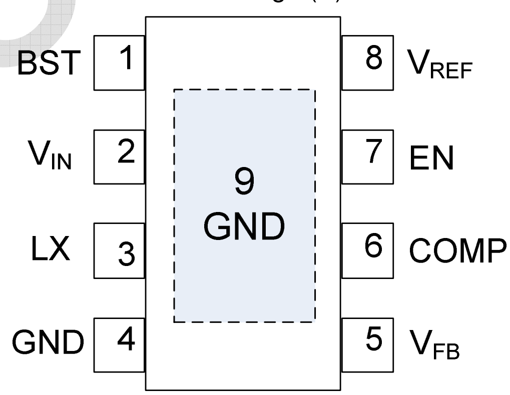


Pin Description

Pin #	Symbol	Description
1	BST	The bootstrap capacitor (BOOST PIN) tied to this pin is used as the bias source for the drive to the internal power switch. Use a 470nF or greater capacitor from the BST to the SW pin.
2	V_{IN}	Input Power. Supplies bias to the IC and is also the power input to the step-down converter main power switch. Bypass V_{IN} with low impedance ceramic with sufficient capacitance to minimize switching frequency ripple as well as high frequency noise.
3	LX	Step-Down converter switching node that connects the internal power switch to the output inductor.
4	GND	Ground
5	V_{FB}	Feedback input. A resistor network of two resistors is used to set-up the output voltage connected between V_{OUT} and GND. The node between the two resistors is connected to Feedback pin with a 1.23V reference voltage.
6	COMP	The COMP pin connects to the output of the internal transconductance error amplifier. A series RC network is connected from the COMP pin to GND. An additional capacitor can also be placed in parallel with the series RC network. See the section on error amplifier compensation for more details.
7	EN	Enable/UVLO. A voltage greater than 2.5V at this pin enables the switching regulator only. For complete low current shutdown, the EN pin voltage needs to be less than 2.4V.
8	V_{REF}	Reference Output. V_{REF} is the 5V reference voltage output. It can supply up to 1mA to external circuitry. If used, bypass V_{REF} to GND with a 10nF or greater capacitor. Leave V_{REF} unconnected if not used.
9	GND (PADDLE)	Ground paddle to be connected to PCB ground plane.

Pin Configuration

8L SOIC
SO Package (S)



Top View

Absolute Maximum Ratings [1]

V_{IN} Supply Voltage……………………………………………-0.3V to 34V
V_{LX} pin Voltage……………………………………………-1V to V_{IN} + 0.3V
BST Voltage……………………………………………-0.3V to V_{sw} + 6V
V_{FB}, COMP, V_{REF}, EN Voltage……………………………………-0.3V to 6V
Storage Temperature Range…………………………-65ºC to 150ºC
Lead Temperature……………………………………………260ºC
Junction Temperature……………………………………………150ºC

Recommended Operating Conditions [2]

Input Voltage……………………………………………6V to 32V
Ambient Operating Temperature…… ………………-40ºC to 85ºC

Thermal Information

8L SOIC θ_{JA} ……………………………………………45ºC/W
8L SOIC θ_{JC} ……………………………………………10ºC/W

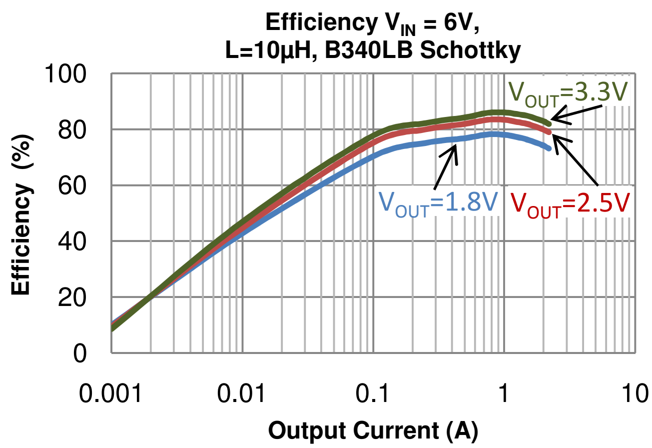
Electrical Characteristics

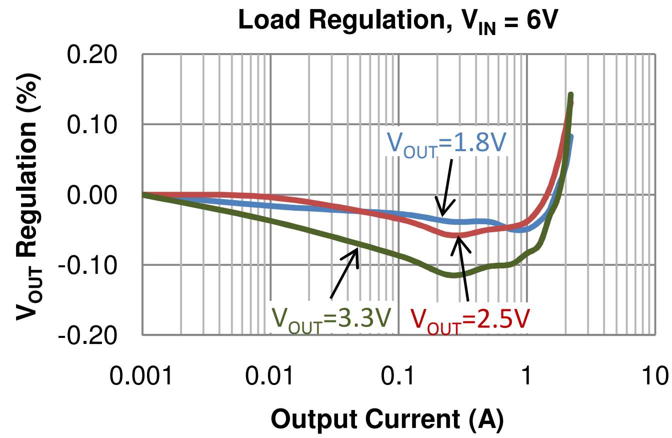
T_A= 25°C and V_{IN} = V_{EN} = 12V, V_{OUT} = 3.3V (unless otherwise noted).

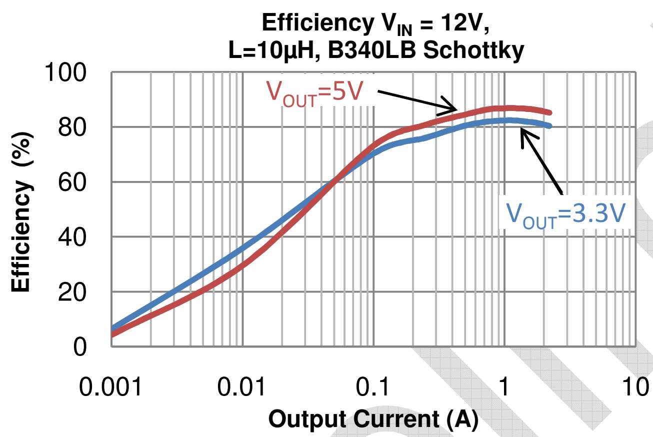
Parameter	Symbol	Conditions	Min	Typ	Max	Units
Input Voltage Range	V_{IN}		6	12	32	V
Minimum Input Voltage	V_{IN_MIN}	V_{LX} switching, $V_{REF} \neq 5V$		3.3		V
Bias Current	I_{VIN_QS}	$V_{EN} \geq 2.5V$, V_{FB} = 1.5V		2.2	2.5	mA
Shutdown Supply Current	I_{VIN_SD}	V_{EN} = 0V		1.5	2	µA
Feedback Voltage	V_{FB}	I_{OUT} = 0A	1.200	1.230	1.260	V
Feedback Bias Current	I_{FB}			100	250	nA
Error Amplifier Voltage Gain	A_V			325		V/V
Error Amplifier Transconductance	G_{EA}	ΔI_{COMP} = ±10µA		245		µA/V
Switch V_{CESAT}	V_{CESAT}	I_{OUT} = 1A		250		mV
Switch Leakage Current	I_{LX_LEAK}	V_{EN} = 0V, V_{LX} = 0V		0.1	10	µA
Current Limit	I_{CLIM_LIM}	V_{OUT} = 3.3V	3.4	4	6	A
Current Sense Transconductance Output current to Comp. Pin Voltage	G_{CS}			4		A/V
Enable Shutdown Threshold	V_{EN_LOW}		2.2	2.4	2.6	V
Enable Threshold High	V_{EN_HIGH}	V_{EN} Rising	2.3	2.5	2.7	V
Enable Threshold Hysteresis	$V_{EN\ HYS}$			100		mV
Oscillator Frequency	F_{OSC}		300	330	360	KHz
Maximum Duty Cycle	D_{MAX}	V_{FB} = 0V		95		%
Minimum Duty Cycle	D_{MIN}	V_{FB}=1.5V			1	%
Reference Voltage	V_{REF}	I_{REF} = 0µA		5		V
Reference Load Regulation		Δ I_{REF} = 0 to 1.5mA		50		mV
Reference Line Regulation		I_{REF} = 100µA, V_{IN} = 6V to 32V		150		mV
Thermal Shutdown	T_{SD}			150		°C
Thermal Shutdown Hysteresis	T_{SDHys}			20		°C

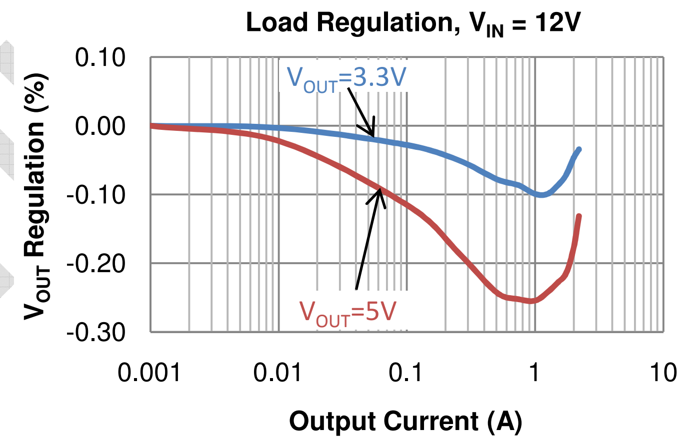
Notes:
1. Stresses above those listed in Absolute Maximum Ratings may cause permanent damage to the device.
2. Operation outside of the recommended operating conditions is not guaranteed

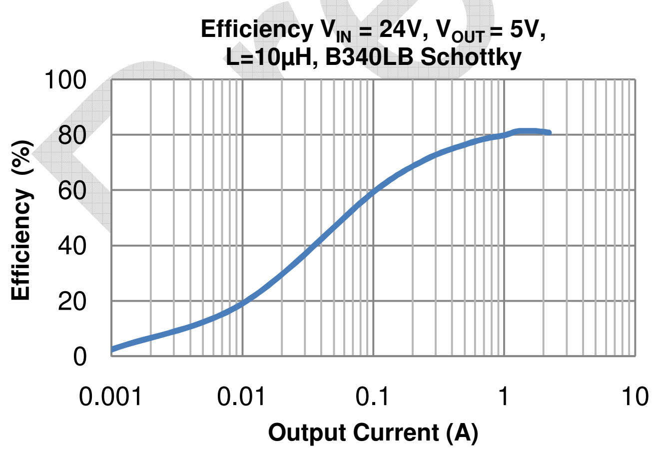
Typical Characteristics (T_A = 25°C unless otherwise specified)

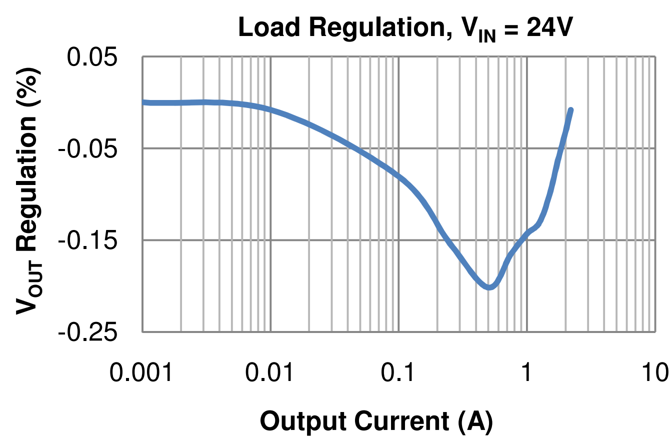






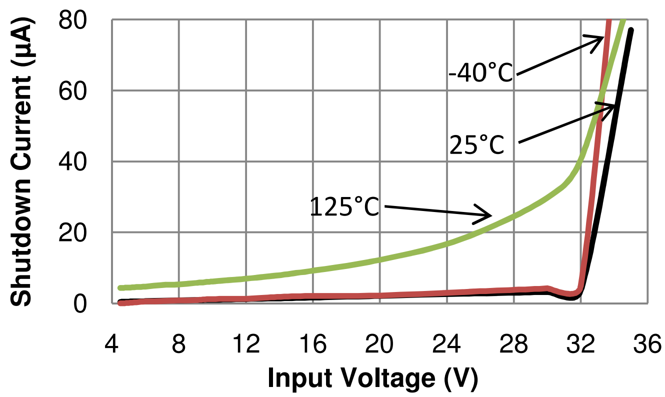




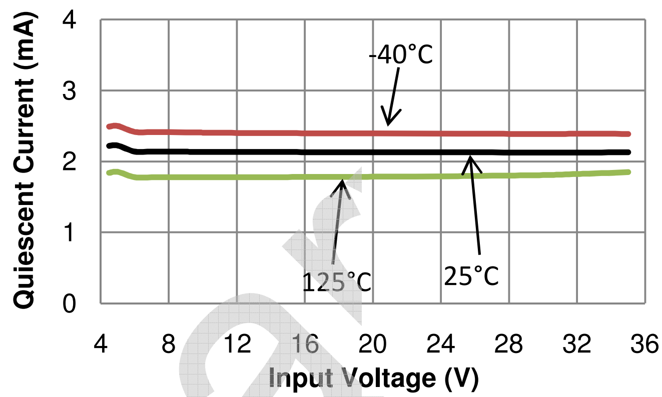


Typical Characteristics (T_A = 25℃ unless otherwise specified)

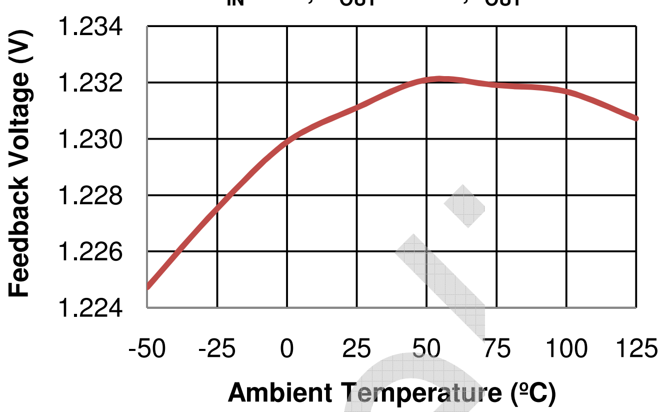
Shutdown Current vs. Input Voltage



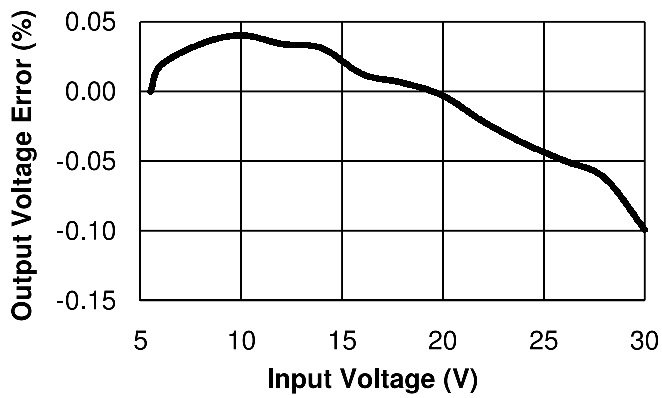
Quiescent Current vs. Input Voltage



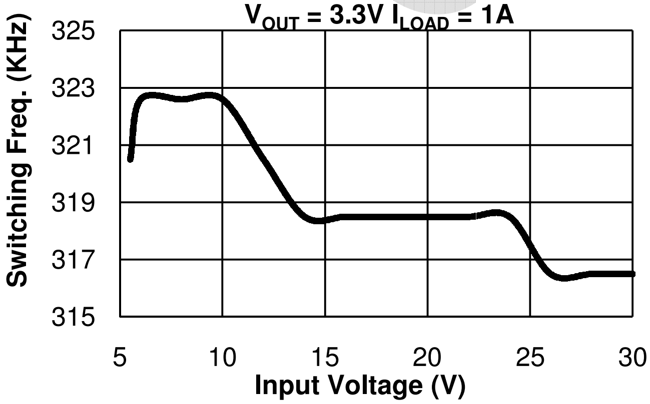
Feedback Voltage (V_{FB}) vs. Temperature
V_{IN} = 6V, V_{OUT} = 3.3V, I_{OUT} = 1A



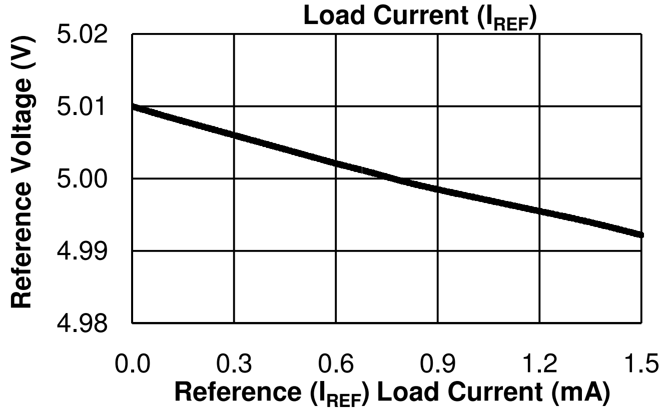
Line Regulation V_{OUT} = 3.3V, I_{OUT} = 1A



Switching Freq. Vs. Input Voltage
V_{OUT} = 3.3V I_{LOAD} = 1A

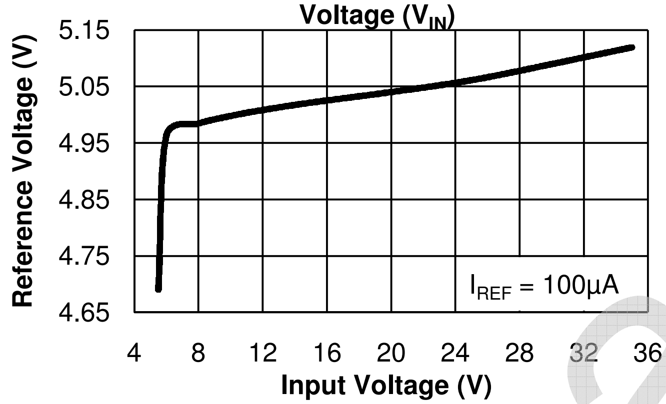


Reference Voltage (V_{REF}) Vs. Reference Load Current (I_{REF})

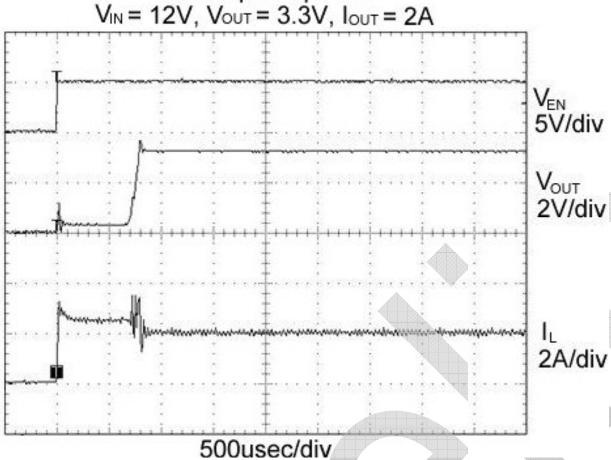


Typical Characteristics (T_A = 25°C unless otherwise specified)

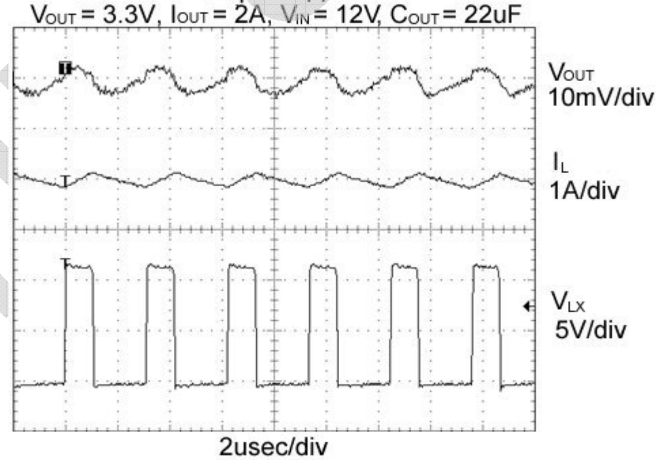
Reference Voltage (V_{REF}) Vs. Input Voltage (V_{IN})



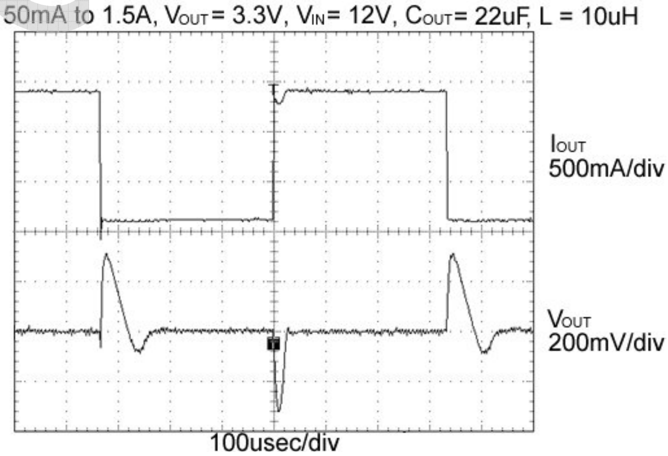
Start-Up Response
V_{IN} = 12V, V_{OUT} = 3.3V, I_{OUT} = 2A



Output Ripple
V_{OUT} = 3.3V, I_{OUT} = 2A, V_{IN} = 12V, C_{OUT} = 22uF



Load Transient Response
I_{LOAD} = 150mA to 1.5A, V_{OUT} = 3.3V, V_{IN} = 12V, C_{OUT} = 22uF, L = 10uH



Functional Block Diagram

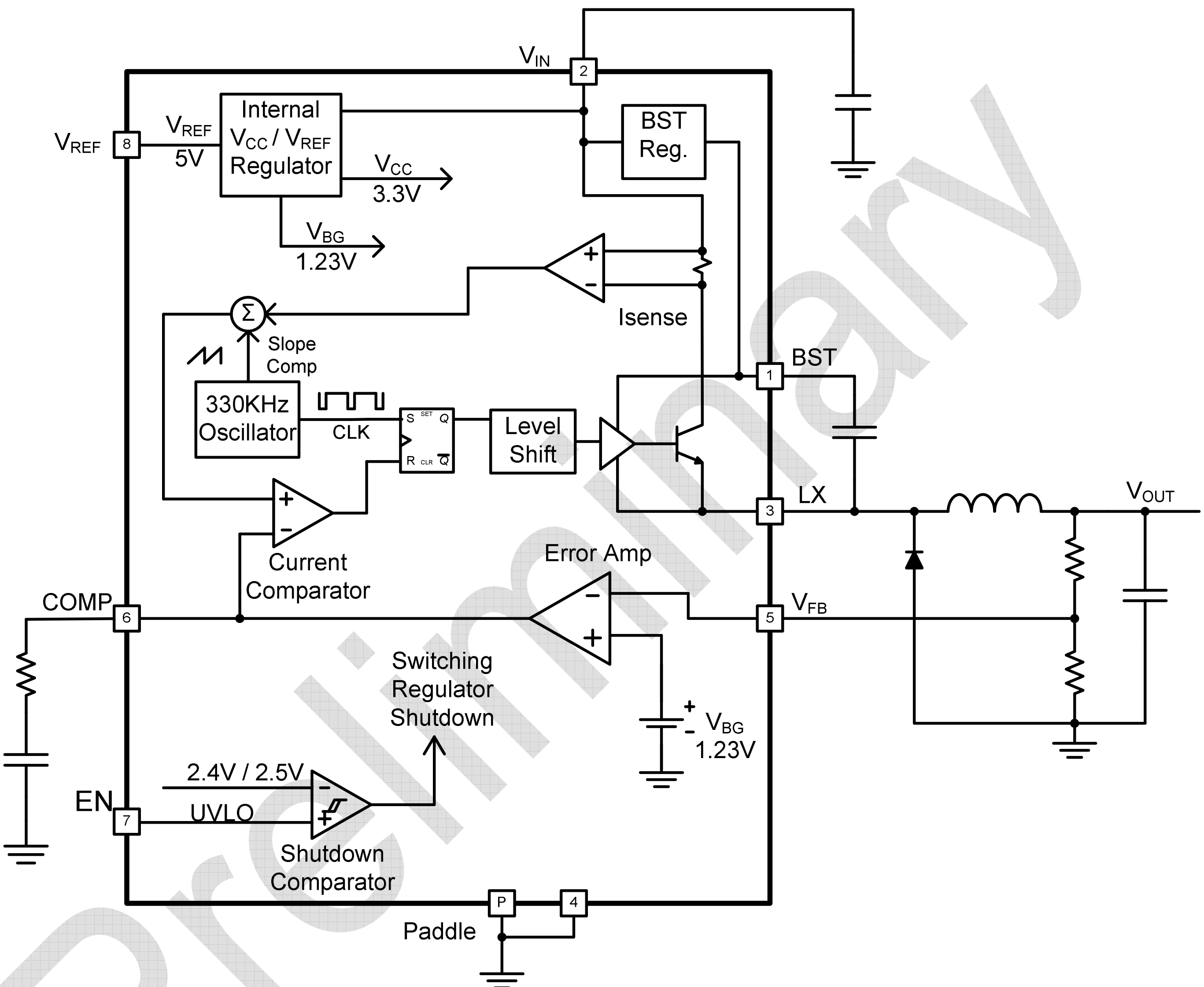


Figure 1: Functional Block Diagram of AMS 4154

Device Summary

The AMS4154 is a high frequency 2A fixed frequency step-down converter. The peak current mode step-down converter is externally compensated and is stable with low ESR ceramic output capacitors. The output voltage is sensed through an external resistive divider that feeds the negative input to an internal transconductance error amplifier. The output of the error amplifier is connected to the input to a peak current mode comparator. The inductor current is sensed as it passes through the high side power switch and fed to the current mode comparator. The error amplifier regulates the output voltage by controlling the peak inductor current passing through the power switch so that, in steady state, the average inductor current equals the load current. The step-down converter has an input voltage range of 6V to 32V with an output voltage as low as 1.23V.

Enable

The enable threshold for the step-down converter is 2.5V with 100mV of hysteresis.

Fault Protection

Short circuit protection limits the peak current and initiates a "hiccup" mode of operation to limit the input power during short circuit operation. Over-temperature shutdown disables the converter when the junction temperature reached 150C.

Application

Inductor

The step-down converter inductor is typically selected to limit the ripple current from 20% to 40% of the full load output current. Meeting this rule of thumb also guarantees the internal slope compensation is greater than one half of the inductor current down-slope thus avoiding any peak current mode related instability when the duty cycle is greater than 50%.

$$L = (V_{IN}-V_{OUT})\cdot\frac{V_{OUT}}{V_{IN}\cdot I_{OUT}\cdot 0.4\cdot Fs}$$

$$L = (12V-3.3V)\cdot\frac{3.3V}{12V\cdot 2A\cdot 0.4\cdot 330KHz} = 10\mu H$$

For most applications the duty cycle of the AMS4154 step down converter is less than 50% duty and does not require slope compensation for stability. This provides some flexibility in the selected inductor value. Given the above selected value, others values slightly greater or less may be examined to determine the effect on efficiency without a detrimental effect on stability. With the inductor value selected, the ripple current can be calculated:

$$Ipp = \frac{V_{OUT}\cdot(1-D)}{L\cdot Fs}$$

$$Ipp = \frac{3.3V\cdot(1-(3.3V/12V))}{10\mu H\cdot 330KHz} = 0.725A$$

Once the appropriate value is determined, the component is selected based on the DC current and the peak (saturation) current. Select an inductor that has a DC current rating greater than the full load current of the application. The DC current rating is also reflected in the DC resistance (DCR) specification of the inductor. The inductor DCR should limit the inductor loss to less than 2% of the step-down converter output power. The peak current at full load is equal to the full load DC current plus one half of the ripple current.

$$I_{PEAK\_MAX} = I_{OUT} + \frac{V_{OUT}\cdot(1-D)}{2\cdot L\cdot Fs}$$

$$D = \frac{V_{OUT}}{V_{IN}}$$

$$D = \frac{3.3V}{12V} = 0.275$$

$$I_{PEAK\_MAX} = 2A + \frac{(3.3V)\cdot(1-0.275)}{2\cdot 10\mu H\cdot 330KHz} = 2.363A$$

$$Ipp = \frac{(3.3V)\cdot(1-0.275)}{12\mu H\cdot 330KHz} = 0.725A$$

There is a wide range of 3A and above shielded and non-shielded inductors available. Table 1 lists a few inductors that have a current rating of 3A and higher.

Table 1: Typical Inductors

Series	Type	Dimensions (mm) W	L	H
Toko				
D53LC Type A	Shielded	5.0	5.0	5.0
Sumida				
CDRH6D26/HP	Shielded	6.7	6.7	2.6
CDRH6D28	Shielded	5.5	5.7	5.5
CDRH5D28	Shielded	6.7	6.7	3.0
Coilcraft				
DO3308	Shielded	9.4	13.0	3.0
DO3316	Shielded	9.4	13.0	15.1

Output Capacitor

A low ESR X5R or X7R type ceramic capacitor is typically sufficient for most applications. The following equation determines the required low ESR ceramic output capacitance for a given inductor current ripple (I_{PP}) and a (dV_{OUT}) limit of 200mV.

$$C_{OUT} = \frac{I_{PP}}{Fs \cdot 8 \cdot dV_{OUT}} = \frac{0.725A}{330KHz \cdot 8 \cdot 200mV} = 1.37\mu F$$

For applications with large load transients, additional capacitance may be required to keep the output voltage within the specified limits. In this case, the required capacitance can be examined for the load application and load removal. From a full load to no load transient, the required capacitance to limit the output voltage overshoot to less than 200mV for a 3.3V output is:

$$Cbulk = \frac{L \cdot I_{OUT}^2}{V_{OUT+OS}^2 - V_{OUT}^2} = \frac{10\mu H \cdot (2A)^2}{(3.5V)^2 - (3.3V)^2} = 29.4\mu F$$

For the application of a load pulse, the capacitance required from hold up depends on the time it takes for the power supply loop to build up the inductor current to match the load current. For the AMS4154 this can be estimated to be less than 10 µsec or about three clock cycles. For a no load to 1A load pulse the required capacitance to limit the voltage droop to less than 200mV is estimated from:

$$C_{OUT} = \frac{I_{OUT} \cdot t}{dV} = \frac{1A \cdot 10\mu sec}{200mV} = 50\mu F$$

Boot Strap Capacitor

An external boot strap capacitor (C_{BST}) is required for the high side switch drive. The capacitor is charged during the off time while the switch node is at ground. During the on-time portion of the switching cycle the switch node is tied to the input voltage by way of the internal power switch. The boot strap capacitor is always referenced to the switch node so the charge stored in the capacitor during the off time is then used to drive the internal power switch during the on-time. Typical bootstrap capacitor values are in the 470nF to 1µF range type X5R ceramic with a 10V rating. Insufficient values will not be able to provide sufficient base drive current to the power switch during the on time. Values less than 470nF are not recommended. This will result in excessive losses and reduced efficiency.

Output Rectifier Diode

The output freewheeling rectifier (D1) provides a path for the inductor current to flow when the high side integrated power switch is off. A Schottky diode is usually preferred because of its very low forward voltage and recovery time.

The diode reverse voltage rating must be greater than the maximum input voltage rating. The diode conducts the full load current during the off time and therefore should have an average current rating greater than the load current times the one minus the duty cycle.

$$I_{D1} \geq I_{OUT} \cdot (1-D) = I_{OUT} \cdot \left(1 - \frac{V_{OUT}}{V_{IN}}\right) = 2A \cdot \left(1 - \frac{3.3V}{12V}\right) = 1.45A$$

Table 2: Schottky Rectifier Selection

V_{IN}	Package	I_{FWD}	Part Number	Manufacturer
10V	SMA	2A	MBRA210LT	On Semiconductor
	SOD-123	2A	PMEG1020	NXP Semiconductor
20V	SMA	2A	B220A	Diodes Inc.
	SMB	2A	SL22	Vishay/General Semiconductor
24V	SMB	2A	STPS2L25U	ST Microelectronics

Input Capacitor

The low ESR ceramic capacitor is required at the input to filter out high frequency noise as well as switching frequency ripple. Placement of the capacitor is critical for good high frequency noise rejection. See the PCB layout guidelines section for details. Switching frequency ripple is also filtered by the ceramic bypass input capacitor. Given a desired input voltage ripple (V_{RIPPLE}) limit (typical $V_{RIPPLE} \approx$ 100mV), the required input capacitor can be estimated with:

$$D = \frac{V_{OUT}}{V_{IN}}$$

$$C_{IN} = \frac{D \cdot I_{OUT} \cdot (1-D)}{Fs \cdot V_{RIPPLE}}$$

$$C_{IN} = \frac{\left(\frac{3.3V}{12V}\right) \cdot 2A \cdot \left(1-\frac{3.3V}{12V}\right)}{330KHz \cdot 100mV} = 12\mu F$$

For high voltage input converters the duty cycle is always less than 50% so the maximum ripple is at the minimum input voltage. The ripple will increase as the duty cycle approaches 50% where it is a maximum.

Feedback Resistor Selection

The converter uses a 1.23V reference voltage at the positive terminal of the error amplifier. To set the output voltage, a programming resistor from the feedback node to ground must be selected (R1 and R3 of figure 2). A 10KΩ resistor is a good selection for a programming resistor R3. A higher value could result in an excessively sensitive feedback node while a lower value will draw more current and degrade the light load efficiency. The equation for selecting the voltage specific resistor (R1) is:

$$R1 = \left(\frac{V_{OUT}}{V_{REF}}-1\right) \cdot R3 = \left(\frac{3.3V}{1.23V}-1\right) \cdot 10K\Omega = 16.9K\Omega$$

Table 3: Feedback Resistor Values

V_{OUT} (V)	R1 (KΩ) (R3 = 10KΩ)
1.8	4.75
2.5	10.5
3.3	16.9
5.0	30.9
12.0	88.7

Compensation

The loop gain of the converter consist of three parts, the power stage or plant (G_{PWR}), the feedback network which sets the output voltage (G_{FB}) and the error amplifier along with the compensation network (G_{COMP}).

When using low ESR ceramic output capacitors the gain of the power stage in the crossover frequency region is the peak current loop gain times the output capacitance.

$$G_{PWR} = \frac{G_{CS}}{2 \cdot \pi \cdot Fs \cdot C_{OUT}}$$

In the above equation, (Fs) is the switching frequency, G_{CS} is the COMP to current sense transconductance and C_{OUT} is the output capacitance.

The error amplifier gain in the crossover frequency range is the error amplifier transconductance multiplied by the R2 of output compensation network.

$$G_{COMP} = G_{EA} \cdot R2$$

The feedback resistor network is simply a resistive divider.

$$G_{FB} = \frac{R3}{R3 + R1} = \frac{10K}{10K + 16.9K} = 0.37$$

For unity gain crossover (0dB) gain simply set the total loop gain to unity and solve for the compensation resistor value. In this example the crossover frequency is set at one tenth of the switching frequency.

$$G_{COMP} \cdot G_{PWR} \cdot G_{FB} = \frac{G_{EA} \cdot G_{FB} \cdot R2 \cdot G_{CS}}{2 \cdot \pi \cdot 0.1 \cdot Fs \cdot C_{OUT}} = 1$$

$$R2 = \frac{2 \cdot \pi \cdot 0.1 \cdot Fs \cdot C_{OUT}}{G_{EA} \cdot G_{CS} \cdot G_{FB}} = \frac{2 \cdot \pi \cdot 0.1 \cdot 330KHz \cdot 22\mu F}{245\mu A/V \cdot 4A/V \cdot 0.37} \approx 13K\Omega$$

To provide sufficient phase margin at the crossover frequency set the compensation zero a decade below the crossover frequency.

$$C6 = \frac{4}{2 \cdot \pi \cdot R2 \cdot 0.1 \cdot Fs} = \frac{4}{2 \cdot \pi \cdot 13K\Omega \cdot 0.1 \cdot 330KHz}$$

$$C6 \approx 1.5nF$$

In cases where the additional high frequency pole is desired C7 can be added with the pole placed at approximately (10X) the compensation zero frequency.

Table 4: Typical Compensation Values

V_{IN}	V_{OUT}	L1	C2	R2	C6	C7
12V	1.8V	6.8 µH	22 µF ceramic	6.8K	3.3nF	None
12V	2.5V	8.2 µH	22 µF ceramic	10K	2.2nF	None
12V	3.3V	10 µH	22 µF ceramic	13K	1.5nF	None
12V	5V	15 µH	22 µF ceramic	18.2K	1.2nF	None
24V	12V	33 µH	22 µF ceramic	47.5K	470pF	None

Output Power and Thermal Limits

The AMS4154 junction temperature and output current capability depends on the internal dissipation and the junction to case thermal resistance of the SO8 exposed paddle package. This gives the junction temperature rise above the ambient temperature.

The temperature of the PCB will be elevated above the ambient temperature due to the total losses of the step down converter and losses of other circuits and or converters mounted to the PCB.

$$T_{Jmax}=P_d \cdot \theta_{jc}+T_{PCB}+T_{AMB}$$

The losses associated with the AMS4154 overall efficiency are:

1. Inductor DCR Losses
2. Freewheeling Diode (catch diode)
3. AMS4154 Internal losses
   a. Power Switch V_{CESAT} "on" losses
   b. Quiescent Current losses

The internal losses contribute to the junction temperature rise above the case and PCB temperature.

The junction temperature depends on many factors and should always be verified in the final application at the maximum ambient temperature. This will assure that the device does not enter over-temperature shutdown when fully loaded at the maximum ambient temperature.

PCB Layout

The following guidelines should be followed to insure proper layout.

1. V_{IN} Capacitor. A low ESR ceramic bypass capacitor must be placed as close to the IC as possible.
2. Feedback Resistors. The feedback resistors should be placed as close as possible the IC. Minimize the length of the trace from the feedback pin to the resistors. This is a high impedance node susceptible to interference from external RF noise sources.
3. Inductor. Minimize the length of the SW node trace. This minimizes the radiated EMI associated with the SW node.
4. Ground. The most quiet ground or return potential available is the output capacitor return. The inductor current flows through the output capacitor during both the on time and off time, hence it never sees a high di/dt. The only di/dt seen by the output capacitor is the inductor ripple current which is much less than the di/dt of an edge to a square wave current pulse. This is the best place to make a solid connection to the IC ground and input capacitor. This node is used as the star ground shown in Figure 2. This method of grounding helps to reduce high di/dt traces, and the detrimental effect associated with them, in a step-down converter. The inductance of these traces should always be minimized by using wide traces, ground planes, and proper component placement.

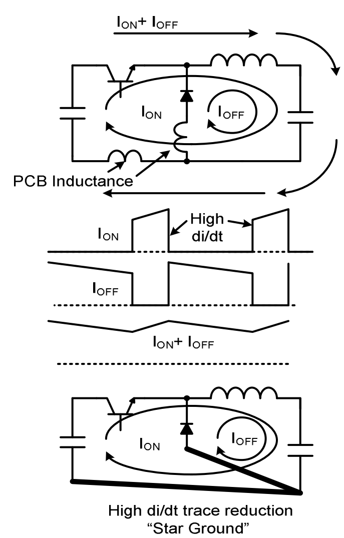


Figure 2: Step Down Converter Layout

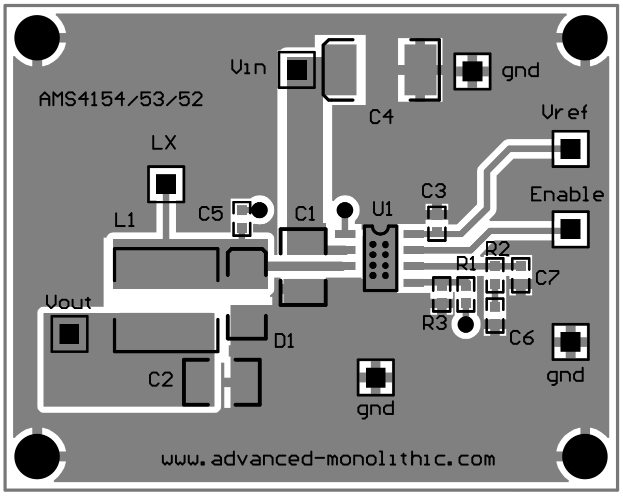


Figure 3: AMS4154 Evaluation Board Top Side

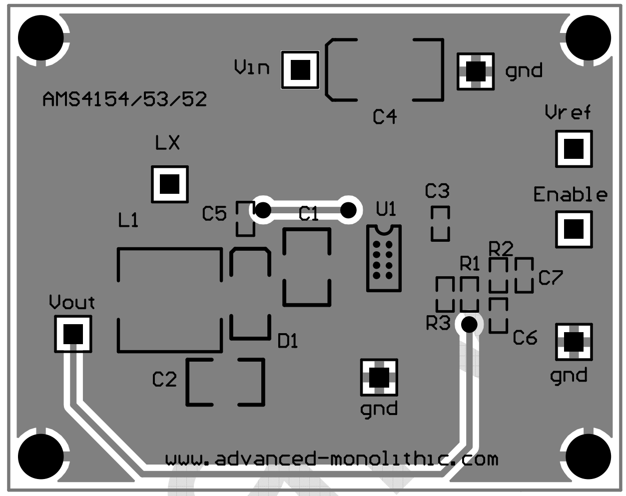


Figure 4: AMS4154 Evaluation Board Bottom Side

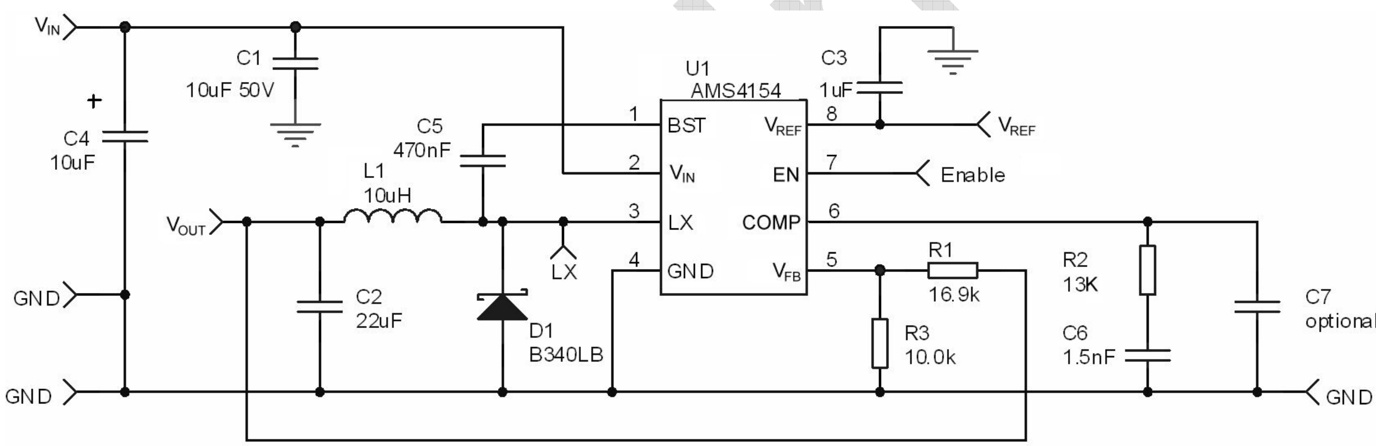


Figure 5: AMS4154 Evaluation Board Schematic

Table 5: Evaluation Board Bill of Materials

Component	Value	Manufacturer	Manufacturer Part Number
L1	10µH (8.3mm x 8.3mm x 3mm)	Sumida	CDRH8D28/HP
R1	See Table 3	Various	CRCW0603xxKxFKEA
R2	13KΩ, 0.1W, 0603, 5%	Various	CRCW060313K0FKEA
R3	10.0KΩ, 0.1W, 0603 1%	Various	CRCW060310K0FKEA
C1	10µF, 50V, X5R, 1210, Ceramic	Taiyo Yuden	UMK325BJ106MM-T
C2	22µF, 10V, X5R, 0805, Ceramic	Taiyo Yuden	LMK212BJ226MG-T
C3	1µF, 10V, X7R, 0805, Ceramic	Taiyo Yuden	LMK212B7105KG-T
C4	10uF, 50V 10% Tantalum	Vishay/Sprague	293D106X9050E2TE3
C5	470nF,50V,20%,X7R,0603	Murata	GRM188R71H104MA01
C6	1.5nF, 50V, 20%, X7R, 0603	Murata	GRM188R71H122MA01
C7	Optional See Table 4		
D1	3A, 40V Schottky (optional)	Diodes Inc.	B340LB
U1	Step-Down Converter	AMS	AMS4154

Ordering Information

Device	Package
AMS4154S[(1)(2)]	SOIC-8 EDP

Notes:

1. Available in tape and reel only. A reel contains 2,500 devices.
2. Available in lead-free package only. Device is fully WEEE and RoHS compliant

Outline Drawing and Landing Pattern

Package dimensions are inches (millimeters) unless otherwise noted.