

General Description

The AMS4155 is a 2A 420 kHz step-down converter in a thermally enhanced exposed paddle SO-8 package. External sync and compensation make the device very flexible for a wide range of applications and external components. Current mode control provides low ESR ceramic output capacitor stability with cycle by cycle current limit and fast transient response. Over-temperature shut down with hysteresis protects the device from excessive die temperatures. The converter has a 1.22V reference for low output voltage settings. Integrated fault protection protects the device in the case of an overload or over-temperature condition.

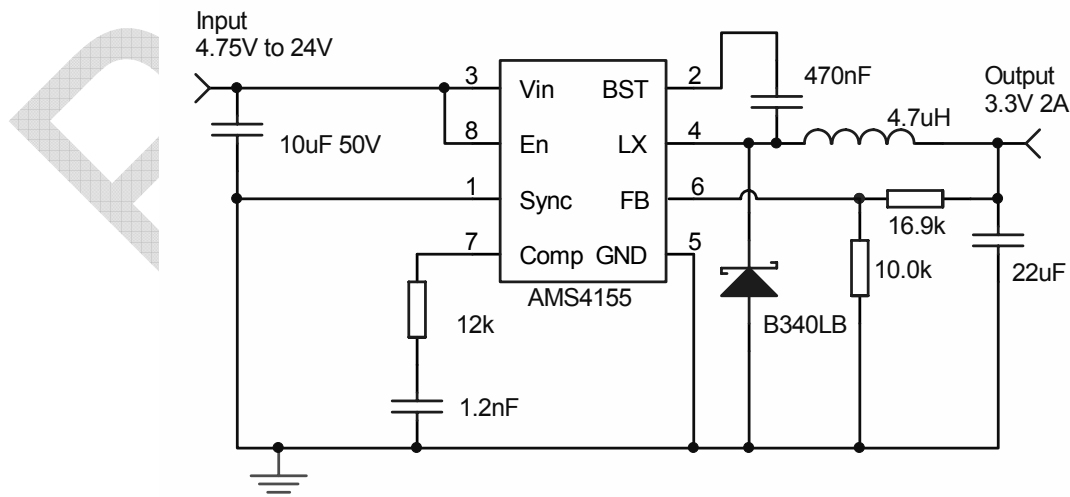
Features

- External Synchronization
- Step-Down Converter
- External Compensation
- Up to 95% Efficiency
- Low ESR Ceramic Output Capacitor Stable
- Under-Voltage Lockout
- 420 kHz Switching Frequency
- Cycle by Cycle with Hiccup Over Current Protection
- Over-Temperature Shutdown
- Up to 2A Output Current
- 4.75V to 24V operating range
- Thermal Shutdown
- Operating Temperature -40°C to 125°C

Applications

- 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

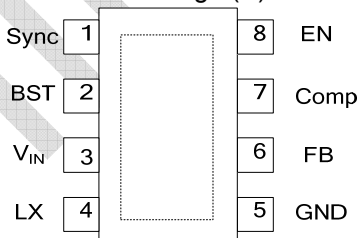


Pin Description

Pin #	Symbol	Description
1	Sync	Input synchronizes converter to an external clock ranging from 460kHz to 1.1MHz. Leave Sync unconnected or tied to GND if not used.
2	BST	The bootstrap capacitor tied to this pin is used as the bias source for the drive to the high side power transistor. Use a 10nF or greater capacitor from the BST to the LX pin.
3	V _{IN}	Input Power. Supplies bias to the IC and is also the power input to the step-down converter main power switch. Bypass Vin with low impedance ceramic with sufficient capacitance to minimize switching frequency ripple as well as high frequency noise.
4	LX	Step-Down converter switching node that connects the internal power switching transistor to the output inductor.
5	GND	Ground
6	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 1.222V reference voltage.
7	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.
8	EN	Enable. A voltage greater than 3.3V at this pin enables the regulator.

Pin Configuration

8L SOIC EDP
SO Package (S)



Top View

2A 24V Step-Down Converter

Absolute Maximum Ratings ⁽¹⁾

V _{IN} Supply Voltage.....	-0.3V to 28V
V _{LX} pin Voltage.....	-1V to 28V
BST Voltage.....	-0.3V to V _{LX} +6V
FB,COMP,Sync, EN Voltage.....	-0.3V to 6V
Storage Temperature Range.....	-65°C to 150°C
Lead Temperature.....	260°C
Junction Temperature.....	150°C

Recommended Operating Conditions ⁽²⁾

Input Voltage.....	4.5V to 24V
Ambient Operating Temperature.....	-40°C to 85°C

Thermal Information

8L SOIC EDP θ_{JA} ⁽³⁾	45°C/W
8L SOIC EDP θ_{JC}	10°C/W
Maximum Power Dissipation.....	2 W

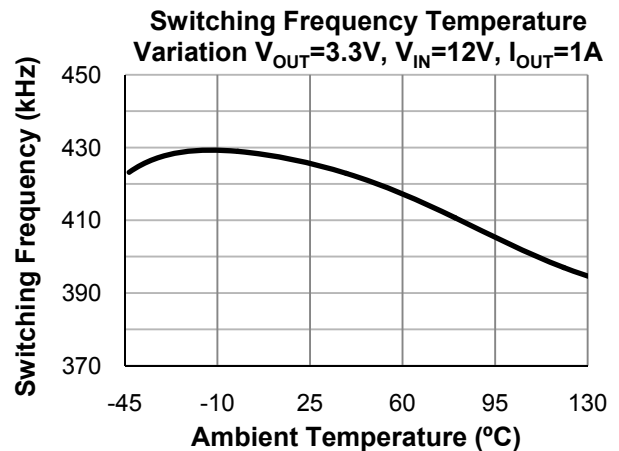
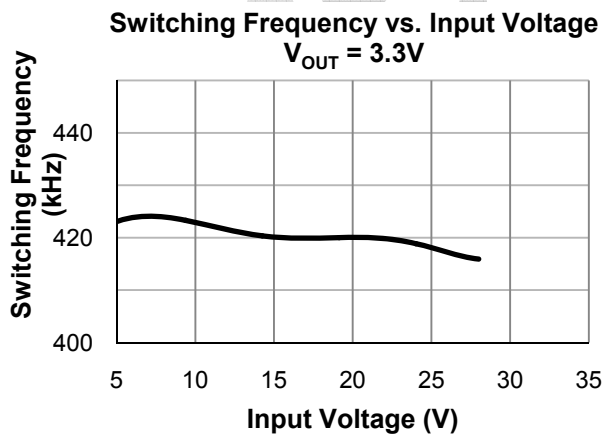
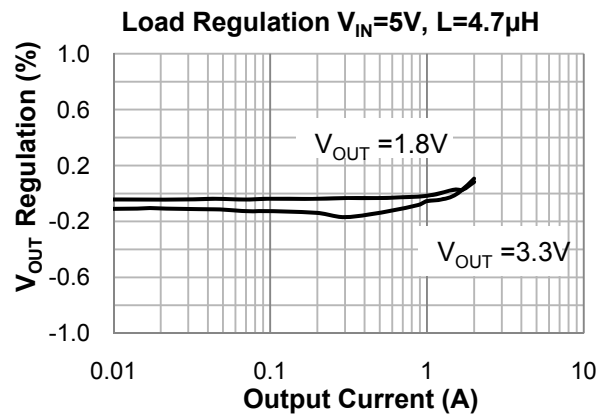
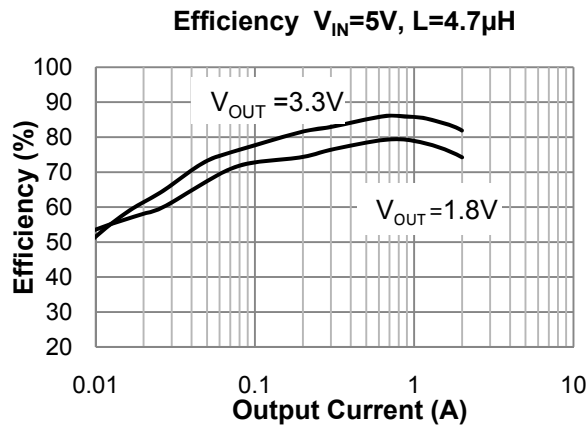
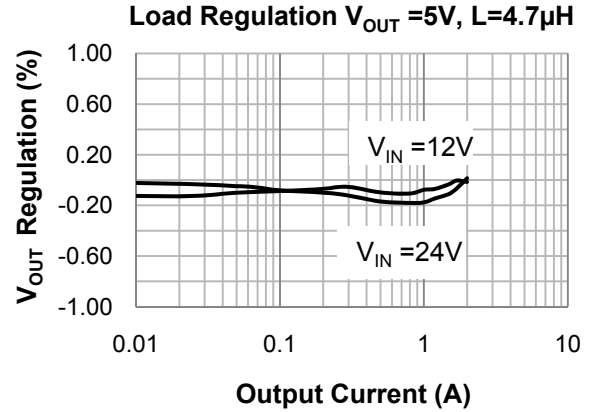
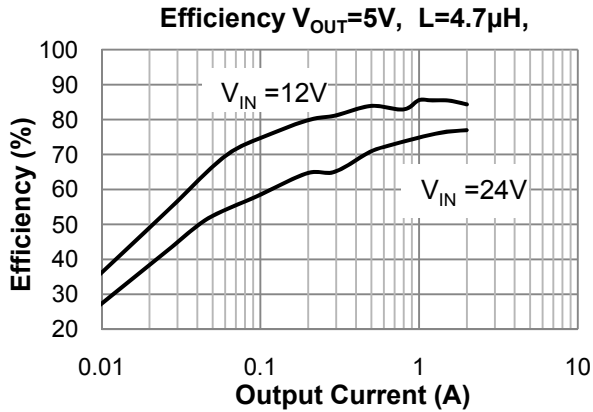
Electrical Characteristics T_A = 25 °C and V_{IN}=V_{EN}=12V, V_{OUT}=3.3V (unless otherwise noted).

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Units
Input Voltage Range	V _{IN}		4.5	12	24	V
Bias Current	I _Q	V _{EN} ≥ 3.5V, V _{FB} = 1.5V		0.411	1.1	mA
Shutdown Supply Current	I _{VINSD}	V _{EN} = 0V		120		nA
Feedback Voltage	V _{FB}	I _{OUT} = 0A	1.215	1.222	1.285	V
Feedback Bias Current	I _{FB}		-0.1		0.1	μA
Switch Forward Voltage	V _{FWD}	I _{OUT} = 1A		0.5		V
Switch Leakage Current	I _{LEAK}	V _{EN} = 0V, V _{LX} = 0V		0.1	10	μA
Current Limit	I _{LIM}	V _{OUT} = 3.3V	3.4	4	6	A
Enable Pull up Current	I _{ENPU}			tbd		μA
Enable Threshold	V _{EN}		tbd	3.3	tbd	V
Enable Threshold Hysteresis	V _{EN HYS}			100		mV
Under Voltage Lockout	V _{UVLO}	V _{IN} rising	tbd	1.8	tbd	V
Under Voltage Lockout Hysteresis	V _{UVLO HYS}			200		mV
Oscillator Frequency	F _{OSC}		420	425	500	kHz
Sync Frequency	F _{SYNC}	Sync Drive 0.5V to 2.7V	460		1100	kHz
Maximum Duty Cycle	D _{MAX}	V _{FB} = 0.8 V		85		%
Minimum Duty Cycle	D _{MIN}	V _{FB} = 1.5V			3	%
Error Amplifier Voltage Gain	A _{EA}			400		V/V
Error Amplifier Transconductance	G _{EA}	ΔI _{COMP} = ±10μA		730		μA/V
Current Sense Transconductance Output current to COMP Pin Voltage	G _{CS}			1.95		A/V
Thermal Shutdown	T _{SD}			150		°C
Thermal Shutdown Hysteresis	T _{SDHYS}			20		°C

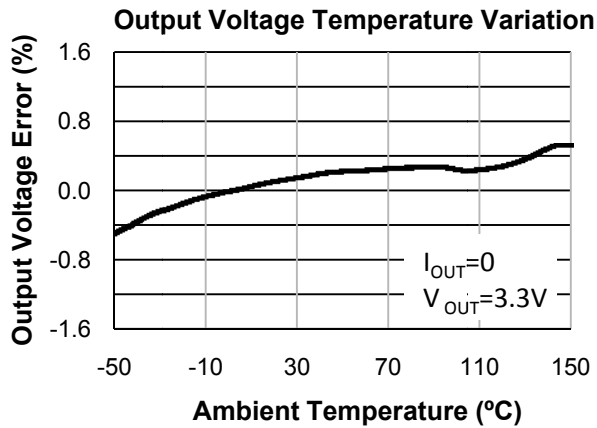
Notes:

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.
3. The total power dissipation for SO-8 EDP package is recommended to 2.5W rated at 25°C ambient temperature. The thermal resistance Junction to Case is 45°C/W. Total power dissipation for the switching regulator and the LDO should be taken in consideration when calculating the output current capability of each regulator

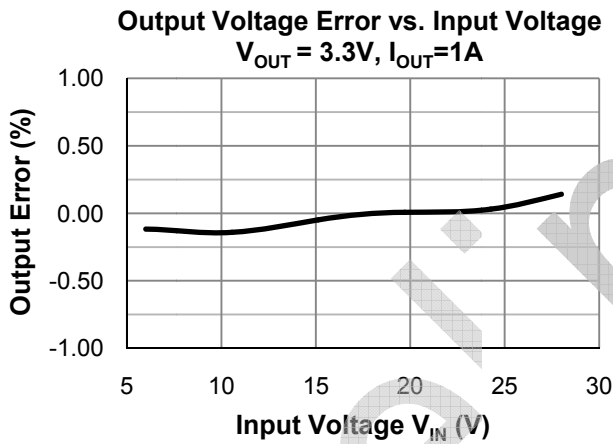
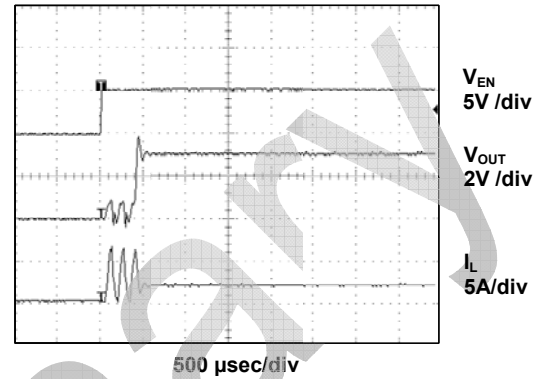
Typical Characteristics



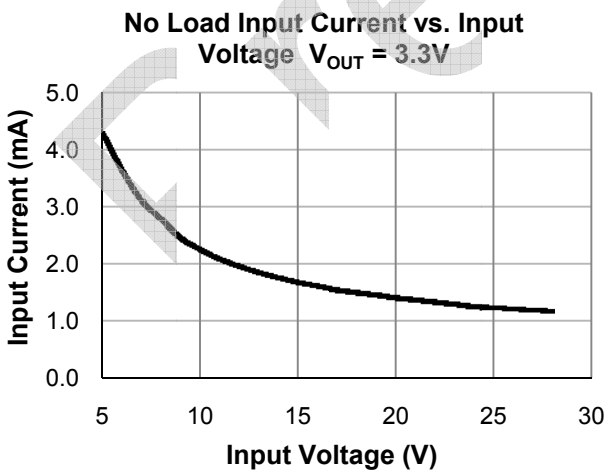
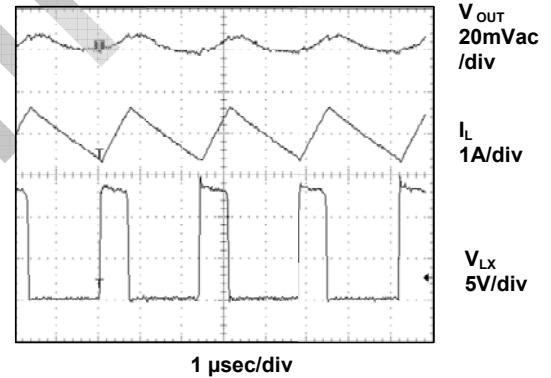
Typical Characteristics



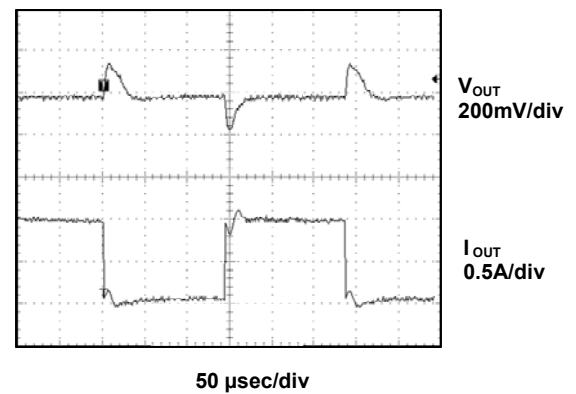
Start-Up Response $V_{IN}=12V, V_{OUT}=3.3V I_{OUT}=2A$



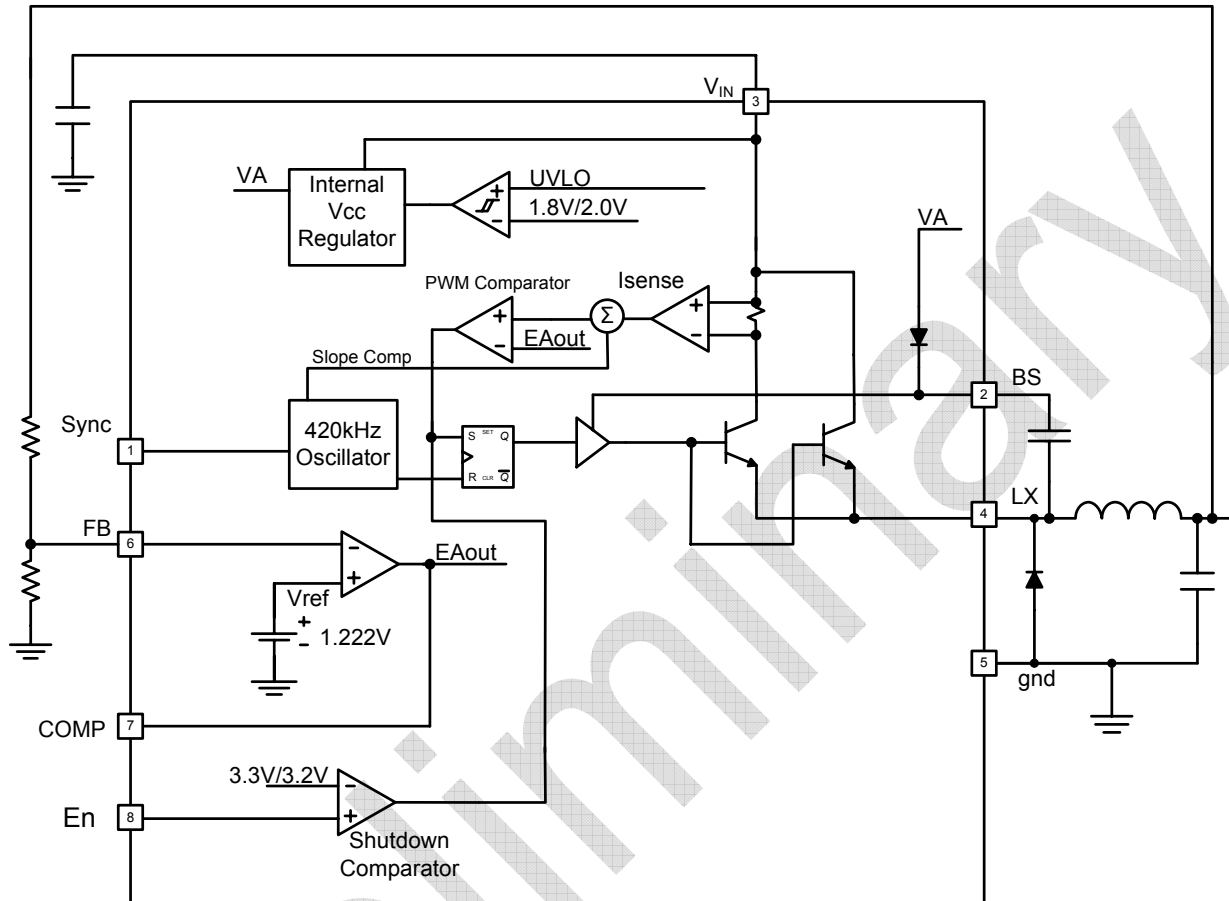
Output Ripple
 $V_{OUT} = 3.3V I_{OUT}=2A, V_{IN}=12V$



Load Transient $C_{OUT}=22\mu F, L=4.7\mu H$
 $I_{OUT} = 600mA$ to $1.5A, V_{OUT} = 3.3V, V_{IN}=12V$



Functional Block Diagram



2A 24V Step-Down Converter

Device Summary

The AMS4155 is a high frequency 2 Amp 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 4.5V to 24V with an output voltage as low as 1.222V.

Enable

The enable threshold for the step-down converter is 3.3V with 100mV of hysteresis.

Fault Protection

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

External Sync

The external sync input allows the converter switching frequency to be synchronized to an external clock. The clock frequency can range from 460kHz to 1.1MHz with typical TTL logic low and high levels of 0.5V and 2.7V. Using the sync input to synchronize multiple converters eliminates beat frequencies in the input ripple and simplifies noise filtering.

Application

Inductor

The step-down converter inductor is typically selected to limit the ripple current to 30 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 downslope thus avoiding any peak current mode related instability when the duty cycle is greater than 50%.

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

$$L = (12V - 2.5V) \cdot \frac{2.5V}{12V \cdot 2A \cdot 0.4 \cdot 425kHz} = 5.8\mu H$$

For most applications the duty cycle of the AMS4155 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 an inductor value selected, the ripple current can be calculated:

$$I_{PP} = \frac{V_{OUT} \cdot (1-D)}{L \cdot f_s}$$

$$I_{PP} = \frac{2.5V \cdot (1-0.21)}{4.7\mu H \cdot 425kHz} = 0.99A$$

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.

$$I_{PK} = I_{OUT} + \frac{V_{OUT} \cdot (1-D)}{2 \cdot L \cdot F_s}$$

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

$$D = \frac{2.5V}{12V} = 0.21$$

$$I_{PKmax} = 2A + \frac{(2.5V) \cdot (1-0.21)}{2 \cdot 4.7\mu H \cdot 425kHz} = 2.5A$$

$$I_{PP} = \frac{(2.5V) \cdot (1-0.21)}{4.7\mu H \cdot 425kHz} = 0.99A$$

2A 24V Step-Down Converter

There are a wide range of 3 Amp and above, shielded and non-shielded inductors available. Table 1 lists a few.

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 output 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}).

$$C_{OUT} = \frac{I_{PP}}{F_s \cdot 8 \cdot dV} = \frac{0.99A}{425kHz \cdot 8 \cdot 20mV} = 14.6\mu F$$

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.

For 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:

$$C_{OUT} = \frac{L \cdot I_{OUT}^2}{V_{OS}^2 - V_{OUT}^2} = \frac{4.7\mu H \cdot (2A)^2}{(3.5V)^2 - (3.3V)^2} = 13.8\mu F$$

For the application of a load pulse the capacitance required for 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 AMS4155 this can be estimated to be less than 10 μ sec or about four 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:

$$C_{OUT} = \frac{I_{OUT} \cdot t}{dV} = \frac{1A \cdot 10\mu sec}{0.2V} = 47\mu F$$

Boot Strap Capacitor

An external boot strap capacitor (C_5) 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 1 μ F 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

2A 24V Step-Down Converter

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, the required input capacitor can be estimated with:

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

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

$$= \frac{\left(\frac{3.3V}{12V}\right) \cdot 2A \cdot \left(1 - \frac{3.3V}{12V}\right)}{425kHz \cdot 0.1V} = 9.7\mu F$$

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 1.222V 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 (R_1 and R_3 of figure 4). A 10k Ω resistor is a good selection for a programming resistor R_3 . 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 (R_1) is:

$$R_1 = \left(\frac{V_{OUT}}{V_{REF}} - 1\right) \cdot R_3 = \left(\frac{2.5V}{1.222V} - 1\right) \cdot 10k\Omega = 10.5k\Omega$$

Table 3. Feedback Resistor values

V_{OUT} (V)	R_1 (k Ω) ($R_3=10k\Omega$)
1.8	4.75
2.5	10.5
3.3	16.9
5.0	30.9
12.0	88.7k

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.

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

In the above equation, f_s 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 times the R_2 of output compensation network.

$$G_{COMP} = G_{EA} \cdot R_2$$

The feedback resistor network is simply a resistive divider.

$$G_{FB} = \frac{R_3}{R_3 + R_1} = \frac{10k}{10k + 16.9k} = 0.37$$

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.

$$G_{COMP} \cdot G_{PWR} \cdot G_{FB} = \frac{G_{EA} \cdot G_{FB} \cdot R_2 \cdot G_{CS}}{2 \cdot \pi \cdot 0.1 \cdot f_s \cdot C_{OUT}} = 1$$

$$R_2 = \frac{2 \cdot \pi \cdot 0.1 \cdot f_s \cdot C_{OUT}}{G_{EA} \cdot G_{CS} \cdot G_{FB}} = \frac{2 \cdot \pi \cdot 0.1 \cdot 425kHz \cdot 22\mu F}{700\mu A/V \cdot 1.9A/V \cdot 0.37} \approx 12k\Omega$$

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

$$C_6 = \frac{4}{2 \cdot \pi \cdot R_2 \cdot 0.1 \cdot f_s} = \frac{4}{2 \cdot \pi \cdot 12k\Omega \cdot 0.1 \cdot 425kHz}$$

$$C_6 \approx 1.2nF$$

2A 24V Step-Down Converter

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 _{OUT}	L1	C2	R2	C6	C7
1.8V	4.7 μH	22 μF ceramic	6.49k	2.2nF	None
2.5V	4.7 μH	22 μF ceramic	9.1k	2.2nF	None
3.3V	6.8 μH	22 μF ceramic	12k	1.2nF	None
5V	10 μH	22 μF ceramic	18k	820pF	None
12V	22 μH	22 μF ceramic	43k	330pF	None

Output Power and Thermal Limits

The AMS4155 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 AMS4155 overall efficiency are;

1. Inductor DCR Losses
2. Freewheeling Diode
3. AMS4155 Internal losses
 - a. Power Switch V_{fwd} “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 LX node trace. This minimizes the radiated EMI associated with the LX 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 1. 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.

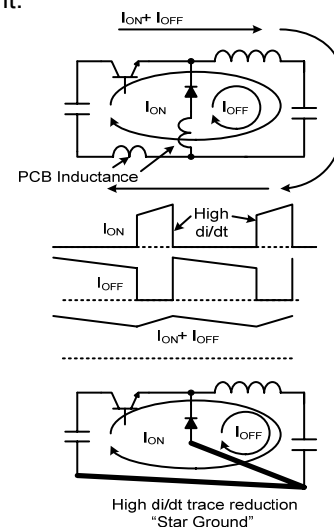


Figure 1. Step Down Converter Layout

2A 24V Step-Down Converter

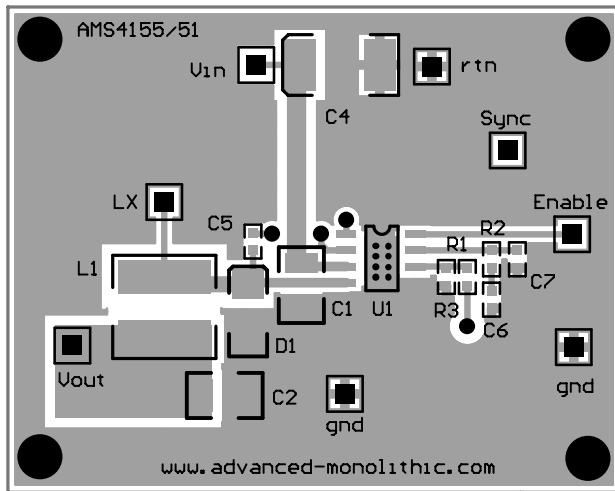


Figure 2. AMS4155 Evaluation Board Top Side

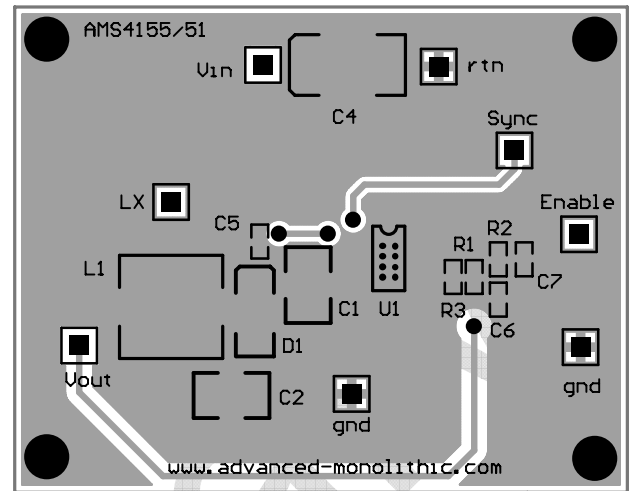


Figure 3. AMS4155 Evaluation Board Bottom Side

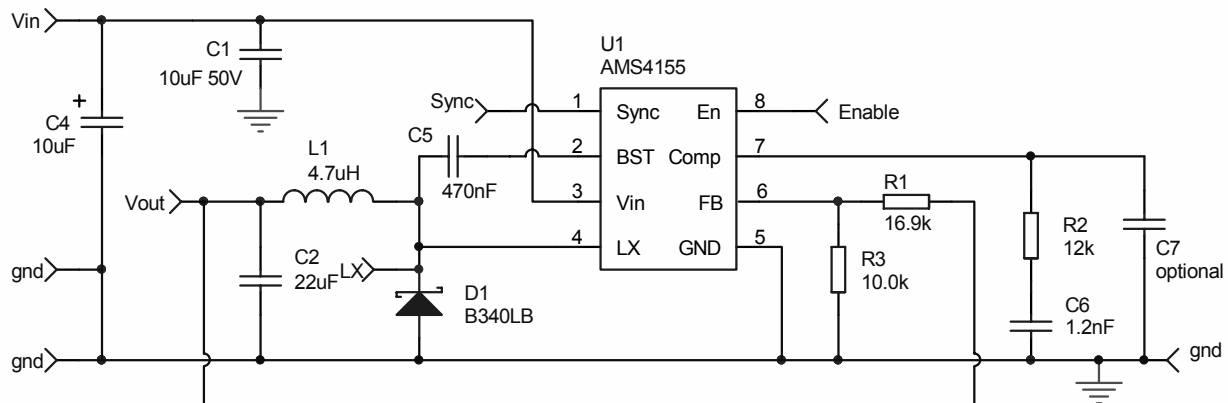


Figure 4. AMS4155 Evaluation Board Schematic

Table 5. Evaluation Board Bill of Materials

Component	Value	Manufacturer	Manufacturer Part Number
L1	4.7 μ H 12.5mm x 12.5mm x 6.5mm	Sumida	CDRH6D26/HP
R1	See table 3	Various	CRCW0603xxKxFKEA
R2	12k, 0.1W, 0603, 5%	Various	CRCW060312K0FKEA
R3	10.0k Ω , 0.1W, 0603 1%	Various	CRCW060310K0FKEA
C1	10 μ F, 50V, X5R, 1210, Ceramic	Taiyo Yuden	UMK325BJ106KM-T
C2	22 μ F, 10V, X5R, 0805, Ceramic	Taiyo Yuden	LMK212BJ226MG-T
C4	10 μ F, 50V 10% Tantalum	Vishay/Sprague	293D106X9050E2TE3
C5	470nF, 50V, 20%, X7R, 0603		GRM188R71H104MA01
C6	1.2n, 50V, 20%, X7R, 0603	Murata	GRM188R71H122MA01
C7	Optional, See Table 4		
D1	3A, 40V Schottky (optional)	Diodes Inc.	B340LB
U1	Step-Down Converter	AMS	AMS4155S

ORDERING INFORMATION

Package Type SOIC	TEMP. RANGE
AMS4155S	-25°C to 125°C

PACKAGE DIMENSIONS inches (millimeters) unless otherwise noted.

8 LEAD SOIC Exposed Paddle PLASTIC PACKAGE (S)

