# AMS2596

**3A 30V Step-Down Converter**

## General Description

The AMS2596 is a high efficiency, non-synchronous step down regulator delivering up to 3A of output current making it ideal for medium to heavy load applications. It is designed to operate with wide input voltage range of 4.5 to 30V while maintaining 1mA of supply current at no load. The output voltage is either factor programmed or set via two external resistors to as low as 1.23V.

The regulator operates at fixed 150kHz switching frequency ensuring low output ripple across the entire load. It requires only four external components for minimum PCB footprint and lowest overall system cost. An independent Enable pin provides electrical On/Off of the regulator. When connected to logic high, the regulator shuts down and consumes less than 100µA of current. Excellent transient response is achieved with no external compensation components.

The device provides under-voltage lockout, output short circuit and over-temperature protection to safeguard the device and under fault conditions. An integrated soft-start controls the ramp of the output voltage and minimizes the inrush current.

The AMS2596 is available in SOIC, TO220, TO252 and TO263 packages, and it is rated for -25 to +125°C temperature range.

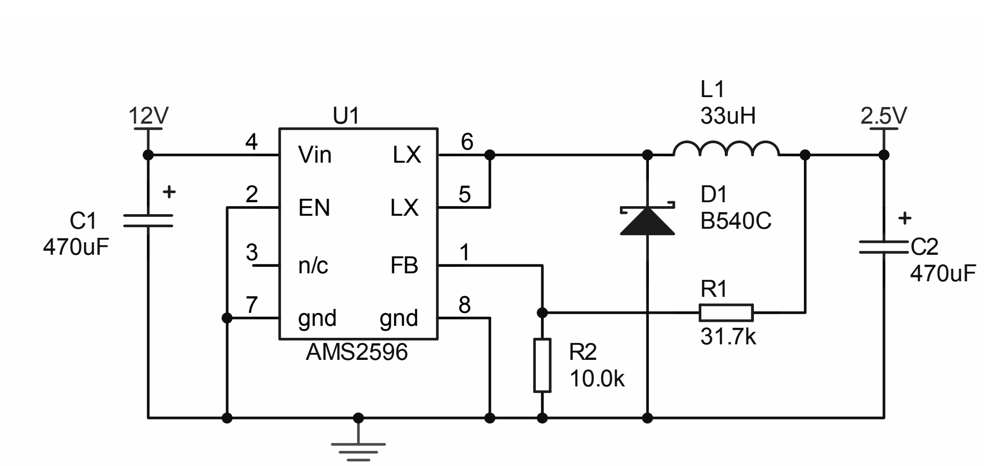
## Features

- $V_{IN}$ range: 4.5 - 30V
- $V_{OUT}$ range: 1.25V to 7V fixed output Voltage in 100mV steps
- Adjustable version output voltage range from 1.2V to 25V
- Up to 5A output current
- 150kHz switching frequency
- 900µA supply current
- 80uA standby quiescent current
- 100% Duty Cycle
- Excellent line and load regulation
- Internal Soft Start
- Internal compensation
- Under voltage lockout
- Current Limit Protection
- Over temperature protection
- -25°C to +125°C Temperature Range
- Available in SOIC-8, TO220-5, TO252-5 and TO263-5 packages

## Applications

- LCD Monitor and TV
- High Current Point of Load Regulator
- System Power
- Set Top Box

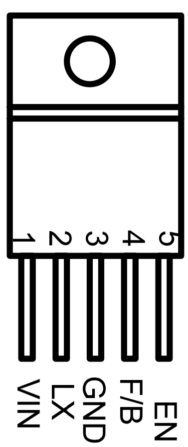
## Typical Application



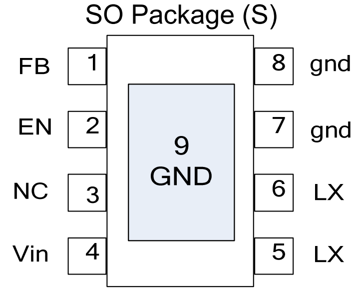
## Pin Description

| TO-263<br>TO-220<br>TO-252<br>Pin# | SOIC-8<br>Pin# | Symbol | Description |
|---|---|---|---|
| 1 | 4 | $V_{IN}$ | Input supply pin. Connect a capacitor between this pin and ground. |
| 2 | 5, 6 | LX | Switching node - connect an inductor between this pin and the output capacitor. |
| 3, tab | 7, 8 | GND | Ground connection. |
| 4 | 1 | FB | Feedback pin. Connect this pin to the center tab of the resistor divider. |
| 5 | 2 | EN | Enable pin. Logic high shuts the device down and consumes 50µA of current. When connected to logic low, the device will resume normal operation. This pin should not be floating. |
| N/A | 3 | NC | No connect. |
|  | 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 30V
FB feedback pin……………………...........……-0.3V to +30V
EN Enable Voltage………………………...…-0.3V to +20V
Storage Temperature Range……….....…..-65ºC to 150ºC
Lead Temperature (Soldering 60se…………….…… 215ºC
Junction Temperature………..………………..…… 150ºC
ESD Suceptability…………………………………….....2kV

### Recommended Operating Conditions [2]

Input Voltage………………………………………..……….4.5V to 28 V
Tj Operating Temperature…… …………………..…….-25ºC to 125ºC

### Thermal Information

8L SOIC EP $\theta_{JA}$ [11] ………………………………………….….60ºC/W
TO263-5 $\theta_{JA}$ [9] ……………………………………………....30ºC/W
TO-252 $\theta_{JA}$ [10] ………………………………………….....57ºC/W
TO-220 $\theta_{JA}$ [8] ……………………………………………50ºC/W

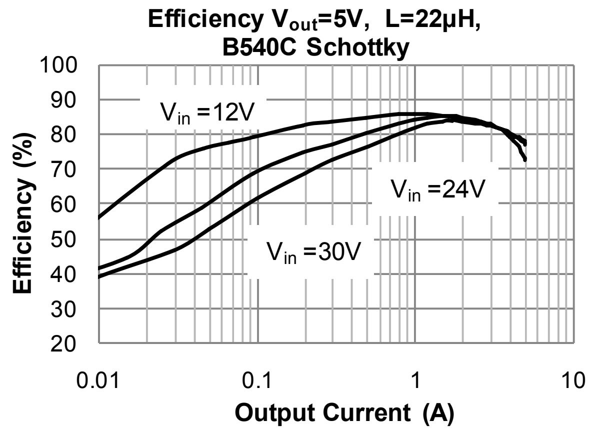
### Electrical Characteristics  $T_A$= 25 °C and $V_{IN}$=12V (unless otherwise noted).

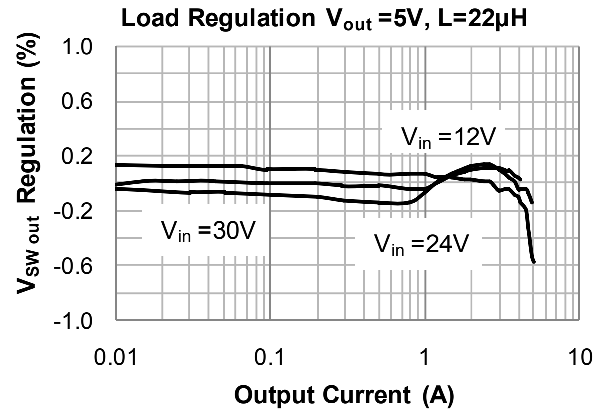
| Parameter | Symbol | Conditions | Min. | Typ. | Max. | Units |
|---|---|---|---|---|---|---|
| $V_{in}$ | $V_{in}$ | | 4.5 | 12 | 20 | V |
| Feedback Voltage | $V_{FBSW}$ | 4.5V ≤ VIN ≤ 30V,<br>0.2A ≤ ILoad ≤ 3A | 1.193<br>1.180 | 1.230 | 1.267<br>1.280 | V |
| Efficiency | η | VIN = 12V, $V_{OUT}$ = 3V, ILoad = 3A | 85 | | % | |
| Oscillator Frequency | $F_{OSC}$ | | 127 | 150 | 173 | kHz |
| Saturation Voltage | $V_{SAT}$ | $I_{SW\ out}$=3A | | 1.16 | 1.4/1.5 | V |
| Maximum Duty Cycle | $D_{MAX}$ | Note 6 | | 95 | 99 | % |
| Minimum Duty Cycle | $D_{MIN}$ | Note 7 | | 0 | | % |
| Current Limit | $I_{LIMSW}$ | $V_{SW\ out}$=5V | 3.6 / 3.4 | 4.5 | 6.9 / 7.5 | A |
| Shutdown Supply Current | $I_{Vinsd}$ | $V_{EN}$ =0V | | 90 | | nA |
| Output Leakage Current | $I_{LK}$ | Output = 0V (Note 8)<br>Output = -1V | | 2 | 50<br>30 | µA |
| Quiescent Current | $I_Q$ | (Note 6) | | 5 | 10 | mA |
| Standby Quiescent Current | $I_{SD}$ | ON/OFF pin = 5V (OFF) | | 80 | 200<br>250 | µA |
| Enable Logic Input<br>Threshold Voltage | | | | 1.3 | | V |
| | $V_{EN(L)}$ | Low (Regulator ON) | | | 0.6 | V |
| | $V_{EN(H)}$ | High (Regulator OFF) | | | 2.0 | V |
| Enable Input Current | $I_{ENH}$ | $V_{LOGIC}$ = 2.5V (Regular OFF) | 5 | 5 | 15 | µA |
| | $I_{ENL}$ | $V_{LOGIC}$ = 0.5V (Regular ON) | 0.02 | 0.02 | 5 | µA |
| Over-temperature | | | | 125 | | °C |

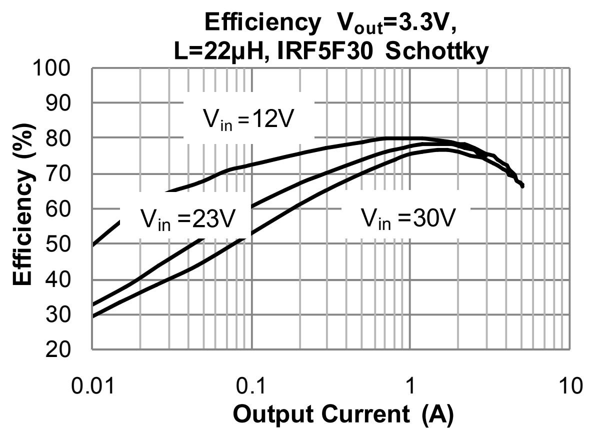
Notes:

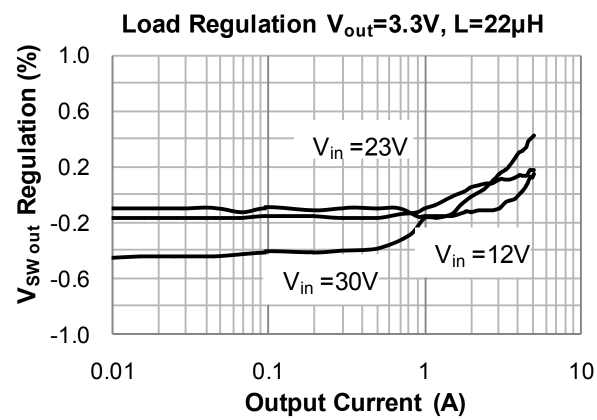
1. Absolute Maximum Ratings indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is intended to be functional, but do not guarantee specific performance limits. For guaranteed specifications and test conditions, see the Electrical Characteristics.
2. $V_O$ = Output Voltage specified from 1.25V to 7V in 100mV increments.
3. Typical numbers are at 25ºC and represent the most likely norm.
4. All limits guaranteed at room temperature (standard type face) and at temperature extremes (bold type face). All room temperature limits are 100% production tested. All limits at temperature extremes are guaranteed via correlation using standard Statistical Quality Control (SQC) methods. All limits are used to calculate Average Outgoing Quality Level (AOQL).
5. Feedback pin removed from output and connected to 0V to force the output transistor switch ON.
6. Feedback pin removed from output and connected to 12V for Fixed and Adjustable version, to force the output transistor switch OFF.
7. With output transistor switch turned off.
8. Junction to ambient thermal resistance (no external heat sink) for the TO-220 package mounted vertically, with the leads soldered to a printed circuit board with (1 oz.) and a heat sink approximately 1 $in^2$.
9. Junction to ambient thermal resistance with the TO-263 package tab soldered to a double side printed circuit board with 2.5 $in^2$ of (1 oz.) copper area.
10. Junction to ambient thermal resistance with the TO-252 package tab soldered to a single sided printed circuit board with 2.5 $in^2$ of (1 oz.) copper area.
11. Junction to ambient thermal resistance with the SO-8 EDP package soldered to a double sided printed circuit board 5 via under the package paddle crossing to the other side of PCB on 2.5 $in^2$ 1oz Cu.

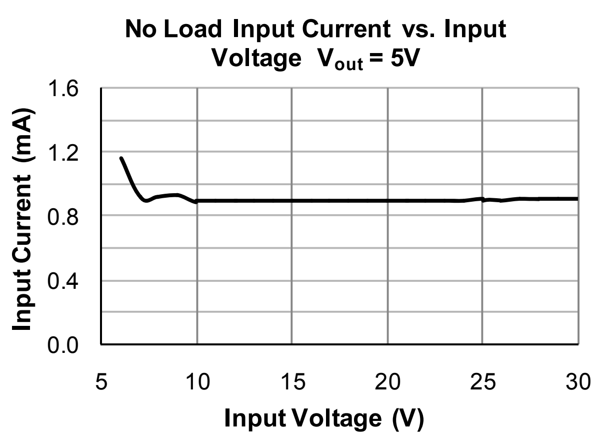
## Typical Characteristics

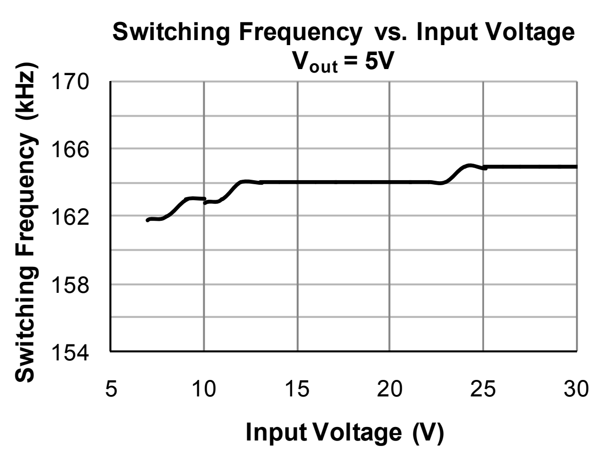


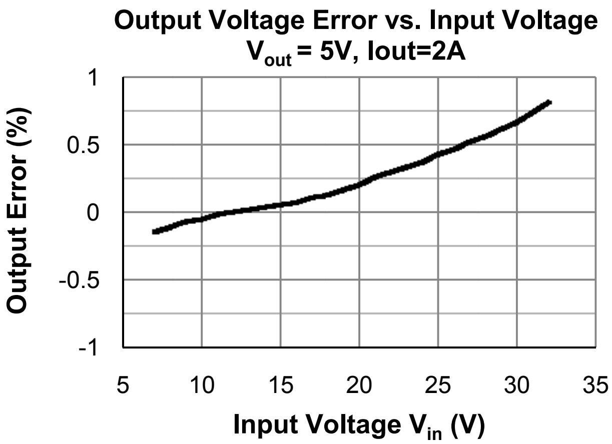



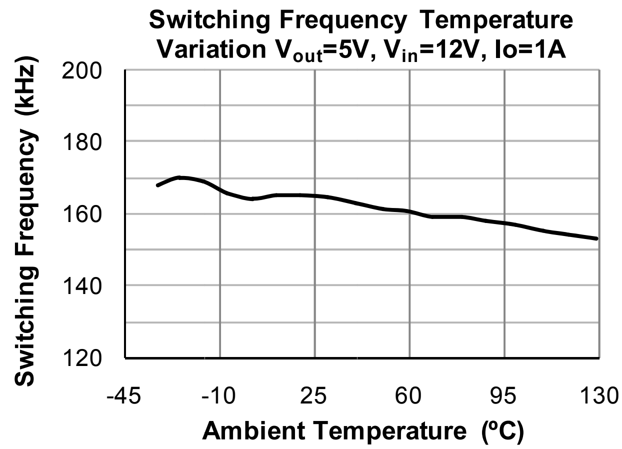



## Typical Characteristics

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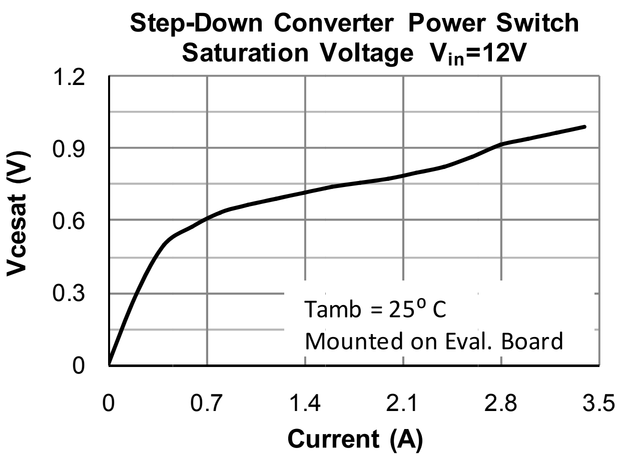
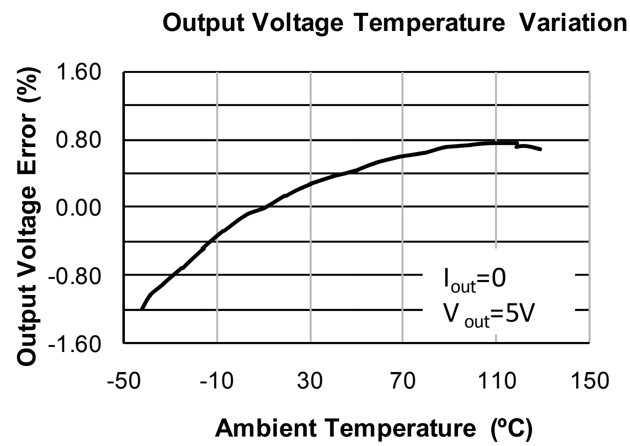
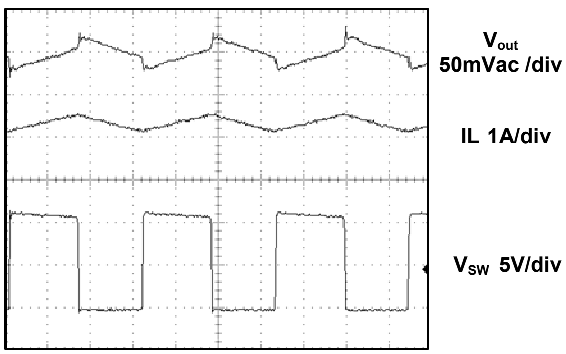


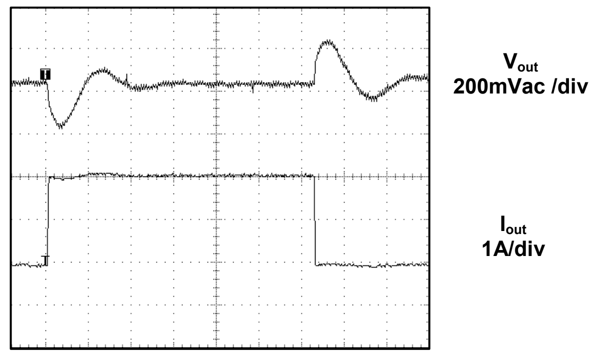
## Typical Characteristics

**Output Ripple**
**$V_{out}$ =2.5V, $I_{out}$=1.8A, $V_{in}$=12V**



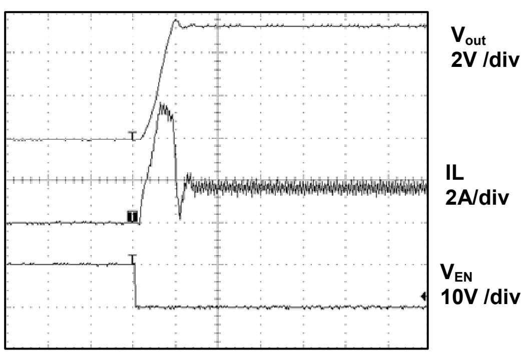

**1 µsec/div**

**Load Transient**
**1A to 3A, $V_{out}$ = 5V, $V_{in}$=12V**



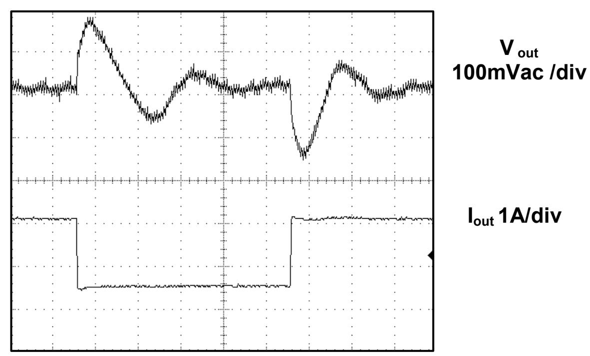

**40 µsec/div**

**Start-Up Response**



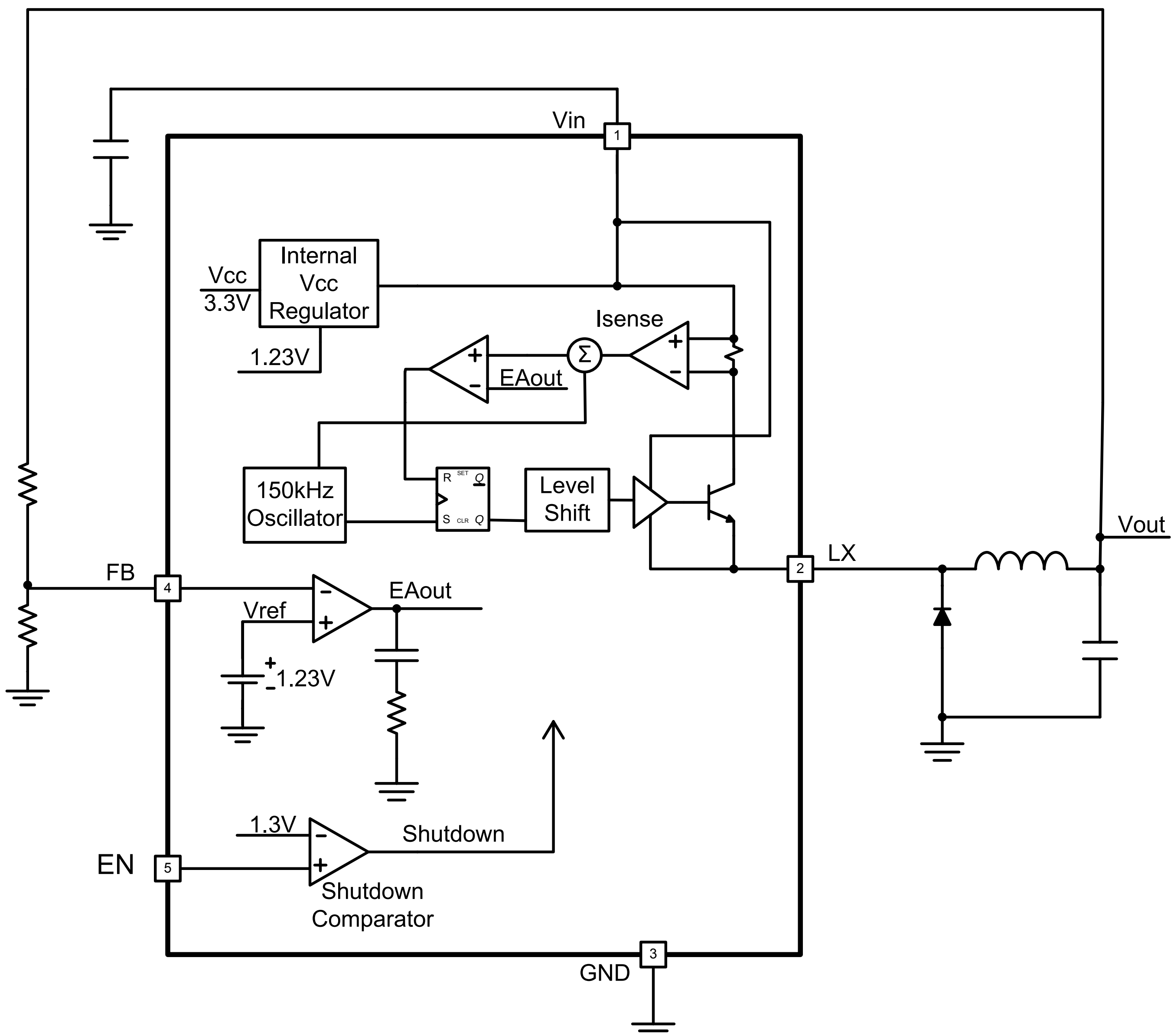

**400 µsec/div**

**Load Transient**
**500mA to 2A, $V_{out}$ = 5V, $V_{in}$=12V**




**20 µsec/div**

## Functional Block Diagram



**Device Summary**

The AMS2596 is a high voltage fixed frequency step-down converter with a current capability of up to 5A.

The peak current mode step-down converter has internal compensation and is stable with a wide range of ceramic, tantalum, and electrolytic output capacitors. The step-down converter 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 power switch, amplified and is also 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 20V with an output voltage as low as 0.6V.

**Shutdown**

The enable input has two levels so that the step-down converter can be enabled independently of the LDO. The enable threshold for the step-down converter is 2.0V while the enable threshold for the linear regulator output is 2.5V typical.

**Fault Protection**

Short circuit and over-temperature shutdown disable the converter and LDO in the event of an overload condition.

## Application

**Inductor**

The step-down converter inductor is typically selected to limit the ripple current to 40% of the full load output current. Solve for this value at the maximum input voltage where the inductor ripple current is greatest.

$$L=(Vin-Vo)\cdot\frac{Vo}{Vin\cdot Io\cdot 0.4\cdot Fs}$$

$$L=(12V-5V)\cdot\frac{5V}{12V\cdot 3A\cdot 0.4\cdot 150kHz}=16\mu H$$

For most applications the duty cycle of the AMS2596 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 and inductor value selected, the ripple current can be calculated:

$$Ipp=\frac{(Vo+Vfwd)\cdot(1-D)}{\cdot L\cdot Fs}$$

Using the maximum input voltage values the ripple is:

$$Ipp=\frac{(5V+0.2V)\cdot(1-0.44)}{22\mu H\cdot 150kHz}=0.88A$$

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. As mentioned before, the ripple current varies with input voltage and is a maximum at the maximum input voltage.

$$Ipkmax=Io+\frac{(Vo+Vfwd)\cdot(1-Dmin)}{2\cdot L\cdot Fs}$$

$$Dmin=\frac{Vo}{Vinmax}$$

The duty cycle can be more accurately estimated by including the drops of the external Schottky diode and the internal power switch:

$$Dmin=\frac{Vo+Vfwd}{Vinmax-Vo+Vfwd}$$

$$Dmin=\frac{5V+0.2V}{12V-0.3V+0.2V}=0.44$$

Vfwd is the diode freewheeling diode drop and Vsw is the collector to emitter drop of the internal power switch.

With a good estimate of the duty cycle (D) the inductor peak current can be determined:

$$Ipkmax=3A+\frac{(5V+0.2V)\cdot(1-0.44)}{2\cdot 22\mu H\cdot 150kHz}=3.44A$$

There are a wide range 2 and 3 Amp, shielded and non-shielded inductors available. Table 1 lists a few.

**Table 1. Inductor Selection Guide**

| Series | Type | Dimensions (mm) | | |
|---|---|---|---|---|
| | | W | L | H |
| Sumida | | | | |
| CDRH127 | Shielded | 12.3 | 12.3 | 8 |
| CDRH127/LD | Shielded | 12.3 | 12.3 | 8 |
| CDRH105R | Shielded | 10.3 | 10.5 | 5.1 |
| Coilcraft | | | | |
| MSS1246 | Shielded | 12 | 12 | 4.6 |
| MSS1246T | Shielded | 12 | 12 | 4.6 |
| DO5022P | Non-Shielded | 18 | 15 | 7.1 |
| DO5010H | Non-Shielded | 18 | 15.3 | 7.6 |

## Output Capacitor

The optimum solution for the switching regulator is to use a large bulk capacitor for large load transients in parallel with a smaller, low ESR, X5R or X7R ceramic capacitor to minimize the switching frequency ripple.

## High Frequency Ripple

The following equation determines the required low ESR ceramic output capacitance for a given inductor current ripple (Ipp).

$$C=\frac{Ipp}{Fs\cdot 8\cdot dV}=\frac{0.88A}{150kHz\cdot 8\cdot 20mV}=36\mu F$$

## Large Signal Transient

For applications with large load transients an additional capacitor may be required to keep the output voltage within the limits required during large load transients.

In this case the required capacitance can be examined for the load application and load removal.

For full load to no load transient the required capacitance is

$$Cbulk=\frac{L\cdot Io^2}{Vos^2-Vo^2}=\frac{22\mu H\cdot (3A)^2}{(5.2V)^2-(5V)^2}=97\mu F$$

For the application of a load pulse the capacitance required form 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 AMS2596 this can be estimated to be less than 20 µsec or about three clock cycles.

$$Cbulk=\frac{Io\cdot t}{dV}=\frac{3A\cdot 20\mu sec}{0.2V}=300\mu F$$

For applications that do not have any significant load transient requirements a ceramic capacitor alone is typically sufficient.

## Input Capacitor

The low esr ceramic capacitor 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 (Vripple) limit, the required input capacitor can be estimated with:

$$Dmax=\frac{Vo+Vfwd}{Vinmin-Vce+Vfwd}$$

Vce is the forward voltage drop of the switching transistor and Vfwd is the external Schottky forward voltage.

$$C=\frac{Dmax\cdot Io\cdot (1-Dmax)}{Fs\cdot Vripple}$$

$$=\frac{\left(\frac{5V+0.2V}{10V-0.3V+0.2V}\right)\cdot 3A\cdot \left(1-\frac{5V+0.2V}{10V-0.3V+0.2V}\right)}{150kHz\cdot 0.2V}=25\mu F$$

.

Vce is the forward voltage drop of the switching transistor and Vfwd is the external Schottky forward voltage. 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 step down converter and LDO both use a 0.6V reference voltage at the positive terminal of the error amplifier. To set the output voltage a programming resistor form the feedback node to ground must first be selected (R2,R3 of figure 4). A 10kΩ resistor is a good selection for a programming resistor. 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 is:

$$R4=\left(\frac{Vout}{Vref}-1\right)\cdot R3=\left(\frac{5V}{1.2V}-1\right)\cdot 10k\Omega=31.67k\Omega$$

**Table 2. Feedback Resistor values**

| Vout (V) | R1,R4 (kΩ) (R2,R3=10kΩ) |
|---|---|
| 1.8 | 4.99 |
| 2.5 | 10.7 |
| 3.3 | 17.4 |
| 5.0 | 31.6 |

**PCB Layout**

The following guidelines should be followed to insure proper layout.

1. Vin Capacitor. A low ESR ceramic bypass capacitor must be placed as close to the IC as possible.
2. Schottky Diode. During the off portion of the switching cycle the inductor current flows through the Schottky diode to the output cap and returns to the inductor through the output capacitor. The trace that connects the output diode to the output capacitor sees a current signal with a very high di/dt. To minimize the associated spiking and ringing, the inductance and resistance of this trace should be minimized by connecting the diode anode to the output capacitor return with a short wide trace.
3. 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.
4. Inductor. Minimize the length of the SW node trace. This minimizes the radiated EMI associated with the SW node.
5. 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.
6. For good thermal performance vias are required to couple the exposed tab of the SO-8 package to the PCB ground plane. The via diameter should be 0.3mm to 0.33mm positioned on a 1.2mm grid.

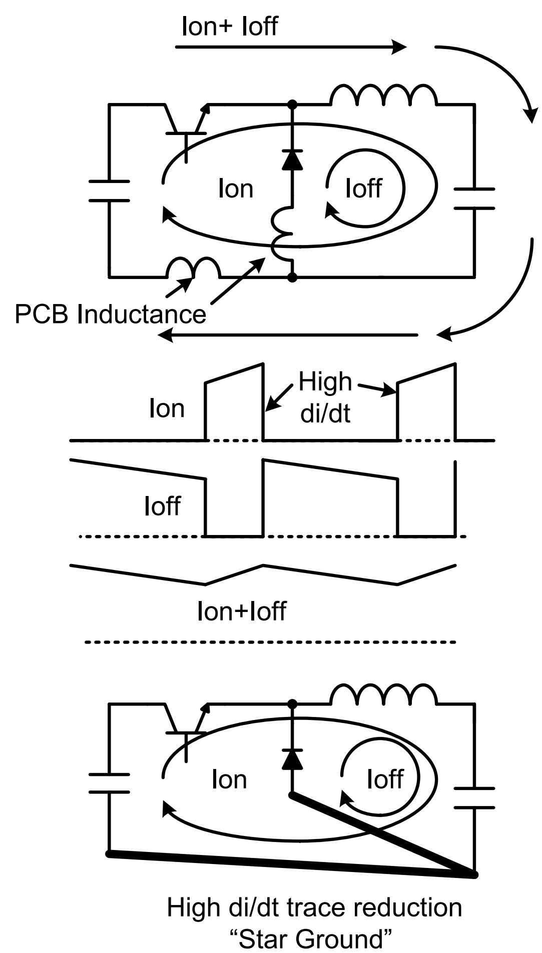



**Figure 1. Step Down Converter Layout**

**<u>Output Power and Thermal Limits</u>**

The AMS2596 junction temperature, Step-Down converter and LDO 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 device paddle and PCB temperature.

The temperature of the paddle and 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.

$$T_{jmax}=Pd \cdot \theta jc+Tpcb+Tamb$$

The losses associated with the AMS2596 overall efficiency are;

1. Output Diode Conduction Losses
2. Inductor DCR Losses
3. AMS2596 Internal losses
    a. Power Switch Forward Conduction and Switching 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.

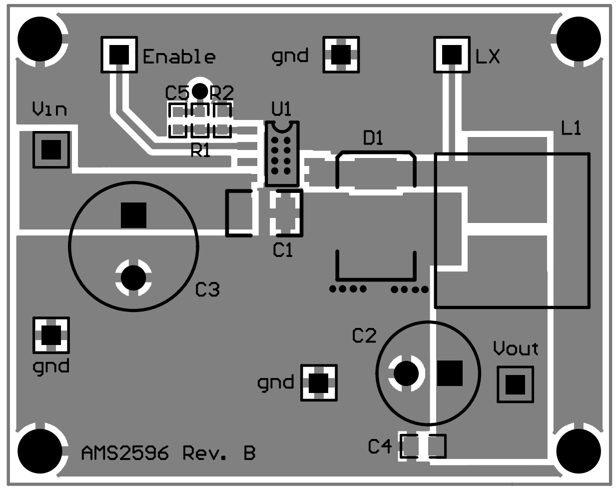



**Figure 2. AMS2596 SO-8 Evaluation Board Top**

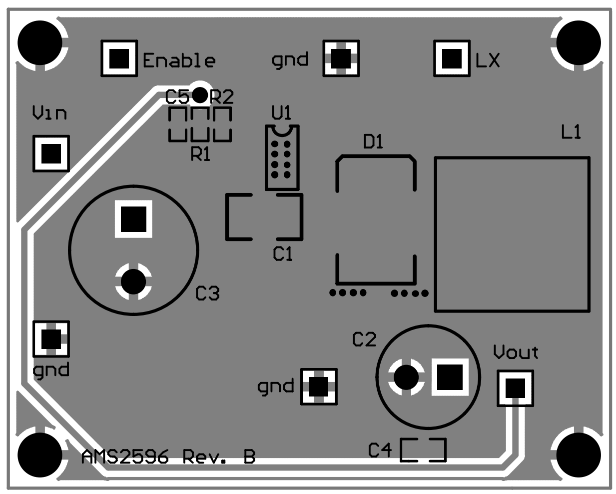



**Figure 3. AMS2596 SO-8 Evaluation Board Bottom**

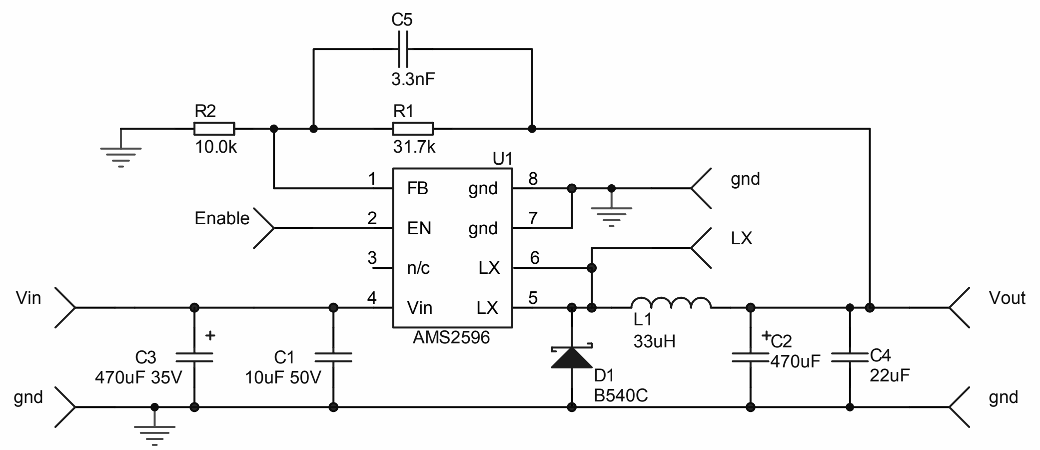



**Figure 4. AMS2596 Evaluation Board Schematic**

**Table 3. Evaluation Board Bill of Materials**

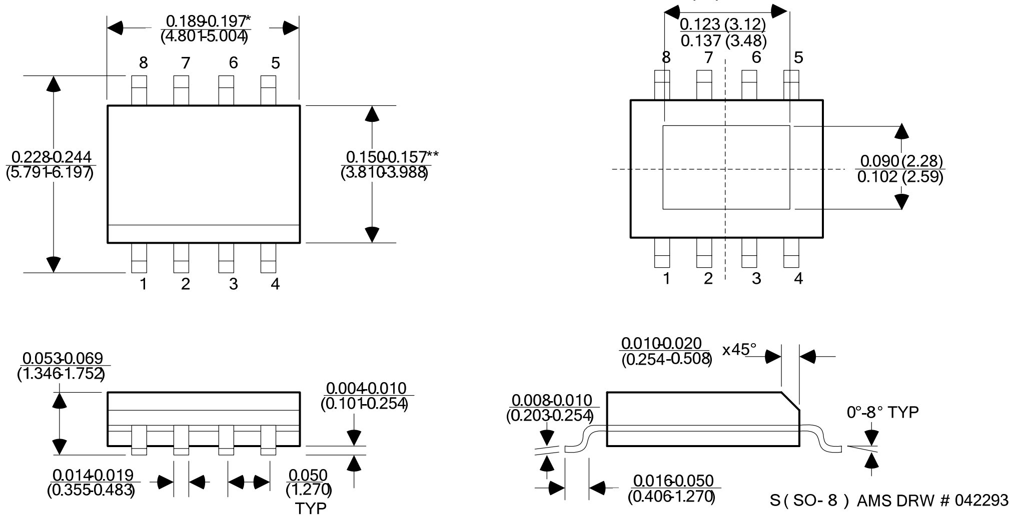
| Component | Value | Manufacturer | Manufacturer Part Number |
|---|---|---|---|
| L1 | 33 µF H 3.9A | | |
| C2 | 470µF, 10V, Electrolytic | | |
| C1 | 10 µF, 50V, X5R, 1210, Ceramic | Taiyo Yuden | UMK325BJ106KM-T |
| C3 | 470uF 35V, Electrolytic | | |
| C4 | 22µF, 10V, X5R, 0805, Ceramic | Taiyo Yuden | LMK212BJ226MG-T |
| C5 | 3.3nF 50V, 20%, X7R, 0603 | Murata | GRM188R71H332MA01 |
| R2 | 10kΩ, 0.1W, 0603 1% | Various | CRCW060310K0FKEA |
| R1 | See table 2 | Various | CRCW0603xxKxFKEA |
| D1 | 5A, 40V Schottky | Diodes Inc. | B540C |
| U1 | Step-Down Converter | AMS | AMS2596 |

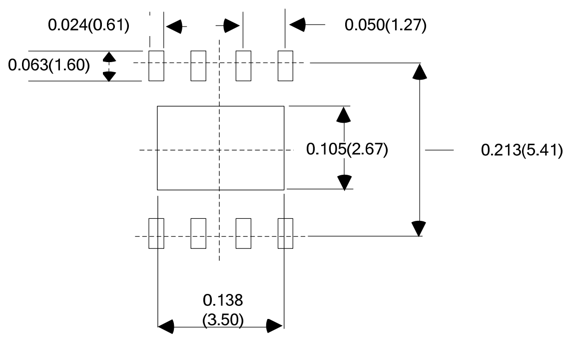
## ORDERING INFORMATION

| PACKAGE TYPE | AMS2596 ADJUSTABLE | AMS2596 FIXEDVOLTAGE | TEMP. RANGE |
|---|---|---|---|
| TO-263 | AMS2596M | AMS2596M-XX | -25ºC to -125ºC |
| TO-220 | AMS2596T | AMS2596T-XX | -25ºC to -125ºC |
| TO-252 | AMS2596D | AMS2596D-XX | -25ºC to -125ºC |
| SO-8 EDP | AMS2596S | AMS2596S-XX | -25ºC to -125ºC |

**PACKAGE DIMENSIONS** inches (millimeters) unless otherwise noted.

8 LEAD SOIC PLASTIC PACKAGES (S)



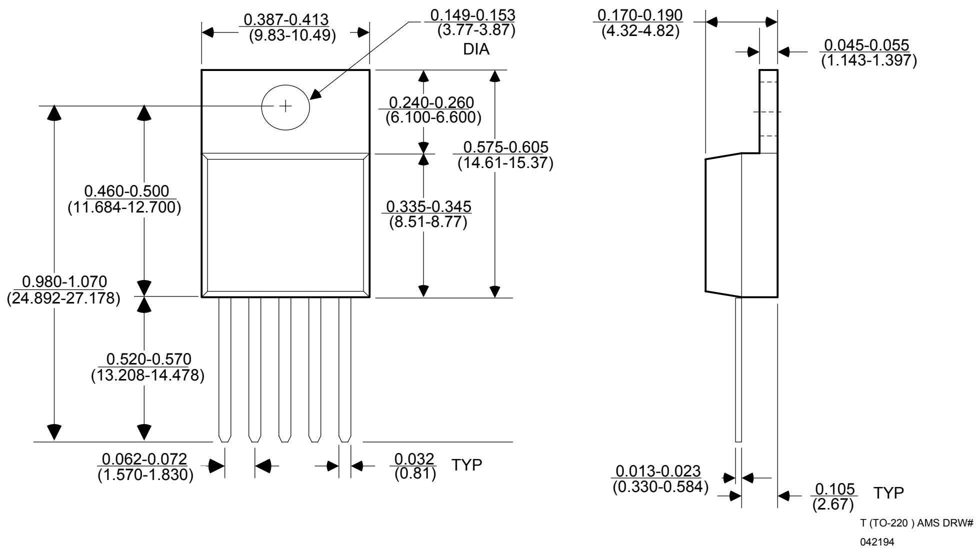

RECOMMENDED LAYOUT PATTERN

*DIMENSION DOES NOT INCLUDE MOLD FLASH. MOLD FLASH SHALL NOT EXCEED 0.006" (0.152mm) PER SIDE

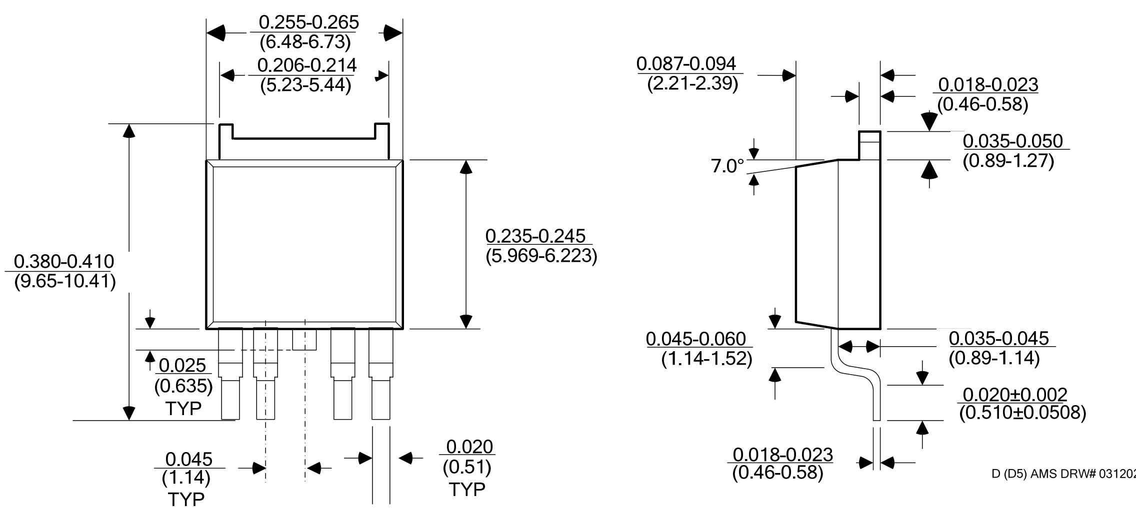
**DIMENSION DOES NOT INCLUDE INTERLEAD FLASH. INTERLEAD FLASH SHALL NOT EXCEED 0.010" (0.254mm) PER SIDE

## PACKAGE DIMENSIONS (continued)

5 LEAD TO-220 PLASTIC PACKAGE (T)




PLASTIC PACKAGE (D) 5 LEAD TO-252



## PACKAGE DIMENSIONS (continued)

5 LEAD TO-263 PLASTIC PACKAGE (M)