LM3460-1.2, -1.5 Precision Controller for GTLp and GTL Bus Termination

Check for Samples: LM3460

FEATURES

- **Precision Output (1%)**
- **Output Voltage Can be Adjusted**
- **Extremely Fast Transient response in GTLp and GTL Bus Termination**
- **Tiny SOT23-5 Package**
- **Output Voltage Capability for GTL or GTLp**
- **Low Temperature Coefficient**

APPLICATIONS

- **GTL Bus Termination (1.2V output @ 7A)**
- **GTLp Bus Termination (1.5V output @ 7A)**
- **Adjustable High-Current Linear Regulator**

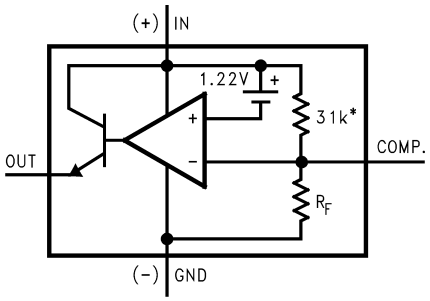
DESCRIPTION

The LM3460 is a monolithic integrated circuit designed for precision control of GTLplus and GTL Bus termination. This controller is available in a tiny SOT23-5 package, and includes an internally compensated op amp, a bandgap reference, an NPN output transistor, and voltage setting resistors.

A trimmed precision bandgap voltage reference utilizes temperature drift curvature correction for excellent voltage stability over the operating range. The precision output control enables the termination voltage to maintain tight regulation, despite fast switching requirements on the bus.

The LM3460 controller is designed to be used with a high current (> 7A) NPN pass transistor to provide the high current needed for the bus termination. The wide bandwidth of the feedback loop provides excellent transient response, and greatly reduces the output capacitance required, thus reducing cost and board space requirements.

CONNECTION DIAGRAM AND PACKAGE INFORMATION



*This resistor is not used on the LM3460-1.2.

Figure 1. LM3460 Functional Diagram

5-LEAD OUTLINE PACKAGE (M5)



Figure 2. Actual Size

*No internal connection, but should be soldered to PC board for best heat transfer.

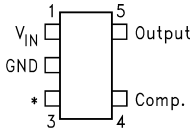


Figure 3. Top View
See Package Number MF05A

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ORDERING INFORMATION

Voltage	Order Number	Package Marking(1)	Supplied As(2)
1.5	LM3460M5-1.5	D06A	1000 Unit Increments on Tape and Reel
1.5	LM3460M5X-1.5	D06A	3000 Unit Increments on Tape and Reel
1.2	LM3460M5-1.2	D09A	1000 Unit Increments on Tape and Reel
1.2	LM3460M5X-1.2	D09A	3000 Unit Increments on Tape and Reel

(1) **MARKING CODE:** The first letter "D" identifies the part as a Driver, and the next two numbers define the voltage for the part. The fourth letter indicates the grade, with "A" designating the prime grade of product.
(2) **AVAILABILITY:** The SOT23-5 package is only available in quantity of 1000 on tape and reel (designated by the letters "M5" in the part number), or in quantity of 3000 on tape and reel (indicated by the letters "M5X" in the part number).

TYPICAL APPLICATIONS

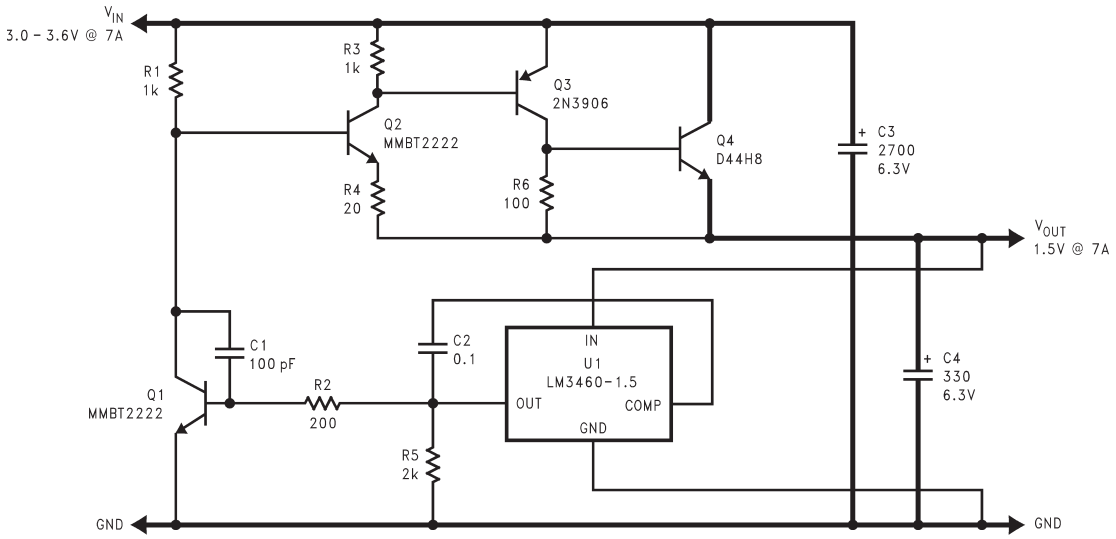


Figure 4. 1.5V TYPICAL APPLICATION (SEE APP CIRCUIT TECHNICAL INFORMATION)

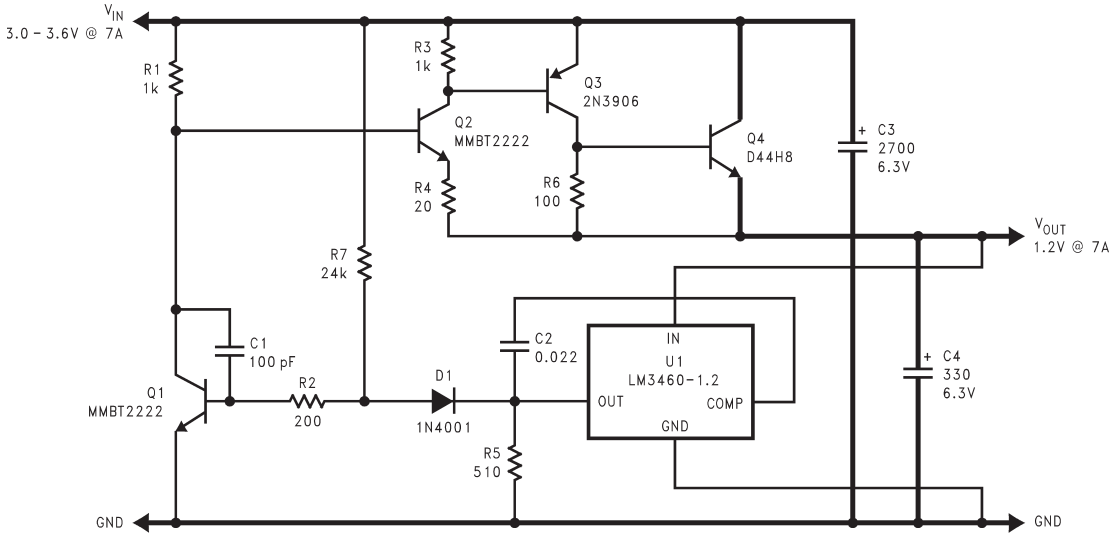


Figure 5. 1.2V TYPICAL APPLICATION (SEE APP CIRCUIT TECHNICAL INFORMATION)

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These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

ABSOLUTE MAXIMUM RATINGS(1)(2)

Input Voltage V_{IN}		20V
Output Current		20 mA
Junction Temperature		150°C
Storage Temperature		−65°C to +150°C
Lead Temperature	Vapor Phase (60 sec.)	+215°C
	Infared (15 sec.)	+220°C
Power Dissipation (T_A = 25°C)(3)		300 mW
ESD Susceptibility(4)	Human Body Model	1500V

(1) Absolute Maximum Ratings are 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 ensure specific performance limits. For ensured specifications and test conditions, see the Electrical Characteristics. The ensured specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.
(2) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/Distributors for availability and specifications.
(3) The maximum power dissipation must be derated at elevated temperatures and is dictated by T_{Jmax} (maximum junction temperature), θ_{JA} (junction ot ambient thermal resistance), and T_A (ambient temperature). The maximum allowable power dissipation at any temperature is ($P_{Dmax} = (T_{Jmax} - T_A)/\theta_{JA}$) or the number given in the Absolute Maximum Ratings, whichever is lower. The typical thermal resistance θ_{JA} when soldered to a printed circuit board is approximately 330° C/W.
(4) The human body model is a 100 pF capacitor discharged through a 1.5 kΩ resistor into each pin.

OPERATING RATINGS(1)(2)

Ambient Temperature Range	0°C ≤ T_A ≤ +70°C
Output Current	1 mA

(1) Absolute Maximum Ratings are 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 ensure specific performance limits. For ensured specifications and test conditions, see the Electrical Characteristics. The ensured specifications apply only for the test conditions listed. Some performance characteristics may degrade when the device is not operated under the listed test conditions.
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ELECTRICAL CHARACTERISTICS
LM3460-1.5

Specifications with standard type face are for T_J = 25°C, and those with **boldface type** apply over **full Operating Temperature Range.** Unless otherwise specified, (+)IN = V_{REG}, V_{OUT} = 200 mV

Symbol	Parameter	Conditions	Typ(1)	Limit(2)	Units
V_{REG}	Regulated Voltage	I_{OUT} = 1 mA	1.5	1.515/ **1.530** 1.485/**1.470**	V (max) V (min)
	Regulated Voltage Tolerance	I_{OUT} = 1 mA		±1 / **±2**	% (max)
I_q	Quiescent Current	I_{OUT} = 1 mA	85	125/**150**	µA (max)
G_m	Transconductance ΔI_{OUT} / ΔV_{REG}	20µA ≤ I_{OUT} ≤ 1 mA V_{OUT} = 500 mV	3.3	1/**0.5**	mA/mV (min)
V_{SAT}	Output Saturation Voltage(3)	V_{IN} = V_{REG} + 100 mV I_{OUT} = 1 mA	0.8	0.95	V (max)
I_L	Output Leakage Current	V_{IN} = V_{REG} − 100 mV V_{OUT} = 0V	0.1	0.5/**1.0**	µA (max)

(1) Typical numbers are at 25°C and represent the most likely parametric norm.
(2) Limits are 100% production tested at 25°C. Limits over the operating temperature range are guaranteed through correlation using Statistical Quality Control (SQC) methods. The limits are used to calculate TI's Average Outgoing Quality Level (AOQL).
(3) V_{SAT} = V_{REG} − V_{OUT}, when the voltage at the IN pin is forced 100mV above the nominal regulating voltage (V_{REG}).

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ELECTRICAL CHARACTERISTICS LM3460-1.5 (continued)

Specifications with standard type face are for T_J = 25°C, and those with **boldface type** apply over **full Operating Temperature Range.** Unless otherwise specified, (+)IN = V_{REG}, V_{OUT} = 200 mV

Symbol	Parameter	Conditions	Typ[1]	Limit[2]	Units
R_F	Internal Feedback Resistor (See Figure 1)		7.1	8.9 5.3	kΩ(max) kΩ(min)
E_n	Output Noise Voltage	I_{OUT} = 1 mA, 10 Hz ≤ f ≤ 10kHz	50		µV (rms)

ELECTRICAL CHARACTERISTICS LM3460-1.2

Specifications with standard type face are for T_J = 25°C, and those with **boldface type** apply over **full Operating Temperature Range.** Unless otherwise specified, (+)IN = V_{REG}, V_{OUT} = 200 mV

Symbol	Parameter	Conditions	Typ[1]	Limit[2]	Units
V_{REG}	Regulated Voltage	I_{OUT} = 1 mA	1.220	1.232/ **1.244** 1.208/**1.196**	V (max) V (min)
	Regulated Voltage Tolerance	I_{OUT} = 1 mA		±1 / **±2**	% (max)
I_q	Quiescent Current	I_{OUT} = 1 mA	85	125/**150**	µA (max)
G_m	Transconductance ΔI_{OUT} / ΔV_{REG}	20µA ≤ I_{OUT} ≤ 1 mA V_{OUT} = 200 mV	3.3	1/**0.5**	mA/mV (min)
V_{SAT}	Output Saturation Voltage[3]	V_{IN} = V_{REG} + 100 mV I_{OUT} = 1 mA	0.8	0.95	V (max)
I_L	Output Leakage Current	V_{IN} = V_{REG} − 100 mV V_{OUT} = 0V	0.1	0.5/**1.0**	µA (max)
R_F	Internal Feedback Resistor (See Figure 1)		10	12.5 7.5	kΩ(max) kΩ(min)
E_n	Output Noise Voltage	I_{OUT} = 1 mA, 10 Hz ≤ f ≤ 10kHz	50		µV (rms)

(1) Typical numbers are at 25°C and represent the most likely parametric norm.
(2) Limits are 100% production tested at 25°C. Limits over the operating temperature range are guaranteed through correlation using Statistical Quality Control (SQC) methods. The limits are used to calculate TI's Average Outgoing Quality Level (AOQL).
(3) V_{SAT} = V_{REG} − V_{OUT}, when the voltage at the IN pin is forced 100mV above the nominal regulating voltage (V_{REG}).

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PRODUCT DESCRIPTION

The LM3460 is a shunt regulator designed for use as a precision control element in a feedback loop. The regulated output voltage is sensed between the IN pin and GROUND pin of the LM3460.

The output of the LM3460 sources current whenever the voltage at the IN pin reaches the regulated voltage.

This current is used to cut off the drive to the external pass transistor, which provides the negative feedback to force the output voltage to be the same value as V_{REG}.

If the voltage on the IN pin is forced above the V_{REG} voltage, the maximum voltage applied to the IN pin should not exceed 20V. In addition, an external resistor may be required on the OUT pin to limit the maximum current to 20 mA.

COMPENSATION

The inverting input of the error amplifier is brought out to simplify closed-loop compensation. Typically, compensation is provided by a single capacitor connected from the COMPENSATION pin to the OUT pin of the LM3460.

Applying a load pulse to the output of the regulator circuit and observing the output voltage response is a good method of verifying the stability of the control loop.

If excessive ringing on the output waveform is observed, this usually indicates marginal stability resulting from insufficient phase margin.

TEST CIRCUIT

The test circuit shown in Figure 6 can be used to measure various LM3460 parameters. Test conditions are set by forcing the appropriate voltage at the V_{OUT} Set test point and selecting the appropriate R_L or I_{OUT} as specified in the Electrical Characteristics section. Use a DVM at the "measure" test points to read the data.

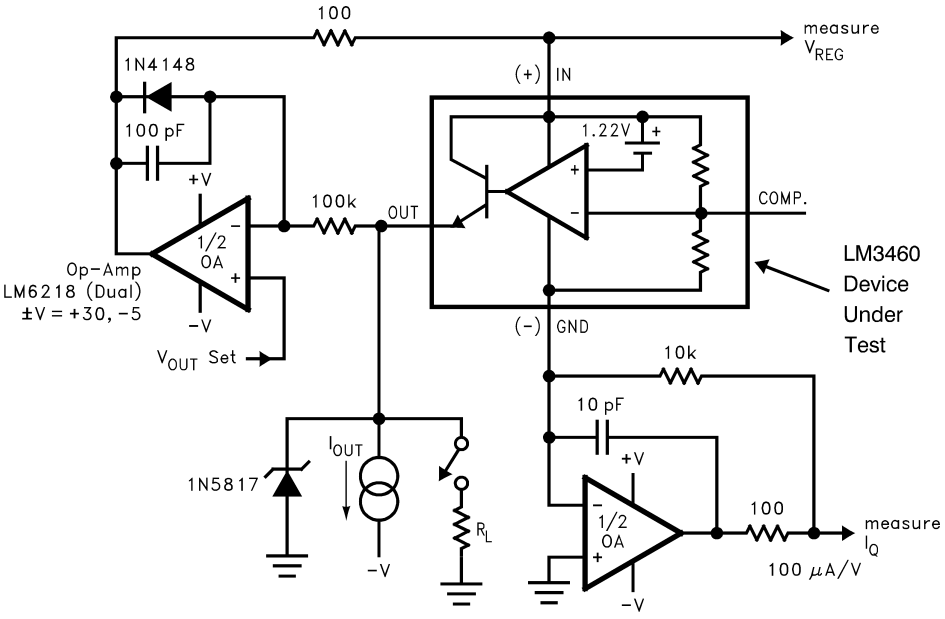


Figure 6. Test Circuit

V_{OUT} Set Note: 0V to 500 mV for LM3460-1.5

0V to 200 mV for LM3460-1.2

SETTING THE OUTPUT VOLTAGE

If a regulated voltage is desired which is not available as a standard voltage, the output voltage may be adjusted by using an external resistive divider (see Figure 7):

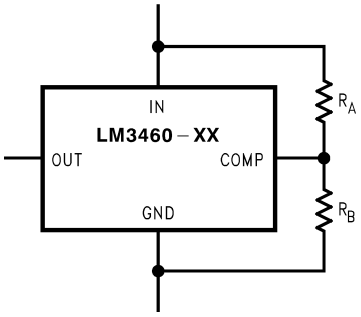


Figure 7. Setting the Output Voltage

$$V_{OUT} = 1.22 + \left(\frac{1.22}{R_A}\right) R_B \quad (1)$$

$$R_B = \frac{(V_{OUT} - 1.22)\, R_A}{1.22} \quad (2)$$

FOR BEST RESULTS: SELECT $R_A < 500\Omega$

The simplest way to calculate the resistor values is to assume a value for R_A and then solve the equation shown for R_B.

To assure best output voltage accuracy, the value selected for R_A should be < 500Ω, and 1% tolerance resistors should be used.

As the ohmic value of R_A is increased, the internal resistive divider inside the LM3460 will cause the output voltage to deviate from the value predicted by the formula shown.

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APP CIRCUIT TECHNICAL INFORMATION

Figure 4 and Figure 5 highlight two applications of the LM3460. This section provides details of circuit function.

1.5V/7A TYPICAL APPLICATION

Figure 4 shows the schematic of a wide-bandwidth linear regulator which provides a regulated 1.5V output at up to 7A of load current from a 3V-3.6V input.

The pass element of the regulator (which supplies the load current) is made up of a three-transistor complimentary Darlington composed of Q2, Q3, and Q4. The bias current flowing through R1 will drive the pass element ON, until such time as Q1 pulls down and takes the drive away from the base of Q2.

The circuit regulates the output to 1.5V using the LM3460 precision controller, which sources current from its output whenever the voltage at the IN pin reaches 1.5V.

When the LM3460 sources current from its output, it turns on Q1 (stealing the base drive for Q2) which reduces the current from the 1.5V regulated output. In this way, a negative feedback loop is established which locks the output at 1.5V.

C1 and C2 are used for compensation, and should be ceramic capacitors.

C4 is required for regulator stability, and both C3 and C4 affect transient response. Circuit performance should be carefully evaluated if substitutions are made for these two components.

PERFORMANCE DATA

All data taken at 20°C ambient:

LOAD/LINE REGULATION: The output voltage changed <0.1 mV as the load was increased from 0-7A, and the input voltage was varied from 3.0V-3.6V.

DROPOUT VOLTAGE: The dropout voltage (which is defined as the minimum input-output voltage differential required to maintain a regulated output) was measured at 7A and found to be 1.4V. This means that a minimum input voltage of 2.9V is required to keep the 1.5V output in regulation.

TRANSIENT RESPONSE: Transient response was tested using a 0.2Ω power resistor connected to the output using a mechanical contact to provide a 0-7A load current step. When the load was applied, the change in output voltage was seen to be < 5 mV with a total recovery time of about 30 µs (see Figure 8).

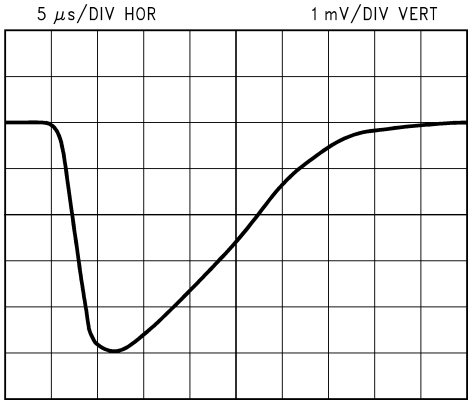


Figure 8. Output Transient Response

HEATSINKING/COMPONENT SELECTION

HEATSINKING: As with *any* linear regulator, the power dissipated in the pass transistor (Q4) is approximately:

$$P = (V_{IN} - V_{OUT}) \times I_{LOAD} \quad (3)$$

Q4 must be provided with adequate heatsinking so that the junction temperature never exceeds 150°C.

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Figure 9 shows the **maximum** allowable values of thermal resistance (from heatsink-to-ambient) that must be provided for various values of the load current.

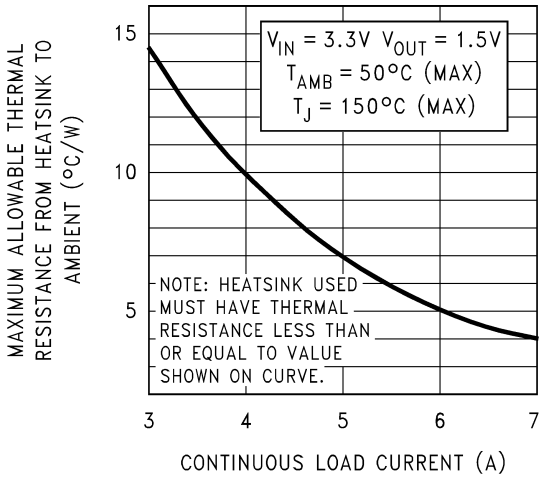


Figure 9. Q4 Heatsink Requirements for Circuit Shown in Figure 4

These values are calculated assuming a maximum ambient of 50°C, 3.3V input, and a TO-220 power transistor mounted using thermal grease and a mica insulator.

A given thermal resistance can be obtained by using different combinations of heatsink and airflow (refer to heatsink manufacturers datasheets).

The design tradeoff here is that heatsinks which are smaller, lighter, and cheaper require more airflow to get the desired value of thermal resistance.

TRANSIENT RESPONSE: If the regulator is to respond quickly to changes in load current demand, the input and output capacitors must be selected carefully.

The output capacitor C4 is most critical, as it must supply current to the load in the time it takes the regulator loop to sense the output voltage change and turn on the pass transistor. A Sanyo Oscon type (or equivalent) will give the best performance here.

The input capacitor C3 is also important, as it provides an energy reservoir from which the regulator sources current to force the output back up to the nominal value. A good, low ESR electrolytic such as a Panasonic HFQ type is a good choice for C3.

LAYOUT TIPS: In order to optimize performance, parasitic inductance due to connecting traces must be minimized. All paths shown as heavy lines on the schematic must be made by traces which are wide and short as possible (component placement should be optimized for minimum lead length).

POWER TRANSISTOR AND DRIVER: The power transistor used at Q4 must have very good current gain at 7A, and wide bandwidth (high f_T) for this circuit to work as specified. The D44H8 is an excellent choice for cost and performance.

The current gain of Q4 dictates the power dissipation in its driver (Q3) which must supply the base current to Q4. If the gain of Q4 is lowered, Q3 must source more current into its base (and the power dissipation in Q3 goes up proportionately).

The D44H8 has a guaranteed minimum gain of 40 @ 4A, with typical gain much higher. Assuming the gain of Q4 is about 30% lower at 7A, it will still be > 28. Therefore, to support 7A of load current, Q3 must supply 250 mA to the base of Q4 (worst case).

The power dissipation in Q3 (assuming 3.3V input) will never exceed approximately 250 mW, which is easily handled by 2N3906 in a TO-92 case (which has a thermal resistance of about 180°C/W), but could be a problem for a very small surface mount device.

If substitutions are made for Q3 or Q4, careful attention must be paid to the current gain as well as the f_T.

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TRANSISTOR BANDWIDTH: Fast transient response that the regulator be able to respond quickly to any change in output voltage (which will occur if the current drawn by the load suddenly changes).

All of the transistors specified in the schematic are very wide-band devices (have high f_T values) which is necessary for fast response. If substitutions are made for any of the transistors, this specification must be considered.

1.2V/7A TYPICAL APPLICATION

The 1.2V @ 7A design in Figure 5 is very similar in function to the design shown in Figure 4. Most of the circuit descriptions previously detailed for that circuit apply unchanged to Figure 5, will not be repeated.

Detailed information will be presented in the areas which differ between the two circuits.

HEATSINKING

The 1.2V design needs a little more heatsinking because the lower output voltage means more power dissipation in Q4 at any value of load current.

Figure 10 shows the **maximum** allowable values of thermal resistance (from heatsink-to-ambient) that must be provided for various values of the load current.

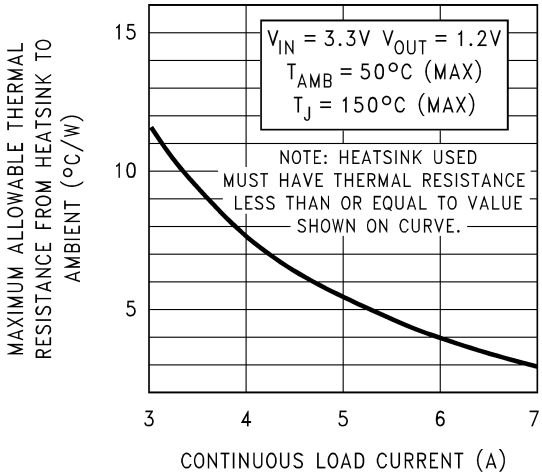


Figure 10. Q4 Heatsink Requirements for Circuit shown in Figure 5

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Q1 DRIVE CIRCUITRY

In the circuit shown in Figure 4, the output of U1 drives the base of Q1 with current when the voltage at V_{OUT} reaches the regulation point. As Q1 turns ON, it steals drive from Q2 which holds the loop in regulation.

The circuit of Figure 5 uses a different drive configuration for Q1, required because of the lower voltage across U1.

With only 1.2V across U1, the OUT pin of the LM3460 cannot swing up high enough in voltage to turn on the V_{BE} of Q1.

In the circuit of Figure 5, drive for Q1 is provided by R7, *but only when U1 sources current:* The operation of the drive scheme is as follows:

If the voltage at V_{OUT} is below 1.2V, no current flows from the OUT pin of U1. Q1 is held OFF as the current flowing down through R7 goes through D1 and R5 to ground.

IMPORTANT: Diode D1 is a 1N4001 because its V_F must be much less than the V_{BE} of Q1 (a signal diode like 1N4148 will not work here).

When U1 is not sourcing current, the voltage at the OUT pin (and the cathode of D1) will be held at about 50 mV by the R7/D1/R5 divider. The current flowing to ground through these components is about 110 µA.

Because D1 is a 1A power diode, the V_F across D1 at this small value of current will be much less than the V_{BE} needed to turn ON Q1 (so Q1 is held off by D1).

When U1 begins to source current (to cut off the pass transistor and regulate V_{OUT}) it forces the voltage at the cathode of D1 to rise.

This action causes the current that was flowing through D1 to flow into the base of Q1, turning it ON and taking drive away from the base of Q2.

This action provides the negative feedback required to regulate V_{OUT} and allows the LM3460 to operate with only 1.2V of total supply voltage across the device.

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REVISION HISTORY

Changes from Revision C (April 2013) to Revision D **Page**

- Changed layout of National Data Sheet to TI format 10

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