MOTOROLA

LT1585A

5A Low Dropout Fast Response Positive Adjustable and Fixed Voltage Regulators

The LT1585A is a low dropout 3–terminal voltage regulator with 5A output current capability.

Design has been optimized for low voltage applications where transient response and minimum input voltage are critical. This voltage regulator features a low dropout voltage and fast transient response. These improvements make them ideal for low voltage microprocessor applications requiring a regulated 2.5V to 3.6V output with an input supply below 7V.
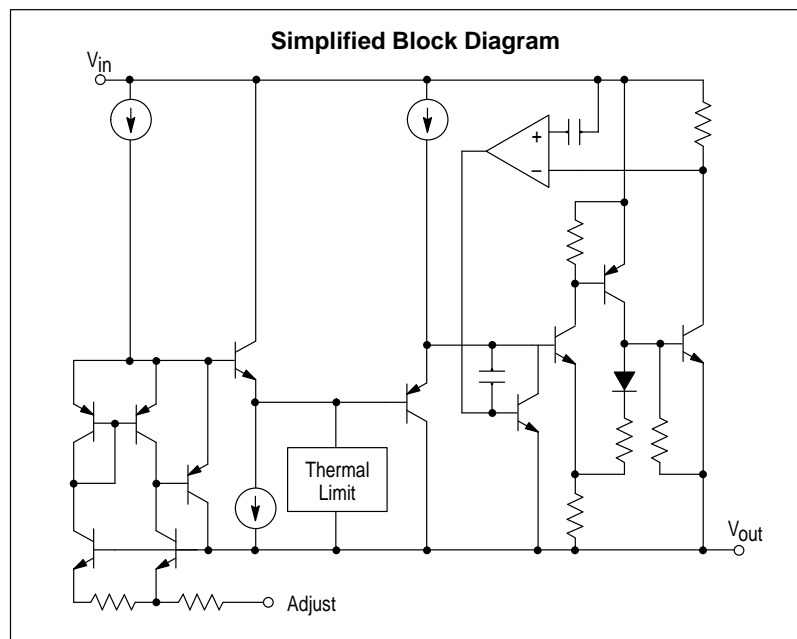
Current limits is trimmed to ensure specified output current and controlled short–circuit current. On–chip thermal limiting provides protection against any combination of overload that would create excessive junction temperatures. The LT1585A is available in the industry standard 3–pin TO–220 and D2PAK power package.

Features

- Fast Transient Response
- Guaranteed Dropout Voltage at Multiple Currents
- Load Regulation: 0.05% Typ
- Trimmed Current Limit
- On–Chip Thermal Limiting
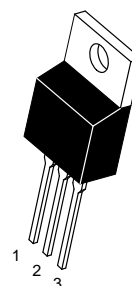- Standard 3–Pin Power Package

Applications

- Pentium® Processor Supplies
- Power PC™ Supplies
- Other 2.5V to 3.6V Microprocessor Supplies
- Low Voltage Logic Supplies
- Battery–Powered Circuitry
- Post Regulator for Switching Supply

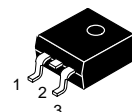**5A LOW DROPOUT FAST RESPONSE POSITIVE ADJUSTABLE AND FIXED VOLTAGE REGULATOR**

SILICON MONOLITHIC INTEGRATED CIRCUIT

T SUFFIX
PLASTIC PACKAGE
CASE 221A

Adjustable output:
Pin 1. Adjust
2. V_{out}
3. V_{in}

Fixed 1.5V output:
Pin 1. Gnd
2. V_{out}
3. V_{in}

CM SUFFIX
PLASTIC PACKAGE
CASE 936
(D2PAK)

ORDERING INFORMATION

Device	Tested Operating Temp. Range	Output Voltage Type	Package
LT1585ACT	0 to 125°C	ADJ.	TO–220
LT1585ACM	0 to 125°C	ADJ.	D2PAK
LT1585ACT–1.5	0 to 125°C	FIXED 1.5V	TO–220
LT1585ACM–1.5	0 to 125°C	FIXED 1.5V	D2PAK

Simplified Block Diagram

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Rev 0

LT1585A

ABSOLUTE MAXIMUM RATINGS (Absolute Maximum Ratings indicate limits beyond which damage to the device may occur)

Rating	Symbol	Pin #	Value	Unit
Maximum Supply Voltage	V_{in}	3	12	V
Power Dissipation				
Case 221A (TO–220) (T_J = +25°C)	P_D		Internally Limited	W
Thermal Resistance, Junction–to–Ambient	$R_{\theta JA}$		65	°C/W
Thermal Resistance, Junction–to–Case	$R_{\theta JC}$		5.0	°C/W
Case 936 (D^2PAK) (T_J = +25°C)	P_D		Internally Limited	W
Thermal Resistance, Junction–to–Ambient	$R_{\theta JA}$		70	°C/W
Thermal Resistance, Junction–to–Case	$R_{\theta JC}$		5.0	°C/W
Storage Temperature Range	T_{stg}		–65 to 150	°C
Minimum ESD Rating (Human Body Model: C = 100pF, R = 1.5 kΩ)			3.0	kV
Lead Temperature (Soldering, 10 sec.)			260	°C
Maximum Junction Temperature	T_J		150	°C

OPERATING RATINGS (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)

Rating	Symbol	Pin #	Value	Unit
Operating Junction Temperature Range	T_J		0 to +125	°C
Supply Voltage		3	7.0	V

ELECTRICAL CHARACTERISTICS (0 < T_J < +125°C, unless otherwise noted)

Characteristic	Symbol	Pin #	Min	Typ	Max	Unit
Reference Voltage (LT1585A)	V_{ref}	1				V
(V_{in}–V_{out}) = 3V, I_{out} = 10mA, T_J = 25°C			1.238	1.250	1.262	
1.5V ≤ (V_{in}–V_{out}) ≤ 5.75V, 10mA ≤ I_{out} ≤ 5A			1.225	1.250	1.275	
Output Voltage (LT1585A–1.5)		2				V
V_{in} = 5V, T_J = 25°C, I_{out} = 0mA			1.485	1.5	1.515	
3V ≤ V_{in} ≤ 7V, 0mA ≤ I_{out} ≤ 5A			1.470	1.5	1.530	
Line Regulation [Notes 1, 2]	Reg_{line}	2				%
LT1585A: 2.75V ≤ V_{in} ≤ 7V, I_{out} = 10mA			–	0.005	0.2	
LT1585A–1.5: 3V ≤ V_{in} ≤ 7V, I_{out} = 0mA			–	0.005	0.2	
Load Regulation [Notes 1, 2]	Reg_{load}	2				%
LT1585A: (V_{in}–V_{out}) = 3V, T_J = 25°C, 10mA ≤ I_{out} ≤ 5A			–	0.05	0.3	
LT1585A–1.5: V_{in} = 5V, T_J = 25°C, 0mA ≤ I_{out} ≤ 5A			–	0.05	0.3	
LT1585A: (V_{in}–V_{out}) = 3V, 10mA ≤ I_{out} ≤ 5A			–	0.05	0.5	
LT1585A–1.5: V_{in} = 5V, 0mA ≤ I_{out} ≤ 5A			–	0.05	0.5	
Dropout Voltage	V_{in}–V_{out}					V
LT1585A: ΔV_{REF} = 1%, I_{OUT} = 3A			–	1.150	1.300	
LT1585A–1.5: ΔV_{OUT} = 1%, I_{OUT} = 3A			–	1.150	1.300	
LT1585A: ΔV_{REF} = 1%, I_{OUT} = 5A			–	1.200	1.400	
LT1585A–1.5: ΔV_{OUT} = 1%, I_{OUT} = 5A			–	1.200	1.400	
Current Limit [Note 3]	I_{Limit}	2				A
(V_{in}–V_{out}) = 5.5V			5.0	6.0	–	
Adjust Pin Current (LT1585A)	I_{Adj}	1	–	55	120	μA
Adjust Pin Current Change (LT1585A) [Note 3]		1				μA
1.5V ≤ (V_{in}–V_{out}) ≤ 5.75V, 10mA ≤ I_{out} ≤ 5A			–	0.2	5.0	
Minimum Load Current (LT1585A) 1.5V ≤ (V_{in}–V_{out}) ≤ 5.75V	$I_{Load\ min}$	2	–	2.0	10	mA
Quiescent Current (LT1585A–1.5) V_{in} = 5V		1	–	7.0	13	mA
Ripple Rejection	RR	2				dB
LT1585A: f = 120Hz, C_{out} = 25μF $T_{ant.}$, (V_{in}–V_{out}) = 3V, I_{out} = 5A			60	72	–	
LT1585A–1.5: f = 120Hz, C_{out} = 25μF $T_{ant.}$, V_{in} = 4.5V, I_{out} = 5A			60	72	–	
Thermal Regulation T_J = 25°C, 30ms Pulse	$T°Reg$		–	0.004	–	%/W
Temperature Stability	$T°Stab$		–	0.5	–	%
Long Term Stability T_J = 125°C, 1000 Hrs			–	0.03	1.0	%
RMS Output Noise (% of V_{out}) T_J = 25°C, 10Hz ≤ f ≤ 10kHz			–	0.003	–	%

NOTES 1. See thermal regulation specifications for changes in output voltage due to heating effects. Load and line regulation are measured at a constant junction temperature by low duty cycle pulse testing.
    2. Line and load regulations are guaranteed up to the maximum power dissipation 28.8W for the LT1585A in T–package. Power dissipation is determined by input/output differential and the output current. Guaranteed maximum output power will not be available over the full input/output voltage range.
    3. The LT1585A has constant current limit with changes in input–to–output voltage.

LT1585A

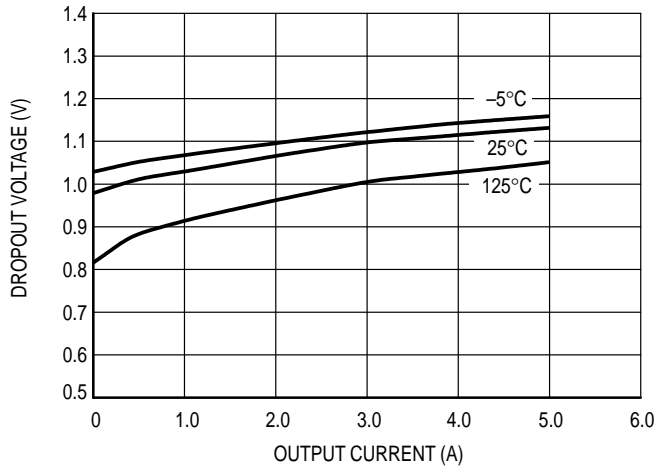**Figure 1. Dropout Voltage vs Output Current**

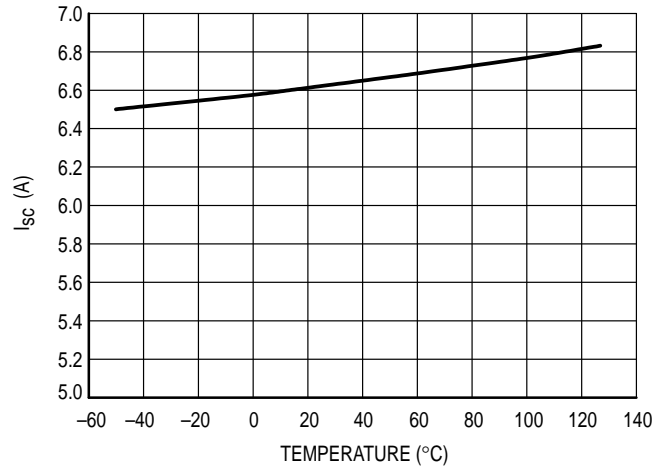**Figure 2. Short–Circuit Current vs Temperature**

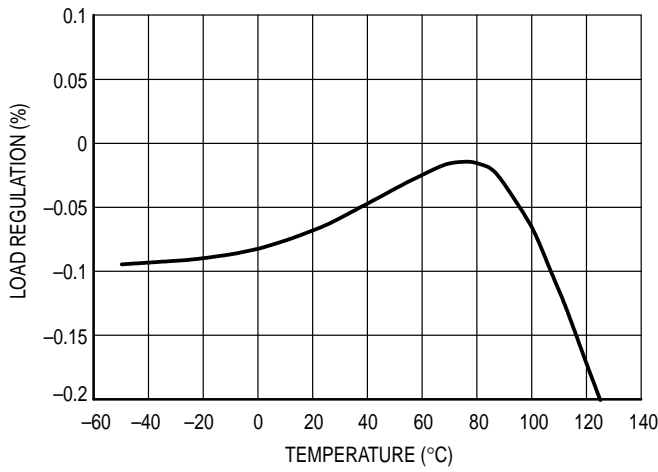**Figure 3. Load Regulation vs Temperature**

Figure 4. LT1585A Reference Voltage vs Temperature
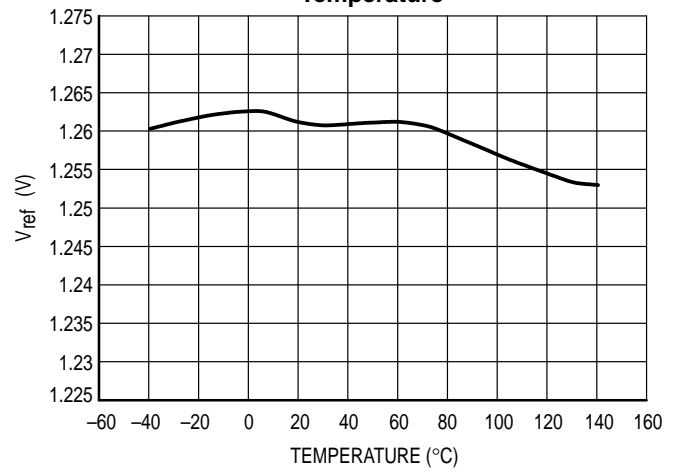

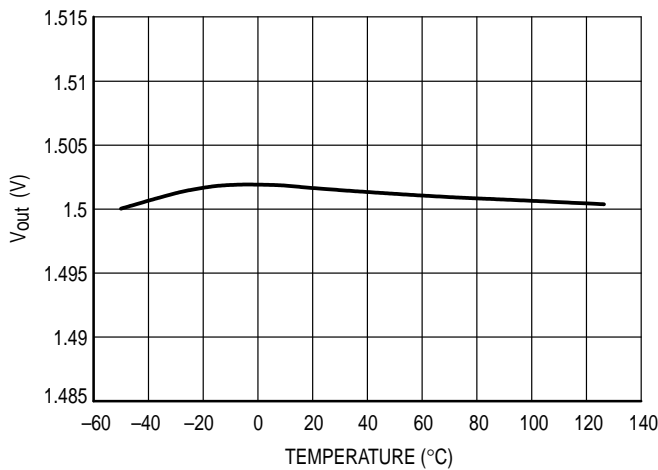**Figure 5. LT1585A–1.5 Output Voltage vs Temperature**

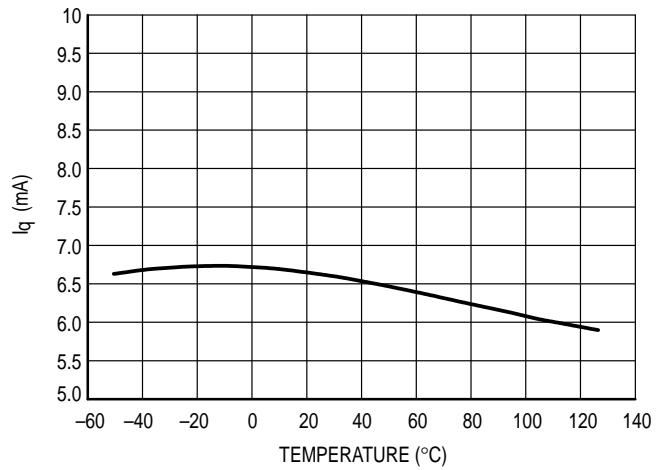**Figure 6. LT1585A–1.5 Quiescent Current vs Temperature**

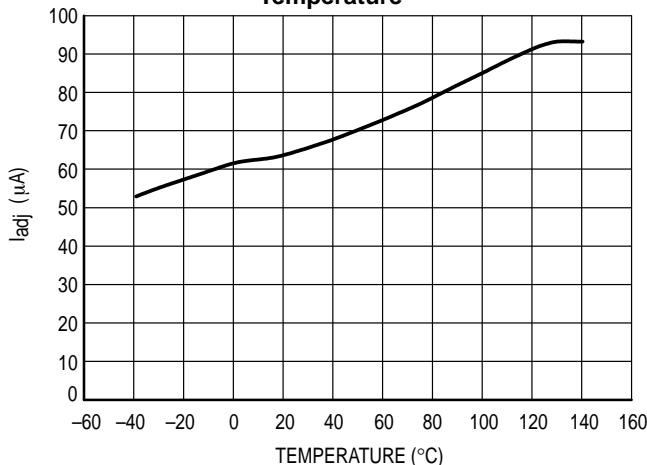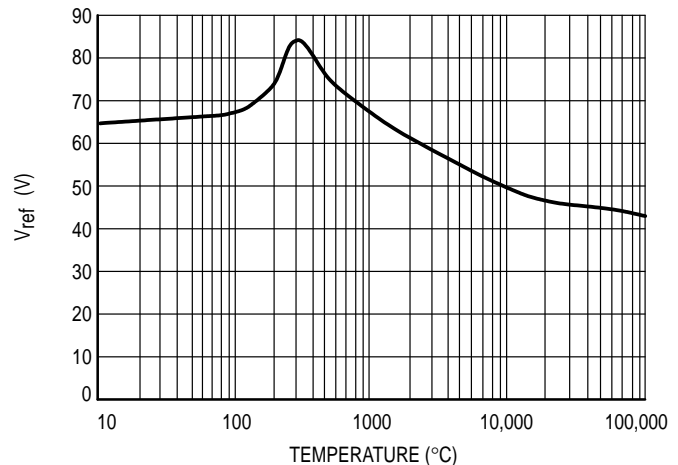**Figure 7. LT1585A Adjust Pin Current vs Temperature**

Figure 8. Ripple Rejection vs Frequency

OPERATING DESCRIPTION

APPLICATIONS INFORMATION
General

The LT1585A 3–terminal adjustable positive voltage regulator is easy to use and has all the protection features expected in high performance linear regulators. The device is short–circuit protected, safe–area protected and provides thermal shutdown to turn off the regulator should the junction temperature exceed about 150°C.

The LT1585A voltage regulator requires an output capacitor for stability. However, the improved frequency compensation permits the use of capacitors with much lower ESR while still maintaining stability. This is critical in addressing the needs of modern, low voltage, high speed microprocessors.

Current generation microprocessors cycle load current from almost zero to amps in tens of nanoseconds. Output voltage tolerances are tighter and include transient response as part of the specification.

The LT1585A is specifically designed to meet the fast current load–step requirements of these microprocessors and save total cost by needing less output capacitance in order to maintain regulation.

Stability

The circuit design in the LT1585A requires the use of an output capacitor as part of the frequency compensation. For all operating conditions, the addition of a 22μF solid tantalum or a 100μF aluminium electrolytic on the output ensures stability. Normally, the LT1585A can use smaller value capacitors. Many different types of capacitors are available and have widely varying characteristics.

These capacitors differ in capacitor tolerance (sometimes ranging up to ±100%), equivalent series resistance, equivalent series inductance and capacitance temperature coefficient. The LT1585A frequency compensation optimizes frequency response with low ESR capacitors. In general, use capacitors with an ESR of less than 1 Ω.

On the LT1585A, bypassing the adjust pin improves ripple rejection and transient response. Bypassing the adjust pin increases the required output capacitor value. The value of 22μF 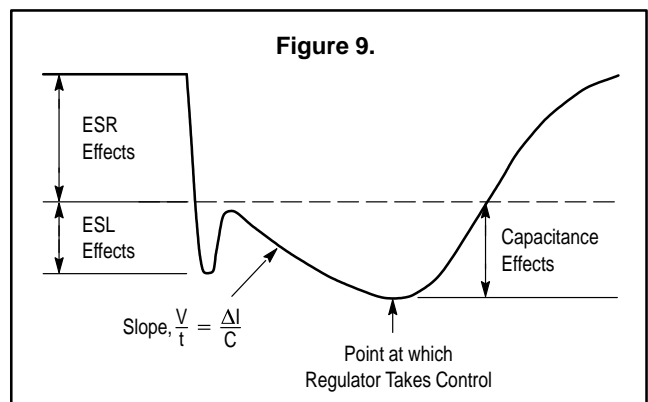tantalum or 100μF aluminium covers all cases of bypassing the adjust terminal. With no adjust pin bypassing, smaller values of capacitors provide equally good results.

Normally, capacitor values on the order of several hundred microfarads are used on the output of the regulators to ensure good transient response with heavy load current changes.

Output capacitance can increase without limit and larger values of output capacitance further improve the stability and transient response of the LT1585A.

Large load current changes are exactly the situation presented by modern microprocessors. The load current step contains higher order frequency components that the output decoupling network must handle until the regulator throttles to the load current level. Capacitors are not ideal elements and contain parasitic resistance and inductance. These parasitic elements dominate the change in output voltage at the beginning of a transient load step change.

The ESR of the output capacitors produces an instantaneous step in output voltage ($\Delta V = \Delta I \bullet ESR$). The ESL of the output capacitors produces a droop proportional to the rate of change of output current ($V = L \bullet \Delta I/\Delta t$). The output capacitance produces a change in output voltage proportional to the time until the regulator can respond ($\Delta V = \Delta t \bullet \Delta I/C$). These transient effects are illustrated in Figure 9.

Figure 9.

ESR Effects

ESL Effects

Capacitance Effects

Slope, $\dfrac{V}{t} = \dfrac{\Delta I}{C}$

Point at which Regulator Takes Control

The use of capacitors with low ESR, low ESL and good high frequency characteristics is critical in meeting the output voltage tolerances of these high speed microprocessors. These requirements dictate a combination of high quality, surface mount tantalum capacitors and ceramic capacitors.

The location of the decoupling network is critical to transient response performance. Place the decoupling network as close as possible to the processor pins because trace runs from the decoupling capacitors to the processor pins are inductive. The ideal location for the decoupling network is actually inside the microprocessor socket cavity. In addition, use large power and ground plane areas to minimize distribution drops.

A possible stability problem that occurs in monolithic linear regulators is current limit oscillations. The LT1585A essentially has a flat current limit over the range of input supply voltage. The lower current limit rating and 12V maximum supply voltage rating for these devices permit this characteristic.

Current limit oscillations are typically nonexistent, unless the input and output decoupling capacitors for the regulators are mounted several inches from the terminals.

Protection Diodes

In normal operation, the LT1585A does not require any protection diodes. Older 3–terminal regulators require protection diodes between the output pin and the input pin or between the adjust pin and the output pin to prevent die overstress.

Built–in internal resistors limit internal current paths on the adjust pin. Therefore, even with bypass capacitors on the adjust pin, no protection diode is needed to ensure device safety under short–circuit conditions.

A protection diode between the input and output pins is usually not needed. An internal diode between the input and output pins on the LT1585A can handle microsecond surge currents of 50A to 100A. Even with large value output capacitors it is difficult to obtain those values of surge currents in normal operation. Only with large values of output capacitance, such as 1000μF to 500μF, and with the input pin instantaneously shorted to ground can damage occur. A crowbar circuit at the input of the LT1585A can generate those levels of current, and a diode from output to input is then recommended. This is shown in Figure 10. Usually, normal power supply cycling or system "hot plugging and unplugging" will not generate current large enough to do any damage.

The adjust pin can be driven on a transient basis $\pm$ 7V with respect to the output, without any device degradation. As with any IC regulator, exceeding the maximum input–to–output voltage differential causes the internal transistors to break down and none of the protection circuitry is then functional.


Figure 10.
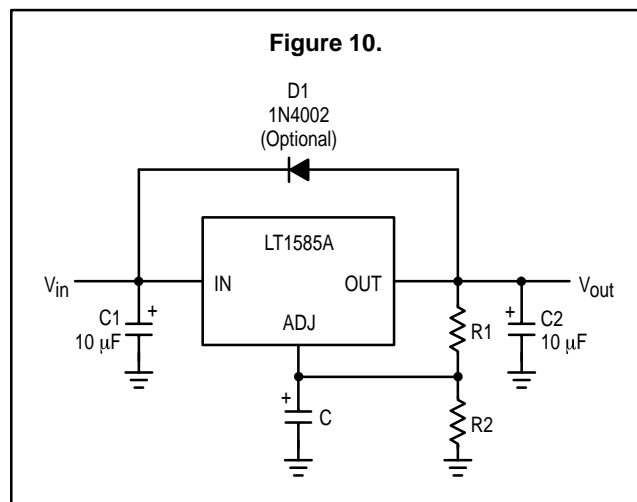
Ripple Rejection

A bypass capacitor from the adjust pin to ground reduces the output ripple by the ratio of $V_{OUT}/1.25$ V. The impedance of the adjust pin capacitor at the ripple frequency should be less than the value of R1 (typically in the rage of 100Ω to 120Ω) in the feedback divider network in Figure 10. Therefore, the value of the required adjust pin capacitor is a function of the input ripple frequency. For example, if R1 equals 100Ω and the ripple frequency equals 120Hz, the adjust pin capacitor should be 22μF. At 10kHz, only 0.22μF is needed.

Output Voltage

The LT1585A adjustable regulator develops a 1.25V reference voltage between the output pin and the adjust pin (see Figure 11). Placing a resistor R1 between these two terminals causes a constant current to flow through R1 and down through R2 to set the overall output voltage. Normally, this current is the specified minimum load current of 10mA. The current out of the adjust pin adds to the current from R1 and is typically 55μA. Its output voltage contribution is small and only needs consideration when very precise output voltage setting is required.

Figure 11. Basic Adjustable Regulator

Figure 11. Basic Adjustable Regulator

$V_{out} = V_{ref} (1 + R2/R1) + I_{adj} (R2)$
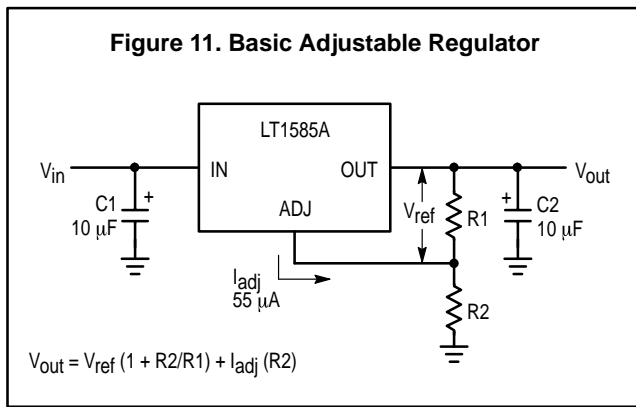
Load Regulation

It is not possible to provide true remote load sensing because the LT1585A are 3–terminal devices. Load regulation is limited by the resistance of the wire connecting the regulators to the load. Load regulation per the data sheet specification is measured at the bottom of the package.

For adjustable voltage devices, negative side sensing is a true Kelvin connection with the bottom of the output divider returned to the negative side of the load. The best load regulation is obtained when the top of resistor divider R1 connects directly to the regulator output and not to the load. Figure 4 illustrates this point. If R1 connects to the load, the effective resistance between the regulator and the load is :

$R_P (1 + R2/R1)$, R_P = Parasitic Line Resistance

The connection shown in Figure 11 does not multiply R_P by the divider ratio. As an example, R_P is about four milliohms per foot with 16–gauge wire. This translates to 4mV per foot at 1A load current. At higher load currents, this drop represents a significant percentage of the overall regulation. It is important to keep the positive lead between the regulator and the load as short as possible and to use large wire or PC board traces.

Figure 12. Connection for Best Load Regulation

Figure 12. Connection for Best Load Regulation

* Connect R1 to Case
  Connect R2 to Load
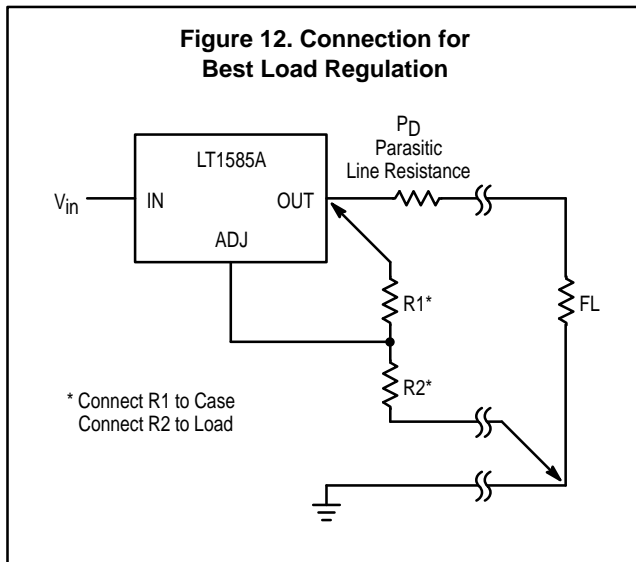
Thermal Considerations

The LT1585A protects the device under overload conditions with internal power and thermal limiting circuitry. However, for normal continuous load conditions, do not exceed maximum junction temperature ratings. It is important to consider all sources of thermal resistance from junction–to–ambient. These sources include the junction–to–case resistance, the case–to–heat sink interface resistance and the heat sink resistance. Thermal resistance specifications have been developed to more accurately reflect device temperature and ensure safe operating temperatures. The Electrical Characteristics section provides a separate thermal resistance and maximum junction temperature for both the control circuitry and the power transistor. Older regulators, with a single junction–to–case thermal resistance specification, use an average of the two values provided here and allow excessive junction temperatures under certain conditions of ambient temperature and heat sink resistance.

Calculate the maximum junction temperature for both sections to ensure that both thermal limits are met.

Junction–to–case thermal resistance is specified from the IC junction to the bottom of the case directly below the die. This is the lowest resistance path for heat flow. Proper mounting ensures the best thermal flow from this area of the package to the heat sink. It is strongly recommended to use thermal compound at the case–to–heat sink interface. Use a thermally conductive spacer if the case of the device must be electrically isolated and include its contribution to the total thermal resistance.

For example, using an LT1585ACT (TO–220 package) with an output adjusted to 3.3 V and assuming:

V_{in} (Max Continuous) = 5.25V (5V + 5%), V_{out} = 3.3V,
    I_{OUT} = 5A.

T_A = 70°C, $\theta_{HEAT SINK}$ = 3°C/W

$\theta_{CASE–TO–HEAT SINK}$ = 1°C/W (with Thermal Compound)

Power dissipation under these conditions is equal to:

$P_D = (V_{in} − V_{out}) (I_{out}) = (5.25 − 3.3) (5) = 9.75W$

Junction temperature will be equal to:

$T_J = T_A + P_D (\theta_{HEAT SINK} + \theta_{CASE–TO–HEAT SINK} + \theta_{JC})$

For the Control Section:

T_J = 70°C + 9.75W (3°C/W + 1°C/W + 0.7°C/W)
    = 115.8°C

115.8°C < 125°C = T_{JMAX}
(Control Section Commercial Range)

For the Power Transistor:

T_J = 70°C + 9.75W (3°C/W + 1°C/W + 3°C/W)
    = 138.3°C

138.3°C < 150°C = T_{JMAX}
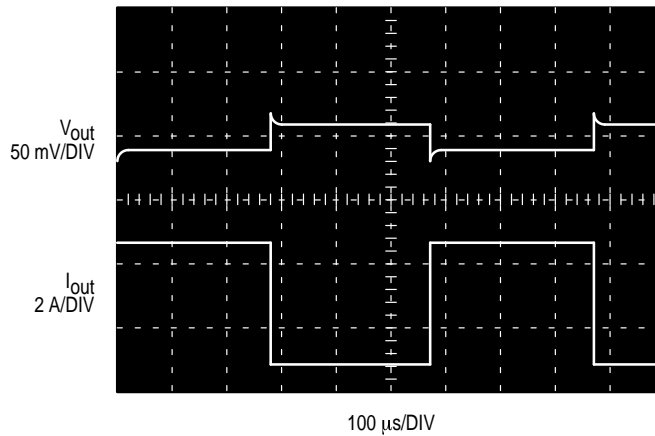(Control Section Commercial Range)

In both cases the junction temperature is below the maximum rating for the respective sections, ensuring reliable operation.

LT1585A

Minimum Parts Count LT1585A Adjustable Circuit for the Intel 120 MHz Pentium Processor

Thermalloy
7020B–MT

LT1585ACT

IN   OUT

ADJ

4.75 V to
5.25 V

C1 to C3
220 μF
10 V
AVX TPS
3 EACH

C4
330 nF
16 V
AVX X7R0805

R1
110 Ω
0.1%

R2
197 Ω
0.1%

Place in Microprocessor Socket Cavity

350 V
5 A

C5 to C10
100 μF
10 V
AVX TPS
4 EACH

C11 to C20
1.0 μF
16 V
AVX V5 V0805
24 EACH

AVX Corp. (803) 448–9411
Thermalloy Inc. (214) 243–4321
Do not substitute components
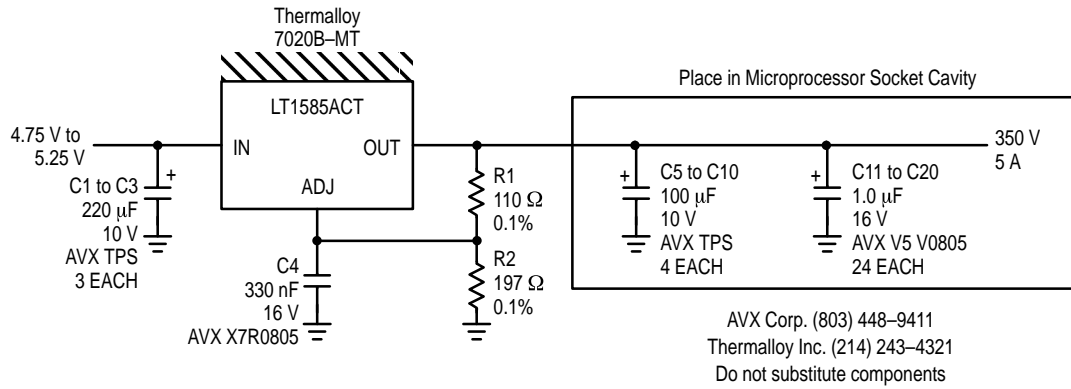
LT1585A Transient Response for 3.8 A Load Current Step*

V_{out}
50 mV/DIV

I_{out}
2 A/DIV

100 μs/DIV

* transient response measured with an Intel power validator.
V_{out} is measured at the power validator.

LT1585A

OUTLINE DIMENSIONS

T SUFFIX
PLASTIC PACKAGE
CASE 221A–09
ISSUE Z

SEATING PLANE
−T−
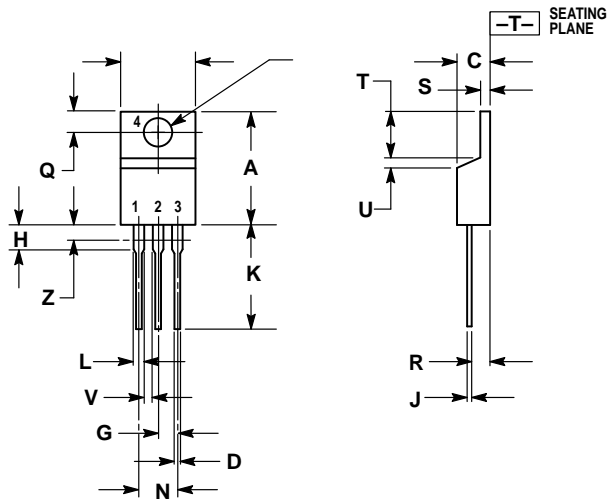
NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. DIMENSION Z DEFINES A ZONE WHERE ALL BODY AND LEAD IRREGULARITIES ARE ALLOWED.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.570	0.620	14.48	15.75
B	0.380	0.405	9.66	10.28
C	0.160	0.190	4.07	4.82
D	0.025	0.035	0.64	0.88
F	0.142	0.147	3.61	3.73
G	0.095	0.105	2.42	2.66
H	0.110	0.155	2.80	3.93
J	0.018	0.025	0.46	0.64
K	0.500	0.562	12.70	14.27
L	0.045	0.060	1.15	1.52
N	0.190	0.210	4.83	5.33
Q	0.100	0.120	2.54	3.04
R	0.080	0.110	2.04	2.79
S	0.045	0.055	1.15	1.39
T	0.235	0.255	5.97	6.47
U	0.000	0.050	0.00	1.27
V	0.045	—	1.15	—
Z	—	0.080	—	2.04

CM SUFFIX
PLASTIC PACKAGE
CASE 936–03
ISSUE B
(D²PAK)

OPTIONAL CHAMFER
−T−
TERMINAL 4

0.010 (0.254) M T
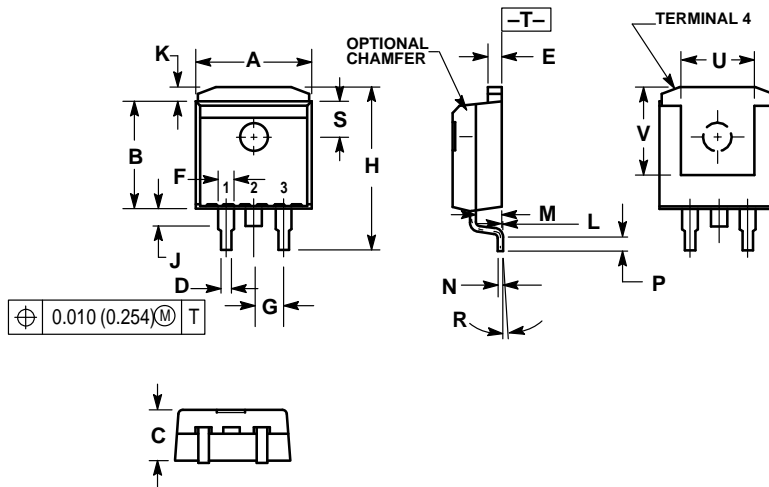
NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: INCH.
3. TAB CONTOUR OPTIONAL WITHIN DIMENSIONS A AND K.
4. DIMENSIONS U AND V ESTABLISH A MINIMUM MOUNTING SURFACE FOR TERMINAL 4.
5. DIMENSIONS A AND B DO NOT INCLUDE MOLD FLASH OR GATE PROTRUSIONS. MOLD FLASH AND GATE PROTRUSIONS NOT TO EXCEED 0.025 (0.635) MAXIMUM.

DIM	INCHES		MILLIMETERS	
	MIN	MAX	MIN	MAX
A	0.386	0.403	9.804	10.236
B	0.356	0.368	9.042	9.347
C	0.170	0.180	4.318	4.572
D	0.026	0.036	0.660	0.914
E	0.045	0.055	1.143	1.397
F	0.051 REF		1.295 REF	
G	0.100 BSC		2.540 BSC	
H	0.539	0.579	13.691	14.707
J	0.125 MAX		3.175 MAX	
K	0.050 REF		1.270 REF	
L	0.000	0.010	0.000	0.254
M	0.088	0.102	2.235	2.591
N	0.018	0.026	0.457	0.660
P	0.058	0.078	1.473	1.981
R	5° REF		5° REF	
S	0.116 REF		2.946 REF	
U	0.200 MIN		5.080 MIN	
V	0.250 MIN		6.350 MIN	

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JAPAN: Motorola Japan Ltd.; SPD, Strategic Planning Office, 141,
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