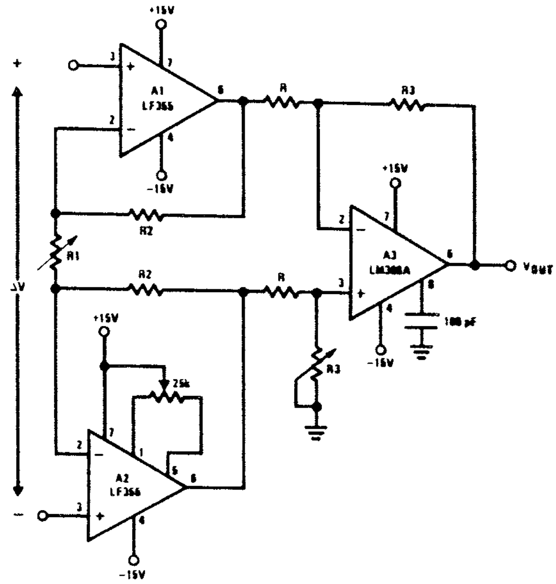
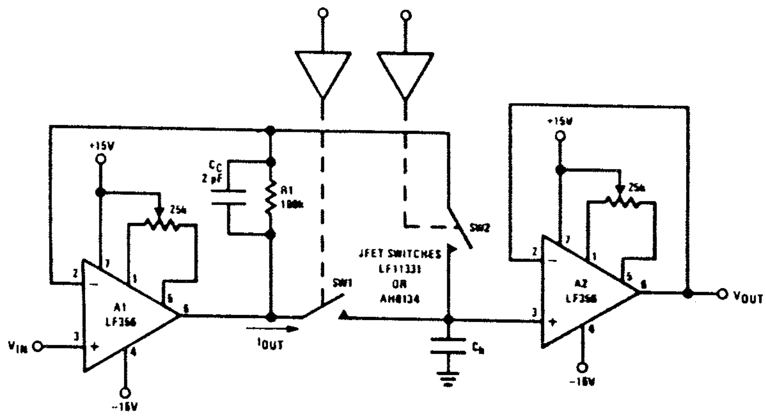
Typical Applications (Continued)

High Impedance, Low Drift Instrumentation Amplifier



- $V_{OUT} = \frac{R3}{R}\left[\frac{2R2}{R1} + 1\right] \Delta V$, $V^- + 2V \le V_{IN}$ common-mode $\le V^+$
- System V_{OS} adjusted via A2 V_{OS} adjust
- Trim R3 to boost up CMRR to 120 dB. Instrumentation amplifier Resistor array RA201 (National Semiconductor) recommended

Fast Sample and Hold



- Both amplifiers (A1, A2) have feedback loops individually closed with stable responses (overshoot negligible)
- Acquisition time T_A, estimated by:

  $T_A \approx \left[\frac{2R_{ON} \cdot V_{IN} \cdot C_h}{S_r}\right]^{1/2}$ provided that:

  $V_{IN} < 2\pi S_r R_{ON} C_h$ and $T_A > \frac{V_{IN} C_h}{I_{OUT(MAX)}}$, R_{ON} is of SW1

  If inequality not satisfied: $T_A \approx \frac{V_{IN} C_h}{20\ mA}$
- LF156 developes full S_r output capability for $V_{IN} \ge 1V$
- Addition of SW2 improves accuracy by putting the voltage drop across SW1 inside the feedback loop
- Overall accuracy of system determined by the accuracy of both amplifiers, A1 and A2

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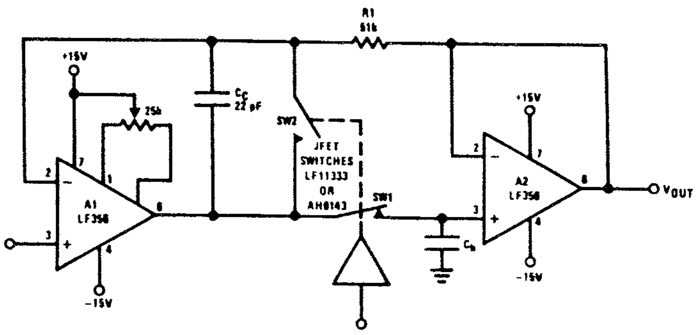
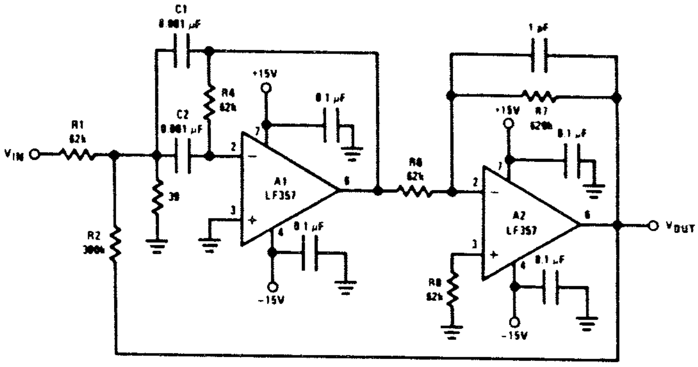
Typical Applications (Continued)

High Accuracy Sample and Hold



- By closing the loop through A2, the V_{OUT} accuracy will be determined uniquely by A1. No V_{OS} adjust required for A2.
- T_A can be estimated by same considerations as previously but, because of the added propagation delay in the feedback loop (A2) the overshoot is not negligible.
- Overall system slower than fast sample and hold
- R1, C_C: additional compensation
- Use LF156 for
  - ▲ Fast settling time
  - ▲ Low V_{OS}

High Q Band Pass Filter

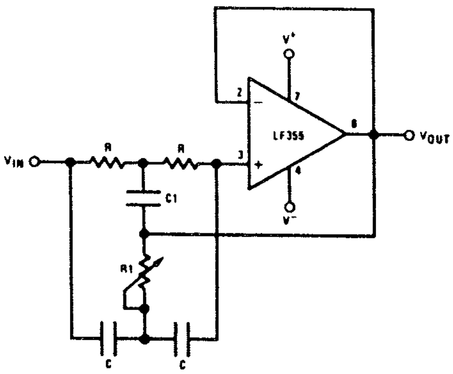


- By adding positive feedback (R2) Q increases to 40
- $f_{BP} = 100$ kHz

$$\frac{V_{OUT}}{V_{IN}} = 10\sqrt{Q}$$

- Clean layout recommended
- Response to a 1 Vp-p tone burst: 300 μs

High Q Notch Filter



- 2R1 = R = 10 MΩ
  2C = C1 = 300 pF
- Capacitors should be matched to obtain high Q
- $f_{NOTCH} = 120$ Hz, notch = −55 dB, Q > 100
- Use LF155 for
  - ▲ Low I_B
  - ▲ Low supply current

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National Semiconductor

Voltage Regulators

LM117/LM217/LM317 3-terminal adjustable regulator

general description

The LM117/LM217/LM317 are adjustable 3-terminal positive voltage regulators capable of supplying in excess of 1.5A over a 1.2V to 37V output range. They are exceptionally easy to use and require only two external resistors to set the output voltage. Further, both line and load regulation are better than standard fixed regulators. Also, the LM117 is packaged in standard transistor packages which are easily mounted and handled.

In addition to higher performance than fixed regulators, the LM117 series offers full overload protection available only in IC's. Included on the chip are current limit, thermal overload protection and safe area protection. All overload protection circuitry remains fully functional even if the adjustment terminal is disconnected.

features

- Adjustable output down to 1.2V
- Guaranteed 1.5A output current
- Line regulation typically 0.01%/V
- Load regulation typically 0.1%
- Current limit constant with temperature
- **100% electrical burn-in**
- Eliminates the need to stock many voltages
- Standard 3-lead transistor package
- 80 dB ripple rejection

Normally, no capacitors are needed unless the device is situated far from the input filter capacitors in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. The adjustment terminal can be bypassed to achieve very high ripple rejections ratios which are difficult to achieve with standard 3-terminal regulators.

Besides replacing fixed regulators, the LM117 is useful in a wide variety of other applications. Since the regulator is "floating" and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input to output differential is not exceeded.

Also, it makes an especially simple adjustable switching regulator, a programmable output regulator, or by connecting a fixed resistor between the adjustment and output, the LM117 can be used as a precision current regulator. Supplies with electronic shutdown can be achieved by clamping the adjustment terminal to ground which programs the output to 1.2V where most loads draw little current.

The LM117K, LM217K and LM317K are packaged in standard TO-3 transistor packages while the LM117H, LM217H and LM317H are packaged in a solid Kovar base TO-5 transistor package. The LM117 is rated for operation from −55°C to +150°C, the LM217 from −25°C to +150°C and the LM317 from 0°C to +125°C. The LM317T and LM317MP, rated for operation over a 0°C to +125°C range, are available in a TO-220 plastic package and a TO-202 package, respectively.

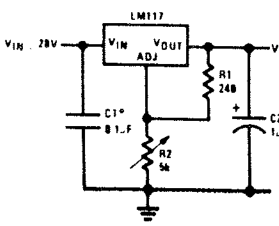
For applications requiring greater output current in excess of 3A and 5A, see LM150 series and LM138 series data sheets, respectively. For the negative complement, see LM137 series data sheet.

LM117 Series Packages and Power Capability

DEVICE	PACKAGE	RATED POWER DISSIPATION	DESIGN LOAD CURRENT
LM117	TO-3	20W	1.5A
LM217 LM317	TO-39	2W	0.5A
LM317T	TO-220	15W	1.5A
LM317M	TO-202	7.5W	0.5A

typical applications

1.2V–25V Adjustable Regulator

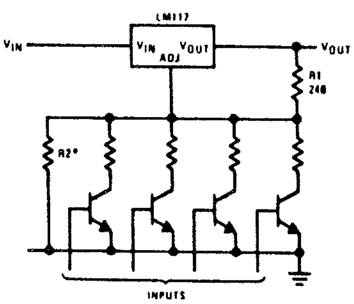


†Optional—improves transient response

*Needed if device is far from filter capacitors

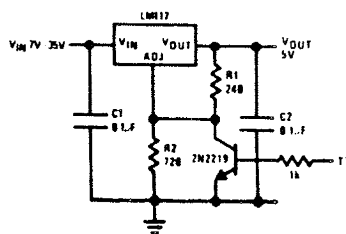
$$^{\dagger\dagger}V_{OUT} = 1.25V\left(1 + \frac{R2}{R1}\right)$$

Digitally Selected Outputs



*Sets maximum V_{OUT}

5V Logic Regulator with Electronic Shutdown*



*Min output ≈ 1.2V

PAPETERIE DES ARTS + MÉTIERS - GENÈVE

LM117/LM217/LM317

absolute maximum ratings

Power Dissipation	Internally limited
Input–Output Voltage Differential	40V
Operating Junction Temperature Range	
LM117	−55°C to +150°C
LM217	−25°C to +150°C
LM317	0°C to +125°C
Storage Temperature	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)	300°C

preconditioning

Burn-In in Thermal Limit	**100% All Devices**

electrical characteristics (Note 1)

PARAMETER	CONDITIONS	LM117/217			LM317			UNITS
		MIN	TYP	MAX	MIN	TYP	MAX	
Line Regulation	T_A = 25°C, 3V ≤ $V_{IN} - V_{OUT}$ ≤ 40V (Note 2)		0.01	0.02		0.01	0.04	%/V
Load Regulation	T_A = 25°C, 10 mA ≤ I_{OUT} ≤ I_{MAX}							
	V_{OUT} ≤ 5V, (Note 2)		5	15		5	25	mV
	V_{OUT} ≥ 5V, (Note 2)		0.1	0.3		0.1	0.5	%
Thermal Regulation	T_A = 25°C, 20 ms Pulse		0.03	0.07		0.04	0.07	%/W
Adjustment Pin Current			50	100		50	100	µA
Adjustment Pin Current Change	10 mA ≤ I_L ≤ I_{MAX} 2.5V ≤ (V_{IN}−V_{OUT}) ≤ 40V		0.2	5		0.2	5	µA
Reference Voltage	3 ≤ (V_{IN}−V_{OUT}) ≤ 40V, (Note 3) 10 mA ≤ I_{OUT} ≤ I_{MAX}, P ≤ P_{MAX}	1.20	1.25	1.30	1.20	1.25	1.30	V
Line Regulation	3V ≤ $V_{IN} - V_{OUT}$ ≤ 40V, (Note 2)		0.02	0.05		0.02	0.07	%/V
Load Regulation	10 mA ≤ I_{OUT} ≤ I_{MAX}, (Note 2)							
	V_{OUT} ≤ 5V		20	50		20	70	mV
	V_{OUT} ≥ 5V		0.3	1		0.3	1.5	%
Temperature Stability	T_{MIN} ≤ T_j ≤ T_{MAX}		1			1		%
Minimum Load Current	V_{IN}−V_{OUT} = 40V		3.5	5		3.5	10	mA
Current Limit	V_{IN}−V_{OUT} ≤ 15V							
	K and T Package	1.5	2.2		1.5	2.2		A
	H and P Package	0.5	0.8		0.5	0.8		A
	V_{IN}−V_{OUT} = 40V							
	K and T Package		0.4			0.4		A
	H and P Package		0.07			0.07		A
RMS Output Noise, % of V_{OUT}	T_A = 25°C, 10 Hz ≤ f ≤ 10 kHz		0.003			0.003		%
Ripple Rejection Ratio	V_{OUT} = 10V, f = 120 Hz		65			65		dB
	C_{ADJ} = 10µF	66	80		66	80		dB
Long-Term Stability	T_A = 125°C		0.3	1		0.3	1	%
Thermal Resistance, Junction to Case	H Package		12	15		12	15	°C/W
	K Package		2.3	3		2.3	3	°C/W
	T Package					4		°C/W
	P Package					12		°C/W

Note 1: Unless otherwise specified, these specifications apply: −55°C ≤ T_j ≤ +150°C for the LM117, −25°C ≤ T_j ≤ +150°C for the LM217 and 0°C ≤ T_j ≤ +125°C for the LM317; V_{IN}−V_{OUT} = 5V and I_{OUT} = 0.1A for the TO-5 and TO-202 packages and I_{OUT} = 0.5A for the TO-3 package and TO-220 package. Although power dissipation is internally limited, these specifications are applicable for power dissipations of 2W for the TO-5 and TO-202 and 20W for the TO-3 and TO-220. I_{MAX} is 1.5A for the TO-3 and TO-220 package and 0.5A for the TO-5 and TO-202 package.

Note 2: Regulation is measured at constant junction temperature, using pulse testing with a low duty cycle. Changes in output voltage due to heating effects are covered under the specification for thermal regulation.

Note 3: Selected devices with tightend tolerance reference voltage available.

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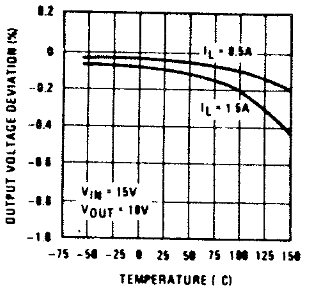
LM117/LM217/LM317

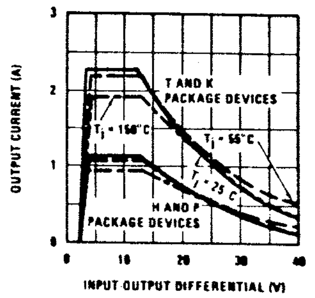
1

typical performance characteristics (K and T Packages)

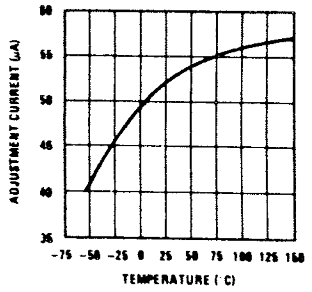
Load Regulation



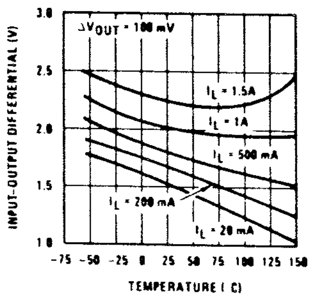
Current Limit



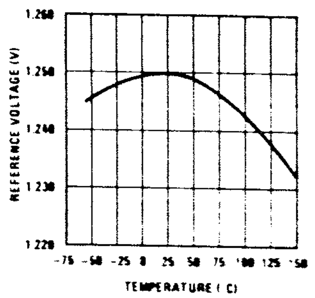
Adjustment Current



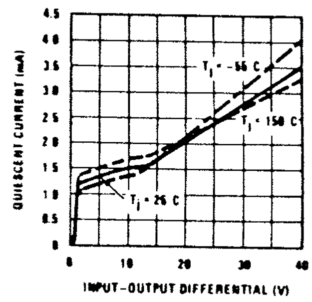
Dropout Voltage



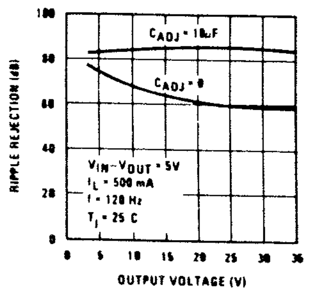
Temperature Stability



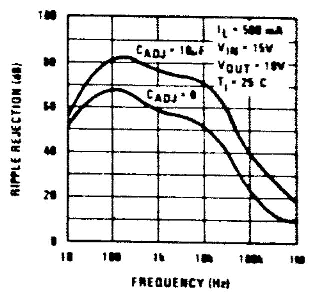
Minimum Operating Current



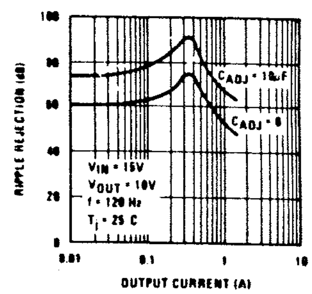
Ripple Rejection



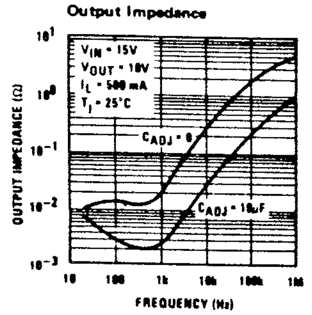
Ripple Rejection



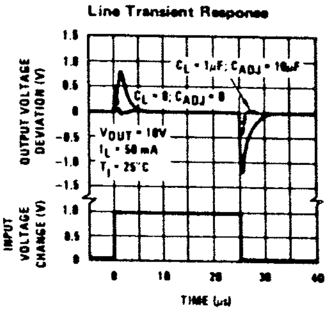
Ripple Rejection



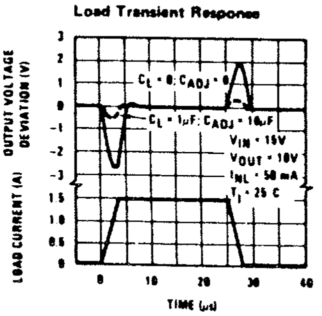
Output Impedance



Line Transient Response



Load Transient Response



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application hints

In operation, the LM117 develops a nominal 1.25V reference voltage, V_{REF}, between the output and adjustment terminal. The reference voltage is impressed across program resistor R1 and, since the voltage is constant, a constant current I_1 then flows through the output set resistor R2, giving an output voltage of

$$V_{OUT} = V_{REF}\left(1 + \frac{R2}{R1}\right) + I_{ADJ}R2$$

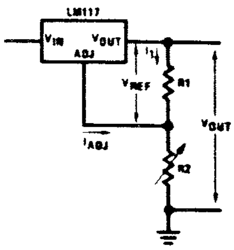

FIGURE 1.

Since the 100μA current from the adjustment terminal represents an error term, the LM117 was designed to minimize I_{ADJ} and make it very constant with line and load changes. To do this, all quiescent operating current is returned to the output establishing a minimum load current requirement. If there is insufficient load on the output, the output will rise.

External Capacitors

An input bypass capacitor is recommended. A 0.1μF disc or 1μF solid tantalum on the input is suitable input bypassing for almost all applications. The device is more sensitive to the absence of input bypassing when adjustment or output capacitors are used but the above values will eliminate the possibility of problems.

The adjustment terminal can be bypassed to ground on the LM117 to improve ripple rejection. This bypass capacitor prevents ripple from being amplified as the output voltage is increased. With a 10μF bypass capacitor 80 dB ripple rejection is obtainable at any output level. Increases over 10μF do not appreciably improve the ripple rejection at frequencies above 120 Hz. If the bypass capacitor is used, it is sometimes necessary to include protection diodes to prevent the capacitor from discharging through internal low current paths and damaging the device.

In general, the best type of capacitors to use are solid tantalum. Solid tantalum capacitors have low impedance even at high frequencies. Depending upon capacitor construction, it takes about 25μF in aluminum electrolytic to equal 1μF solid tantalum at high frequencies. Ceramic capacitors are also good at high frequencies; but some types have a large decrease in capacitance at frequencies around 0.5 MHz. For this reason, 0.01μF disc may seem to work better than a 0.1μF disc as a bypass.

Although the LM117 is stable with no output capacitors, like any feedback circuit, certain values of external capacitance can cause excessive ringing. This occurs with values between 500 pF and 5000 pF. A 1μF solid tantalum (or 25μF aluminum electrolytic) on the output swamps this effect and insures stability.

Load Regulation

The LM117 is capable of providing extremely good load regulation but a few precautions are needed to obtain maximum performance. The current set resistor connected between the adjustment terminal and the output terminal (usually 240Ω) should be tied directly to the output of the regulator rather than near the load. This eliminates line drops from appearing effectvely in series with the reference and degrading regulation. For example, a 15V regulator with 0.05Ω resistance between the regulator and load will have a load regulation due to line resistance of 0.05Ω x I_L. If the set resistor is connected near the load the effective line resistance will be 0.05Ω (1 + R2/R1) or in this case, 11.5 times worse.

Figure 2 shows the effect of resistance between the regulator and 240Ω set resistor.

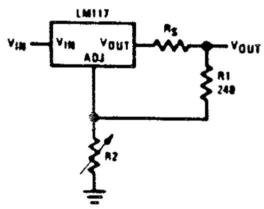

FIGURE 2. Regulator with Line Resistance in Output Lead

With the TO-3 package, it is easy to minimize the resistance from the case to the set resistor, by using two separate leads to the case. However, with the TO-5 package, care should be taken to minimize the wire length of the output lead. The ground of R2 can be returned near the ground of the load to provide remote ground sensing and improve load regulation.

Protection Diodes

When external capacitors are used with *any* IC regulator it is sometimes necessary to add protection diodes to prevent the capacitors from discharging through low current points into the regulator. Most 10μF capacitors have low enough internal series resistance to deliver 20A spikes when shorted. Although the surge is short, there is enough energy to damage parts of the IC.

When an output capacitor is connected to a regulator and the input is shorted, the output capacitor will discharge into the output of the regulator. The discharge

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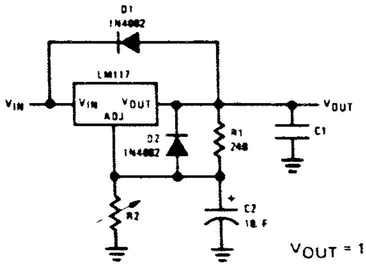
LM117/LM217/LM317

application hints (con't)

current depends on the value of the capacitor, the output voltage of the regulator, and the rate of decrease of V_{IN}. In the LM117, this discharge path is through a large junction that is able to sustain 15A surge with no problem. This is not true of other types of positive regulators. For output capacitors of 25µF or less, there is no need to use diodes.

The bypass capacitor on the adjustment terminal can discharge through a low current junction. Discharge occurs when *either* the input or output is shorted. Internal to the LM117 is a 50Ω resistor which limits the peak discharge current. No protection is needed for output voltages of 25V or less and 10µF capacitance. *Figure 3* shows an LM117 with protection diodes included for use with outputs greater than 25V and high values of output capacitance.



$$V_{OUT} = 1.25V\left(1 + \frac{R2}{R1}\right) + R2I_{ADJ}$$

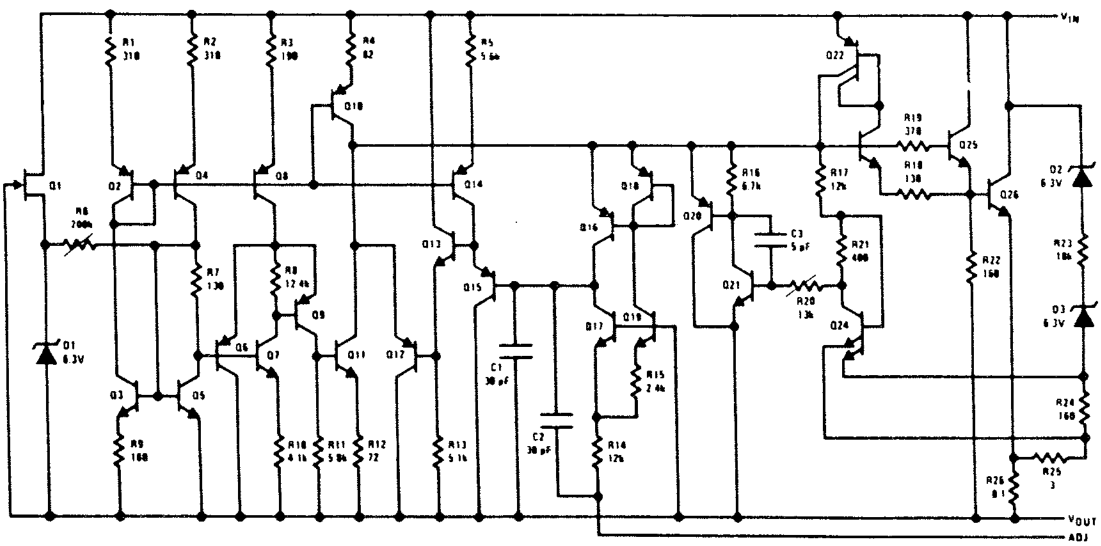
D1 protects against C1

D2 protects against C2

FIGURE 3. Regulator with Protection Diodes

1

schematic diagram



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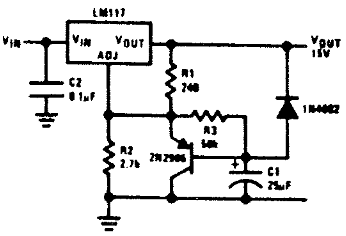
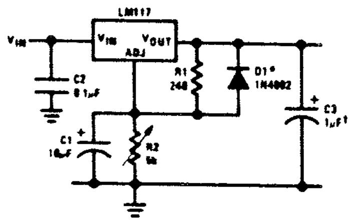
typical applications (con't)

Slow Turn-On 15V Regulator



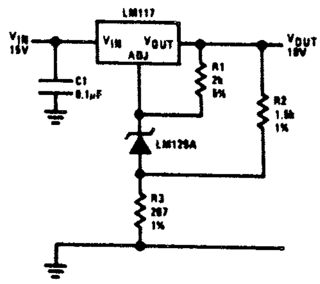
Adjustable Regulator with Improved Ripple Rejection



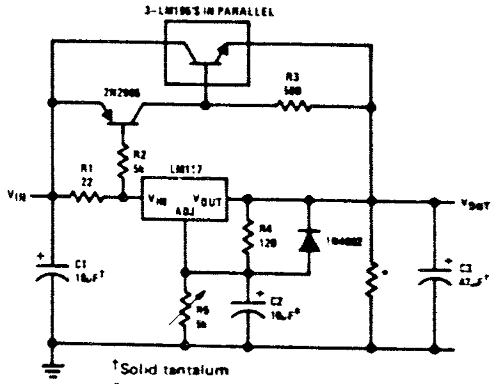
†Solid tantalum

*Discharges C1 if output is shorted to ground

High Stability 10V Regulator



High Current Adjustable Regulator

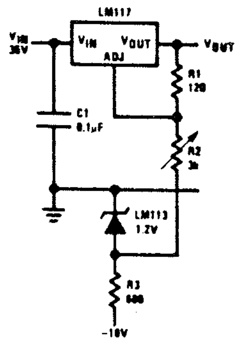


†Solid tantalum

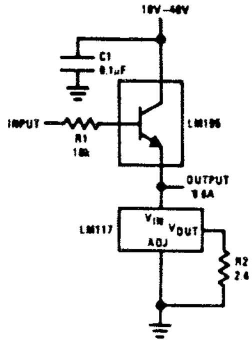
*Minimum load current = 30 mA

‡Optional—improves ripple rejection

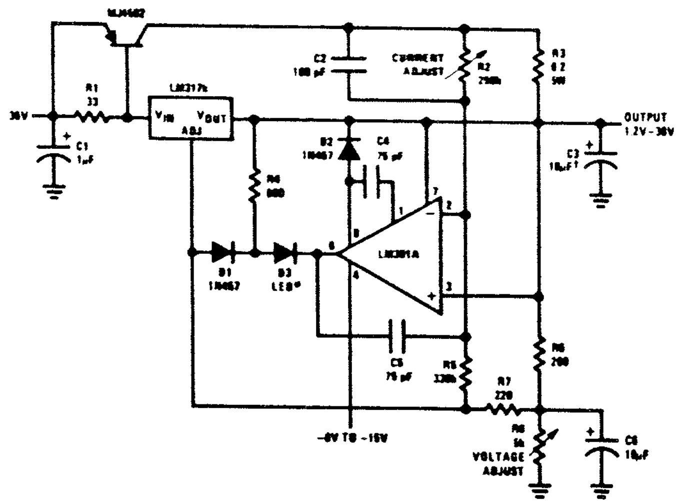
0 to 30V Regulator



Power Follower



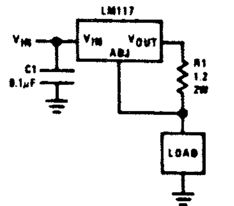
5A Constant Voltage/Constant Current Regulator



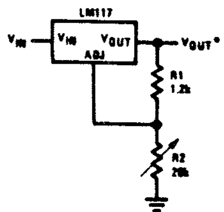
†Solid tantalum

*Lights in constant current mode

1A Current Regulator



1.2V–20V Regulator with Minimum Program Current



*Minimum load current ≈ 4 mA

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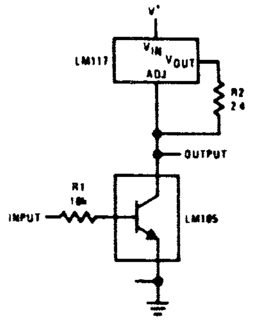
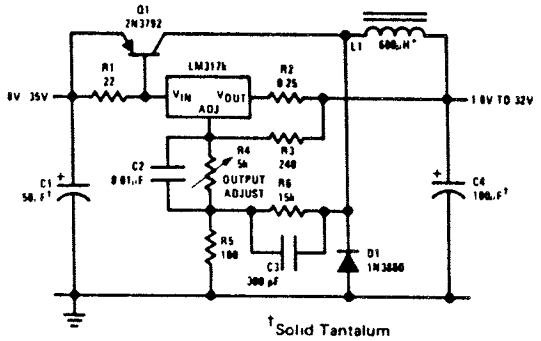
typical applications (con't)

High Gain Amplifier



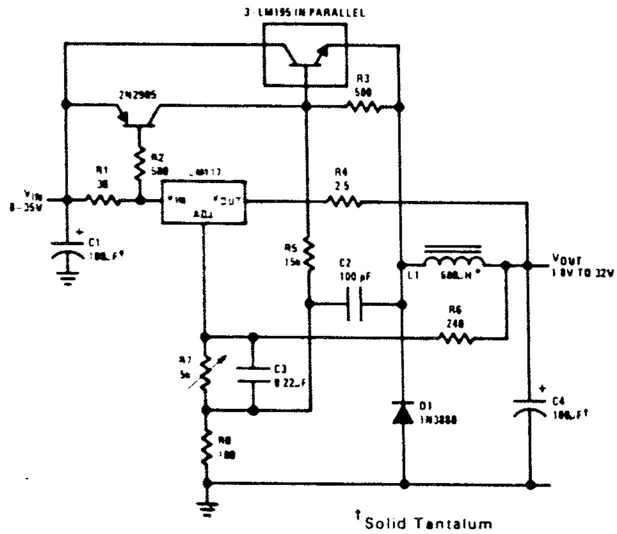
Low Cost 3A Switching Regulator



†Solid Tantalum

*Core—Arnold A-254168-2 60 turns

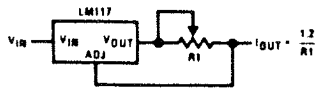
4A Switching Regulator with Overload Protection



†Solid Tantalum

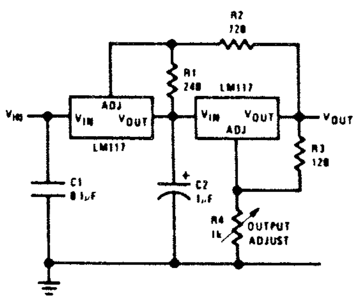
*Core Arnold A-254168-2 60 turns

Precision Current Limiter

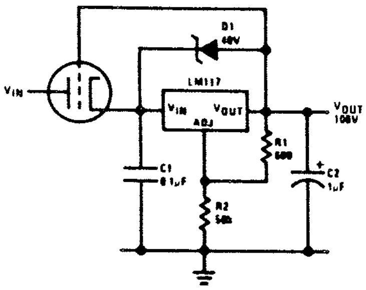


*0.8Ω ≤ R1 ≤ 120Ω

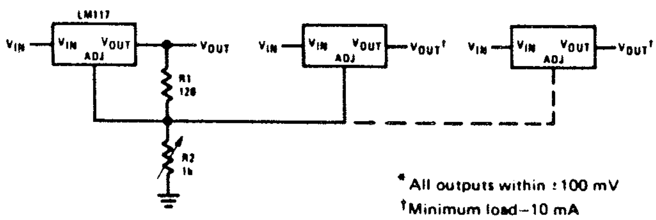
Tracking Preregulator



High Voltage Regulator



Adjusting Multiple On-Card Regulators with Single Control*



*All outputs within ±100 mV

†Minimum load—10 mA

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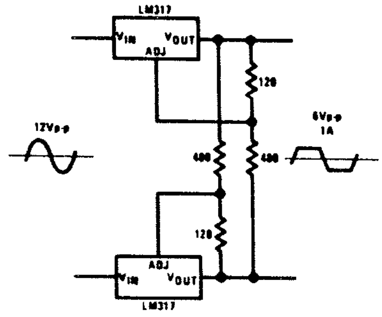
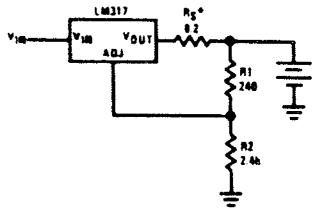
typical applications (con't)

AC Voltage Regulator

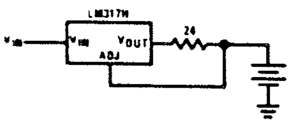


12V Battery Charger

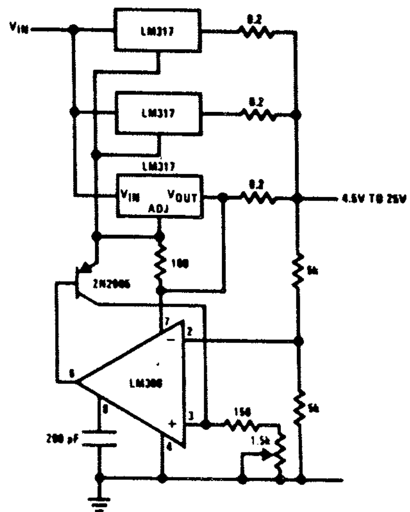


*R_S—sets output impedance of charger $Z_{OUT} = R_S\left(1 + \frac{R2}{R1}\right)$ Use of R_S allows low charging rates with fully charged battery.

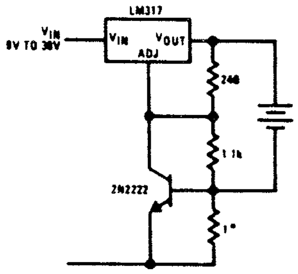
50 mA Constant Current Battery Charger



Adjustable 4A Regulator



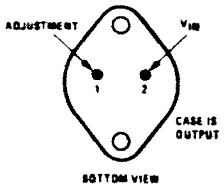
Current Limited 6V Charger



*Sets peak current (0.6A for 1Ω)

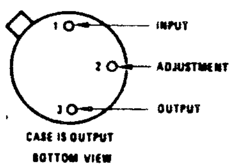
connection diagrams

(TO-3 Steel) Metal Can Package



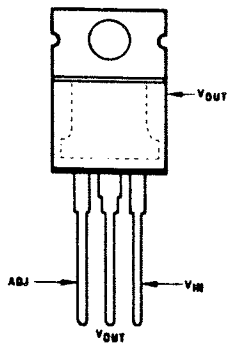
Order Number:
LM117K STEEL
LM217K STEEL
LM317K STEEL
See NS Package K02A

(TO-39) Metal Can Package



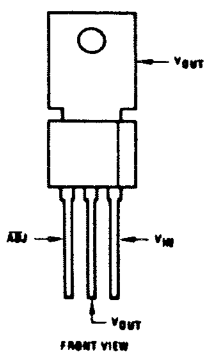
Order Number:
LM117H
LM217H
LM317H
See NS Package H03A

(TO-220) Plastic Package



Order Number:
LM317T
See NS Package T03B

(TO-202) Plastic Package



Order Number:
LM317MP
See NS Package P03A

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