

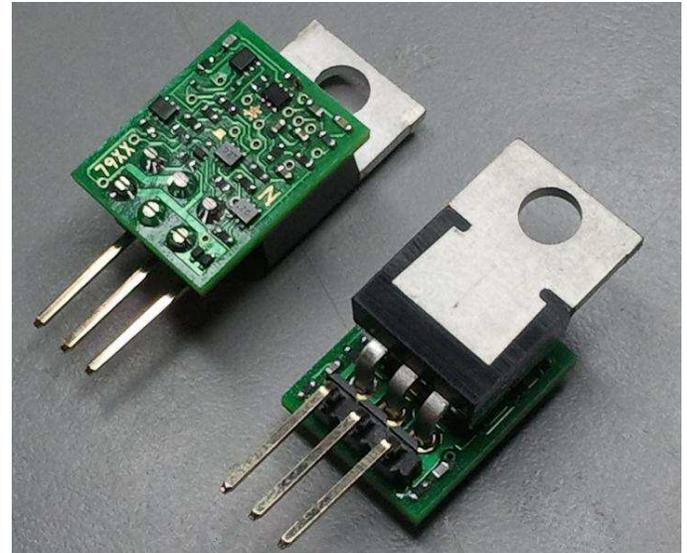


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Discrete Voltage Regulator Family

Description :

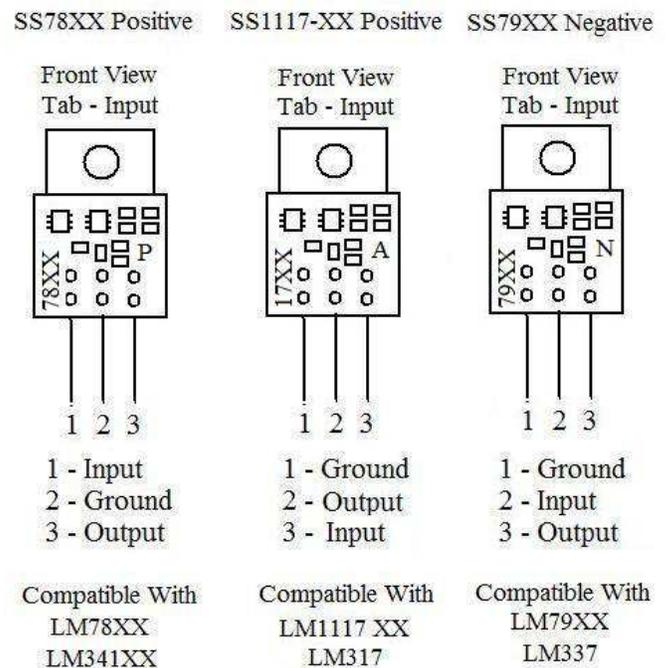
The SS78XX / SS1117XX / SS79XX family of discrete voltage regulators are available in a TO-220 compatible package and are made to drop-in replace inferior monolithic voltage regulators. They are available in a wide output voltage range from +/- 3.3 to +/- 24 volts with over 1 amp of available output current.



Features:

- - 125dB input rejection
- 3.2uV RMS Output Noise in a 20Khz Bandwidth @ 5 Vo
- 2mV Load Regulation
- Output Current Of 1 Amp With Proper Heat Sinking
- Over Current Protection
- Output Decoupling Capacitor On - Board
- TO220 Compatible Package
- Stable With Ceramic And Low ESR Output Capacitors
- Available In Positive And Negative Fixed Outputs
- Available In 3 Different Industry Standard Pin-outs
- Fully Discrete Design Including The Error Amplifier

Pin Assignments



Note that additional circuit modifications are required only when replacing an "adjustable" regulator such as the LM317 / LM337 / LM117-ADJ. When replacing an adjustable regulator, the adjust or ADJ pin must be tied to ground.

Sparkos Labs SS78XX, SS1117XX and SS79XX Discrete Voltage Regulator Family

All SS78XX Devices are Positive polarity, and the "XX" designates the output voltage.
 All SS1117XX Devices are Positive polarity, and the "XX" designates the output voltage.
 All SS79XX Devices are Negative polarity, and the "XX" designates the output voltage.
 Below is a table of standard output voltages and their respective device number.
 Any custom output voltage from +/- 3.3V to +/- 30V is possible.
 Contact Sparkos Labs for more information

Device Number	Polarity	Output Voltage	Board Marking	Device Sticker
SS783.3	Positive	+3.3V	P	P3.3V
SS7805	Positive	+5V	P	P5V
SS786.2	Positive	+6.2V	P	P6.2V
SS7809	Positive	+9V	P	P9V
SS7812	Positive	+12V	P	P12V
SS7815	Positive	+15V	P	P15V
SS7818	Positive	+18V	P	P18V
SS7824	Positive	+24	P	P24V
SS1117-3.3	Positive	+3.3V	A	P3.3V
SS1117-05	Positive	+5V	A	P5V
SS1117-6.2	Positive	+6.2V	A	P6.2V
SS1117-09	Positive	+9V	A	P9V
SS1117-12	Positive	+12V	A	P12V
SS1117-15	Positive	+15V	A	P15V
SS1117-18	Positive	+18V	A	P18V
SS1117-24	Positive	+24	A	P24V
SS793.3	Negative	-3.3V	N	N3.3V
SS7905	Negative	-5V	N	N5V
SS796.2	Negative	-6.2V	N	N6.2V
SS7909	Negative	-9V	N	N9V
SS7912	Negative	-12V	N	N12V
SS7915	Negative	-15V	N	N15V
SS7918	Negative	-18V	N	N18V
SS7924	Negative	-24	N	N24V

Absolute Maximum Ratings					
Exceeding the Absolute Maximum Ratings could result in permanent damage to the device. These ratings are absolute maximum, and are not recommended for normal operation.					
Symbol	Parameter	Conditions	Rating	Unit	Notes
Vin	Input Voltage	SS78XX / SS1117XX	+43V	V	
		SS79XX	-43V		
Io	Output Current - Short To GND	SS78XX / SS1117XX	1.5	A	1
		SS79XX	-1.5	A	1
Pdiss	Total Power Dissipation	Tc = 25°C	50	W	2
RθJC	Thermal Resistance, Junction to Case		2.5	°C/W	
RθJA	Thermal Resistance, Junction to Ambient		62.5	°C/W	
Top	Operating Ambient Temperature		-25 to +85	°C	
Tstg	Storage Temperature		-40 to +120	°C	

Notes:

- 1 The output current is internally limited
- 2 This specification assumes adequate heatsinking

Performance Characteristics							
Unless otherwise noted, Ta = 25°C, Vin = Vo+5V, and the given specification applies to the entire regulator family							
Symbol	Parameter	Conditions	Min	Typ	Max	Units	Notes
Vin	Input Voltage	SS78XX/SS1117XX	Vo+2		+40	V	
		SS79XX	Vo-2		-40	V	
Iq	Quiescent Current		14	18	22	mA	1
Iomin	Minimum Output Current			0		mA	
Vo	Output Voltage Accuracy		-1.5	0	1.5	%	
Vdrop	Dropout Voltage	1 Amp output current		1.85	2	V	2
Zout	Output Impedance			2		mΩ	
Io	Maximum Output Current			1		A	
RR	Ripple Rejection	F = 100Hz		-125		dB	3
Rload	Load Regulation	Io = 0 to 1A		1.8		mV	
N	RMS Output Noise Voltage 20Hz - 20KHz Bandwidth	@ +/- 5Vo		3.5		μV RMS	
		@ +/- 15Vo		6		μV RMS	
		@ +/- 24Vo		10.2		μV RMS	

Notes:

- 1 Quiescent current is supply voltage dependent, and is graphed in the Typical Performance Characteristics section of this data sheet.
- 2 Drop out voltage is load current dependent, and is graphed in the Typical Performance Characteristics section of this data sheet.
- 3 Input rejection is graphed across frequency in the Typical Performance Characteristics section of this data sheet.

Application Circuits:

Figure 1: Typical Application Circuits

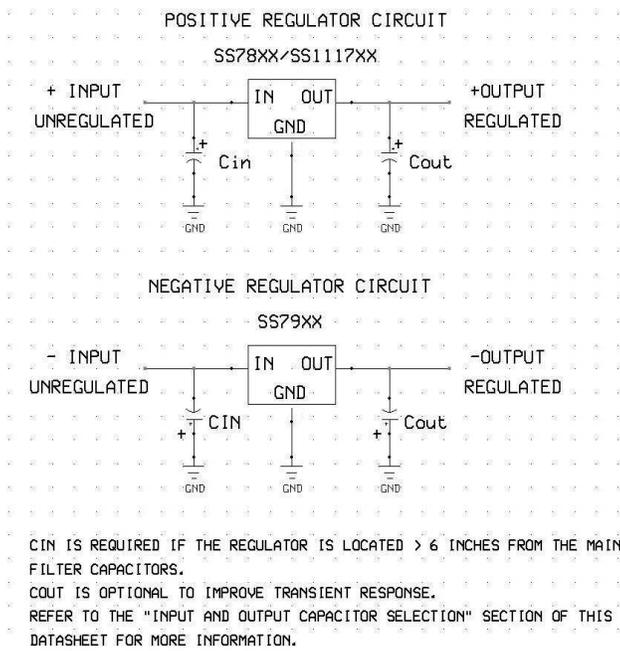
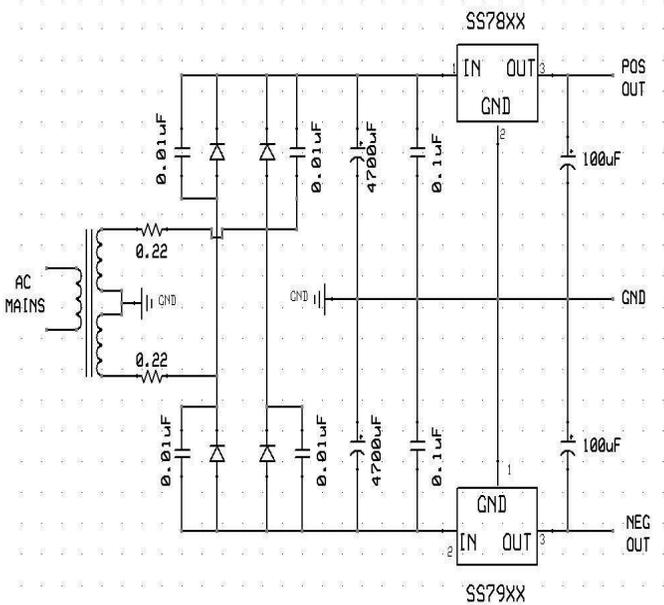
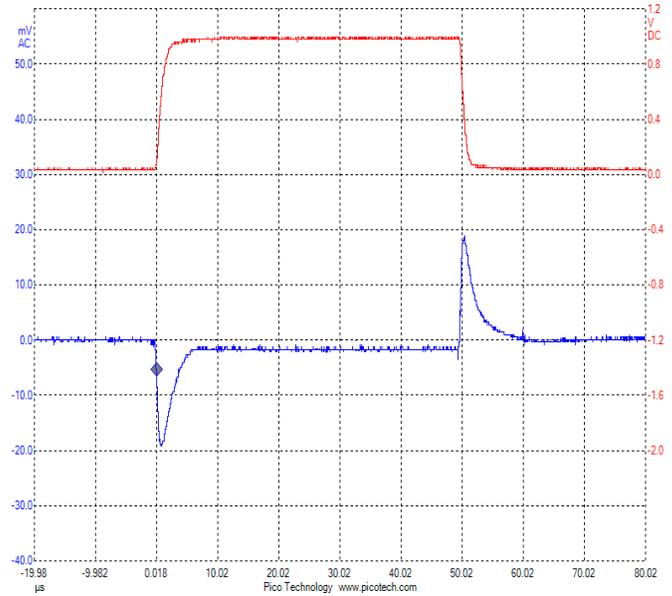


Figure 2: Complete Power Supply



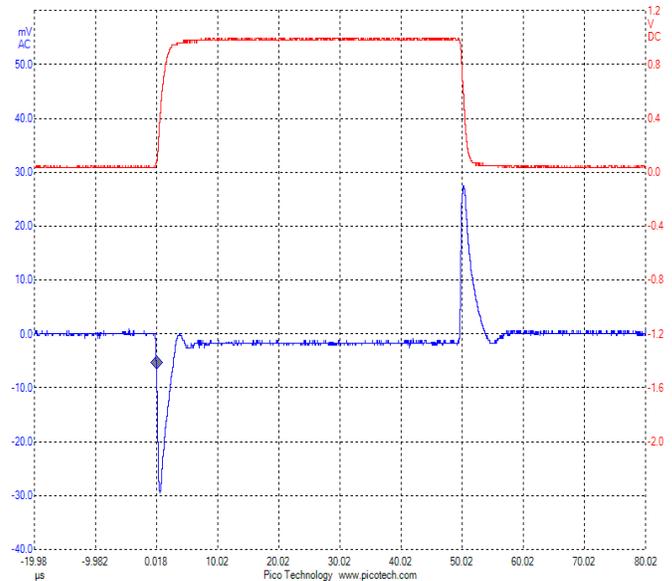
SS78XX / SS1117XX / SS79XX Typical Performance Characteristics:

Figure 3: Positive Transient Response



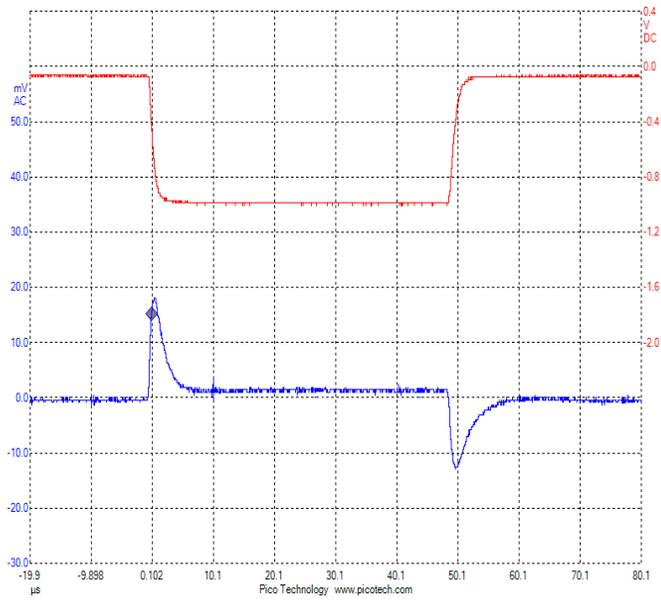
$V_o = +15V$, $V_{in} = +20V$, Load Step = 50mA to 1A
 $C_o = 100\mu F$, 10uS / DIV, 10mV/DIV Load pulse waveform is across 1Ω .

Figure 4: Positive Transient Response



$V_o = +15V$, $V_{in} = 20V$, Load Step = 50mA to 1A
 $C_o = 0\mu F$, 10uS / DIV, 10mV/DIV Load pulse waveform is across 1Ω .

Figure 5: Negative Transient Response



$V_o = -15V$, $V_{in} = -20V$, Load Step = 50mA to 1A
 $C_o = 100\mu F$, 10uS / DIV, 10mV/DIV, Load pulse waveform is across 1Ω.

Figure 7:

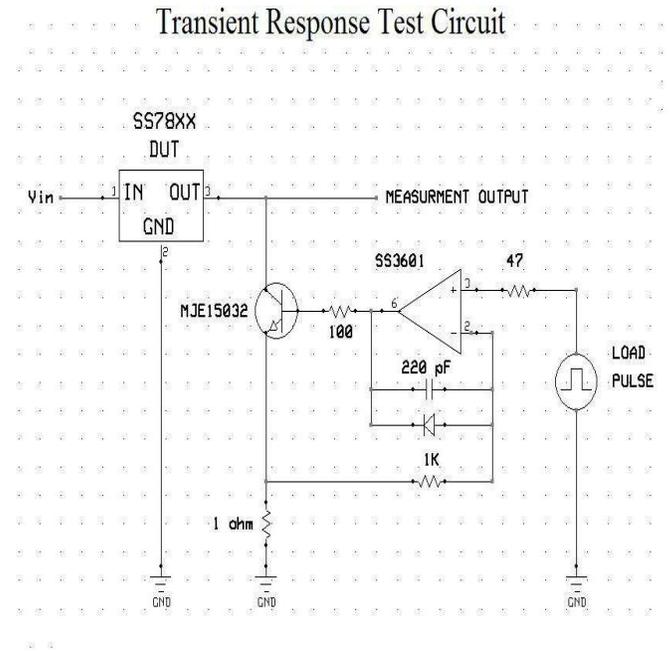
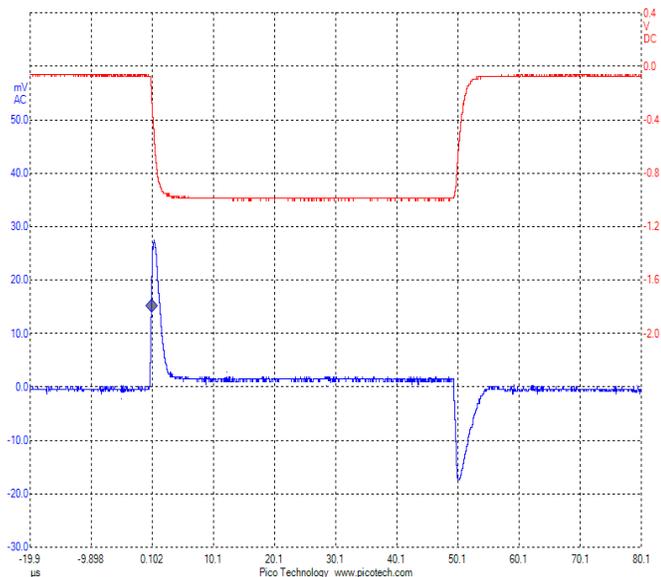


Figure 6: Negative Transient Response



$V_o = +15V$, $V_{in} = 20V$, Load Step = 50mA to 1A
 $C_o = 0\mu F$, 10uS / DIV, 10mV/DIV Load pulse waveform is across 1Ω.

Figure 8:

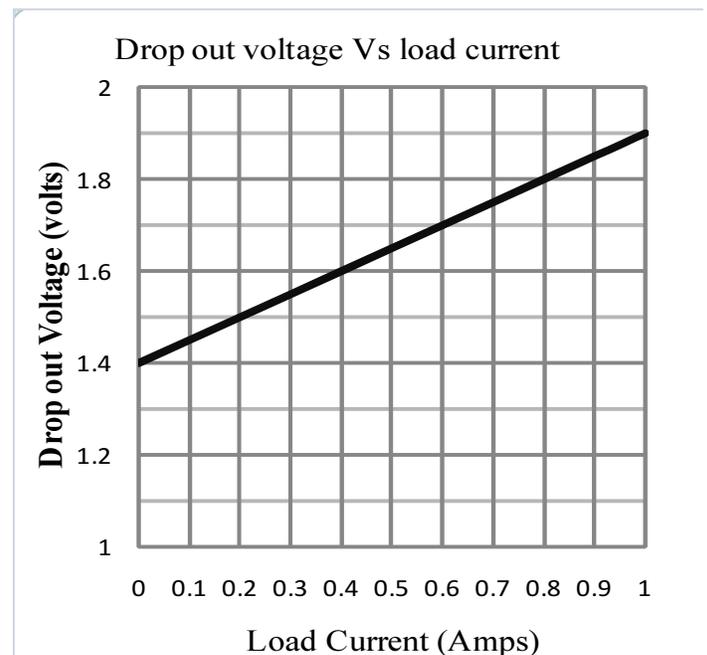


Figure 9:

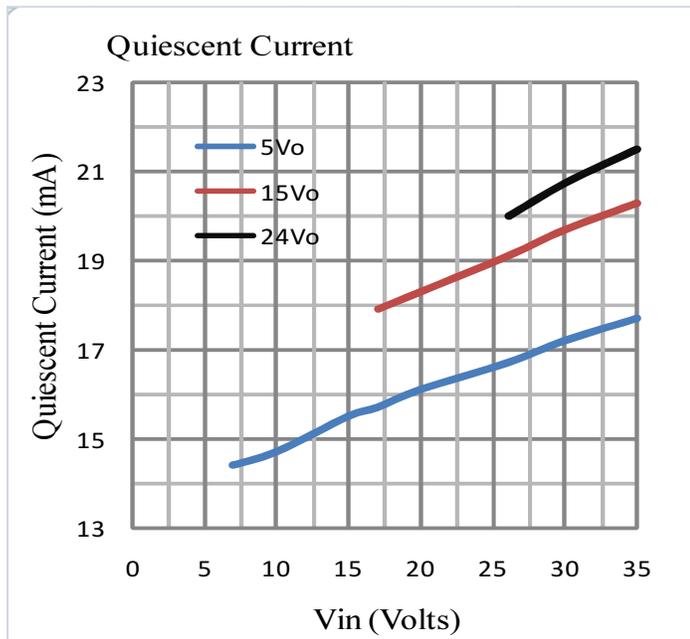


Figure 11:

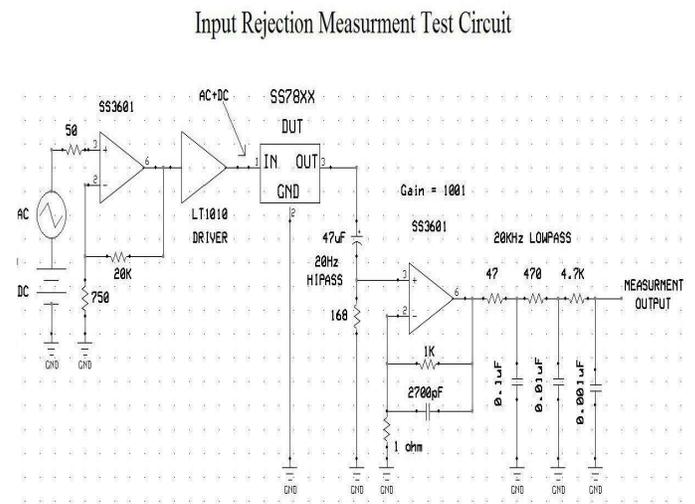


Figure 10:

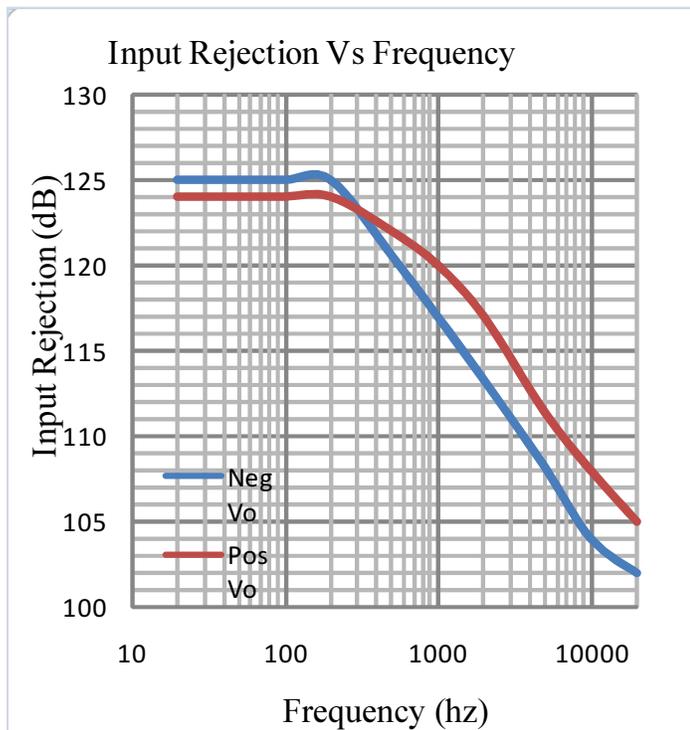
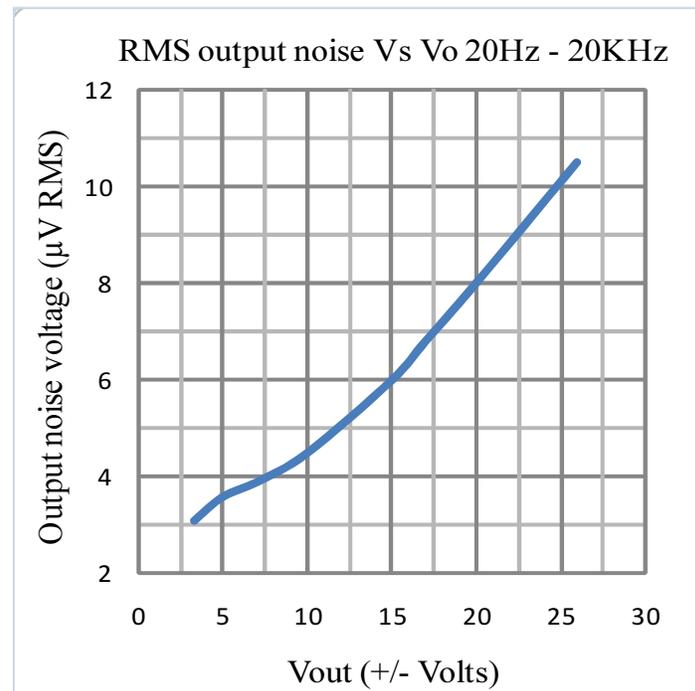


Figure 12:



$V_o = \pm 15V$ $V_{in} = 25VDC + 2VRMS$

Figure 13:

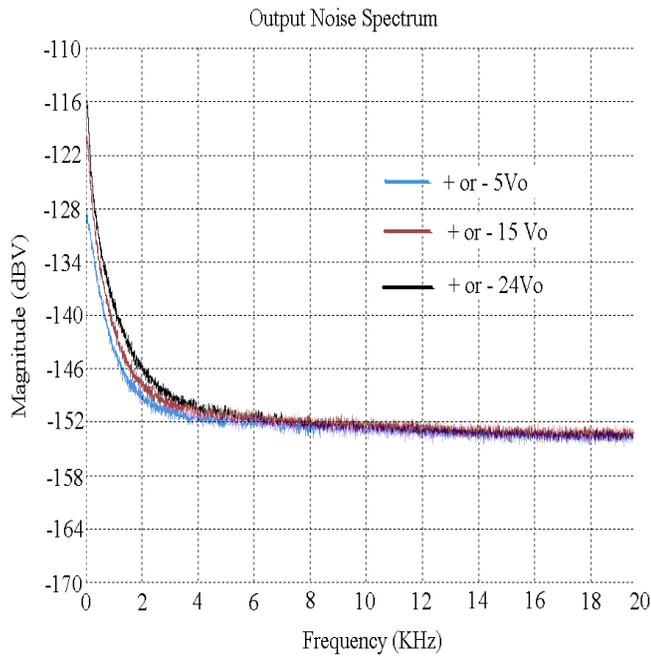


Figure 15:

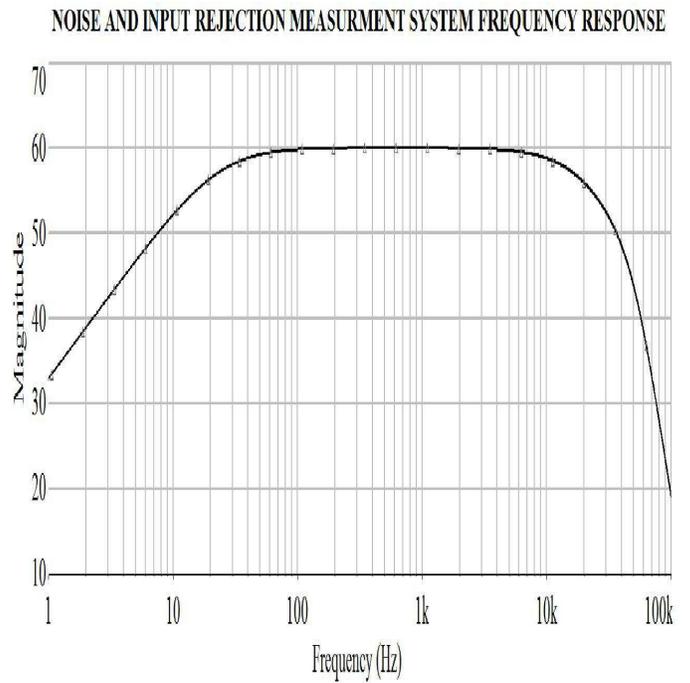


Figure 14:

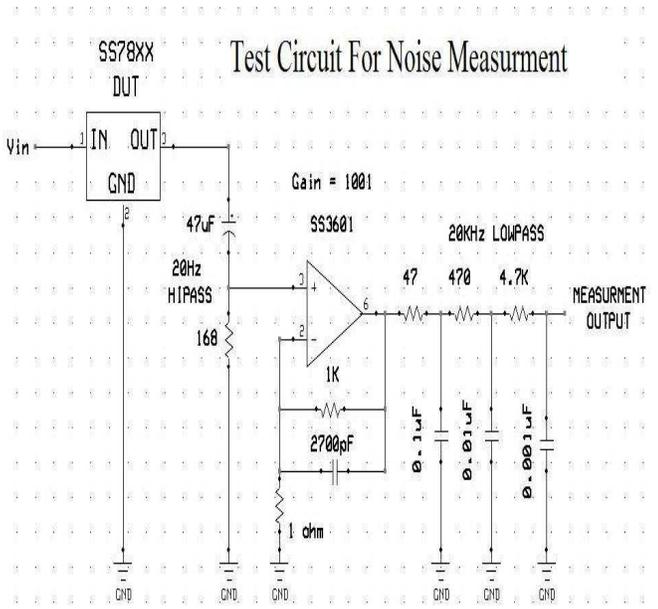
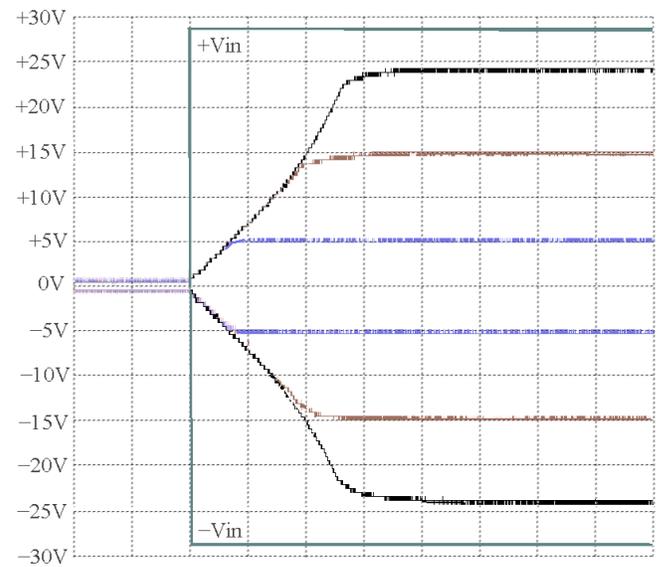


Figure 16: Startup Profile



5mS / DIV, Vo = +/- 5V, +/-15V, +/-24V

Typical Performance Characteristics:

Transient Response: Figures 3 - 6 display the device transient response with and without external output capacitors. It can be seen that the best transient response is obtained by using an external 100 μ F output capacitor located close to the device output. A Panasonic EEU - FR1H101B type capacitor (100 μ F 50V 65m Ω ESR) is the recommended output capacitor. Using this output capacitor increases the transient load current delivery of the device which decreases the amplitude of the transient response "spikes" that occur on the edges of the load pulse. Using an external output capacitor such as this will reduce the regulators bandwidth slightly and increase settling time. The transient response of these devices is consistent across the entire device family regardless of the output voltage. All transient response measurements in Figures 3 - 6 were made with the device soldered into place. No sockets were used for these tests as socketing the device degrades these measurements.

Input Rejection: The input rejection of these devices is pretty consistent across different input and output voltages. It will degrade slightly (4 dB or so) as the input voltage gets within a volt or two of the dropout voltage. Input rejection is plotted across frequency in Figure 10. The measurements in Figure 10 were made with the device soldered into place, and no socket was used as socketing the device degrades this measurement.

Noise Performance: These discrete voltage regulators utilize the lowest noise voltage reference available on the market in a SOT 23 package. Even so, most of the total device noise is still attributed to the voltage reference. To combat this, a two pole filter composed of R3, C1, R5, and C2 in the simplified schematic is used to filter and remove the bulk of the higher frequency noise of the reference. Virtually all of the remaining noise is therefore low

frequency in nature where the filtering is less effective. This can be seen in the noise spectral distribution plot of Figure 13. Having the noise concentrated in the low frequency region is desirable as the circuits' that the device will be powering will almost certainly have higher PSRR at lower frequencies.

The overall noise of the device gets worse at higher output voltages as detailed in Figure 12. The amount of input voltage, and the type and size of input and output capacitors have virtually no affect on device noise performance.

Discrete is Better: These discrete voltage regulators will outperform all monolithic voltage regulators in a TO-220 package in input rejection, output noise, transient response, and line and load regulation. Figure 17 gives a table comparing these discrete devices to a wide array of monolithic voltage regulators.

The discrete design of these devices allows for numerous internal capacitors which are impossible to fabricate in a Monolithic IC. There is an on-board output decoupling capacitor which eliminates the need to add one externally. The error amplifier of the device is also fully discrete and is based on the SS3601 discrete op amp slightly modified for this application. The internal reference voltage is a precision shunt reference with post RC filtering for extremely low noise performance.

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Figure 17: Voltage Regulator Comparison

Device	Noise	Input Rejection	Load Regulation
SS7812	5.3μV	124dB	2mV
LM7812	75 μ V	72dB	8mV
LM340-12	75 μ V	72dB	8mV
LM317	360 μ V	80dB	12mV
LM1117-ADJ	75 μ V	75dB	24mV
LT1086	360 μ V	60dB	12mV
MIC29300	260 μ V	Unspecified	24mV
LT123/LT323	20 μ V	80dB	25mV
LT117/LT317	120 μ V	80dB	5mV

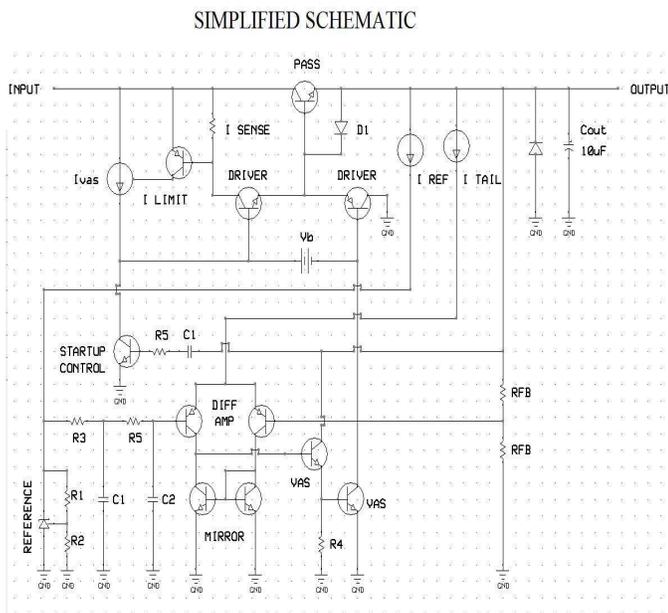
A Simplified schematic of the device can be found in Figure 18, and in reality, the device consists of 17 transistors, 6 diodes, 30 resistors, 9 capacitors, and a precision shunt voltage reference.

The simplified schematic in Figure 18 is for a positive regulator. The negative version of these discrete devices is identical except that all component polarities are reversed. NPN transistors become PNPs and vice versa, and all polarized components are likewise reversed in the negative version of these devices.

Protection Features: These discrete voltage regulator devices employ a myriad of protection features, most of which are not shown on the simplified schematic. Both the forward and reverse output current is limited to 1 Amp and 30mA respectively. The output is protected from being pulled to the opposite polarity by an internal output protection diode. The error amplifier inputs are protected by back to back schottkey diodes in the event that the inputs are driven apart. This condition happens when the device is out of regulation like during startup, dropout, or current limit. These devices do not have any thermal limit or thermal protection. As such, one should take care in ensuring that the device is adequately heat sunk.

Theory Of Operation :

Figure 18:



Overview: The SS78XX / SS1117XX / SS79XX discrete voltage regulators are a series pass design with a fully discrete error amplifier that compares a reference voltage to the feedback voltage, and in turn controls the pass device.

Startup: These devices will begin to supply an output voltage from the moment an input voltage is supplied without any Vin to Output delay as displayed in Figure 16. The output voltage will typically step a volt or so immediately, and then ramp up to the regulated Vout at a rate of 1.5V/mS. This ramping of Vout is controlled by Qstartup in the simplified schematic. There is no output voltage overshoot, and no input voltage ramping time requirement for startup.

Current Limit: These devices can supply up to 1 Amp of output current under all operating conditions. The current limit of the device is therefore set to be higher, and its actual value will range from 1.2 to 1.6 Amps depending on V_{in} , V_{out} , and the temperature of the pass transistor. In order to obtain high output currents, proper heat sinking of the device must be employed. While the current limit feature of the device will prevent instantaneous destruction from short circuits, the device may still fail from overheating if the short circuit is prolonged and the heat sinking is inadequate. Current limiting is accomplished by sensing and limiting the drive current to the pass transistor as opposed to directly sensing the load current. This eliminates the low value (0.5 ohm or so) resistor that usually falls in series with the load that provides current sensing and limiting. Eliminating this resistor improves both the output impedance and transient response.

Output recovery from an over current condition will follow the usual regulator startup profile shown in Fig 16, which is controlled and dictated by $Q_{startup}$ in the simplified schematic.

In the rare event that the device is asked to provide a reversed output current, meaning a positive regulator forced to sink current or a negative one forced to source it, the device is also fully protected and current limited. D1 in the simplified schematic will allow the driver stage to sink current if it is forced to. This is a highly abnormal condition that does not occur in normal system operation. This rare event can be caused by system clamping diodes steering more current into the regulated voltage rail than the normal load on the rail can consume, or by a mere slip of the meter probe that shorts the output of the device back to its input. During any of these conditions, the device will flow reversed output current through D1 and the driver. The reversed current flow is internally limited to 30mA in order

to prevent the device from being destroyed during these abnormal conditions.

Reference Voltage: The internal reference voltage of the device is a precision shunt adjustable reference that is biased with a current source and has an additional two pole post filter to provide extremely low noise performance. Different output voltages within the voltage regulator family are obtained by setting the reference voltage to different values. The reference voltage is set by R1 and R2 in the simplified schematic and it is always one half of V_{out} .

Output Voltage Accuracy: The output voltage accuracy of the device is specified at $\pm 1.5\%$. The global accuracy is determined by the accuracy of the voltage reference, which is $\pm 0.5\%$, the tolerance of the resistors used to set the reference, which are $\pm 0.1\%$ and $\pm 0.5\%$, and the tolerance of the feedback divider resistors, which are $\pm 0.1\%$ each, and $\pm 0.2\%$ combined. Adding all of these up gives us a theoretical global accuracy of $\pm 1.3\%$. The actual specification of $\pm 1.5\%$ was chosen to provide an additional $\pm 0.2\%$ of margin to account for things like offset within the error amplifier, its associated bias currents, and the phase of the moon.

Error Amplifier: The error amplifier in the device is a fully discrete op amp based on the Sparkos Labs SS3601. Having a fully discrete error amplifier allows parts of it to be powered from the output side of the regulator, and other parts from the input side. This eliminates the startup problems that other discrete designs that utilize a monolithic error amplifier powered from the output side can potentially suffer from.

A fully discrete error amplifier also allows heavy filtering to be applied to what would normally be inaccessible internal nodes if a monolithic error

amplifier was used. This filtering is what gives these discrete regulators their unparalleled input rejection specifications.

Pass Transistor: The pass transistor of the device is an MJE15032 / MJE15033 Bipolar Junction Transistor. These devices are rugged, high speed, and have a wide safe operating area. The pass transistor is bi-directionally driven by a push pull emitter follower to yield the best transient response possible. Bi directional drive eliminates the long trailing edge that is present in the transient response of many voltage regulator designs that occurs when the load steps from high current back down to low current.

Applications Information:

External Input and Output Capacitors:

These discrete voltage regulators have an internal 10 μ F tantalum polymer output capacitor. As such, no external output capacitors are required for normal operation or stability. However, the transient response can be improved by having an external 100 μ F low ESR electrolytic output capacitor. A Panasonic EEU - FR1H101B type capacitor (100 μ F 50V 65m Ω ESR) is the recommended output capacitor.

Output capacitors placed close to the regulators output that are of ceramic or film type are not recommended due to their extremely low (sub 10m Ω) ESR. Capacitors of this type will degrade the phase margin of the voltage regulator and worsen the transient response and ringing. Utilizing an electrolytic or tantalum output capacitor is preferred due to their higher ESR of several tens of m Ω as opposed to sub 10m Ω .

The degradation of phase margin caused from low ESR output capacitors holds true for virtually every series pass voltage regulator that utilizes global negative feedback. Many monolithic regulators specify a tantalum or electrolytic output capacitor due to their higher ESR, and will oscillate with

ceramic or film types. To remedy this, Sparkos Labs discrete voltage regulators are designed to have a high phase margin on the order of 100° at unity gain cross over. This "excess phase" is there to ensure stability after being potentially degraded by low ESR output capacitors. This excess phase margin ensures that the device will always be stable, regardless of the capacitive load imposed upon it.

In normal circuits, it will be common to have several 0.1 μ F ceramic or film type bypass capacitors near ICs and the circuits that the regulator is powering. These will usually be placed physically close to the device or circuit that they are bypassing, and not physically near the regulator. As such, the wiring and trace resistance between the two is sufficient to raise the ESR of these capacitors as seen by the regulator to the point that the overall phase margin will be unaffected.

The input bypass capacitor is less critical. It is only required if the regulator is located more than 6 inches from the main power supply filter capacitors. For instances where an input bypass capacitor is required, virtually any value and flavor of capacitor will suffice. Higher values (10s or 100s of μ F) will hold up the input voltage better under transient conditions but only 0.1 μ F is required for stability and normal operation. Ceramic and film type capacitors can be used for input bypassing without affecting the phase margin like they do when used on the output.

Thermal Considerations and Heat

Sinking: As with any linear regulator, these devices will dissipate considerable power at high output currents, and at high input to output voltage differentials. The power dissipated by the device can be approximated by :

$$P_{diss} = (V_{in} - V_o) * I_o$$

The quiescent current of the device adds to the total device power dissipation, however only about half of the quiescent current is dissipated by the pass transistor. If one wishes to factor in quiescent currents when calculating the power dissipation of the pass transistor, the quiescent dissipation of the pass transistor can be calculated by :

$$P_{dissquiescent} = (V_{in} - V_o) * ((V_o / 7.5K) + 7mA)$$

Note that this is the quiescent dissipation of the pass transistor only, and not the quiescent dissipation of the total device.

A heat sink should be selected that will keep the case temperature of the pass transistor to around 70°C maximum under maximum load current and input voltage.

If one is using these devices to replace an existing regulator within a circuit, the existing heat sink should be adequate. It should be noted that the tab of the pass transistor is always tied to V_{in} and an electrical insulator should be used between the pass transistors' tab and the heat sink to prevent the heat sink from becoming live with V_{in} .

Modifying the Output Voltage: The output voltage of these discrete voltage regulators is always a fixed voltage. Any attempts to modify the output voltage or make the output adjustable by putting a voltage divider network or POT on the ground pin of the device is not recommended. The Ground pin of the device should always be hard tied to ground in order to achieve the specified performance. The brave at heart who do attempt to modify the output voltage by placing a voltage divider on the ground pin should keep the voltage divider resistor values as low as possible, and should place a 100uF bypass capacitor across the low-side resistor that goes to ground.

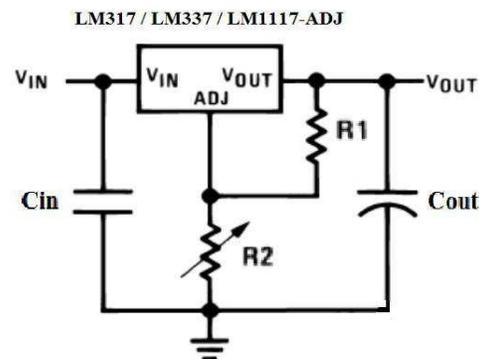
Replacing Adjustable Regulators: The Sparkos Labs family of discrete voltage regulators

SS78XX / SS1117XX / SS79XX

can be used to replace adjustable regulators such as the LM317 / LM337 / LM1117-ADJ with additional circuit modifications.

Adjustable regulators differ from their fixed counterparts by having an adjust pin rather than a ground pin. Figure 20 shows a typical adjustable regulator circuit. The output of an adjustable regulator can be varied by the voltage divider ratio (comprised of R1 and R2 in Fig 20) that is attached to the ADJ pin.

Figure 20: Adjustable Regulator Circuit



In order to replace an adjustable regulator with one of these discrete devices, R2 must be shorted out, and R1 should be removed. If R1 is not removed, it will result in drawing a steady current of $R1/V_{out}$ from the regulator. This may or may not be acceptable, depending on the power rating of R1.

Drop In Replacement Guide: In order to replace a monolithic regulator with these discrete devices, one must know the polarity, pin-out, and output voltage of the device that they wish to replace. A Digikey search of the part being replaced will usually provide the relative information. If one is replacing an adjustable type regulator, the output voltage that it is set to must be known so an appropriate discrete regulator can be chosen and installed. This assumes that any adjustable type regulator is set to a fixed output voltage within the circuit. As mentioned before, the

SS78XX / SS1117XX / SS79XX

resistors that set the output voltage must be shorted out (R2) and removed (R1) in Figure 20. As also mentioned before, attempting to make these discrete devices dynamically adjust their output voltage by using POTs or voltage dividers on the ground pin is not recommended.

If a device being replaced is mounted to a heat sink, that same heat sink should be used with the discrete replacement device. One does not need a larger heat sink when replacing an existing voltage regulator with one of these discrete devices. The existing heat sink will suffice.

Since the tab of these discrete devices is tied to V_{in} , an electrical insulator should be used between the tab and the heat sink to prevent the heat sink from becoming live with V_{in} .

The input and output bypass capacitors within the existing circuit should also be adequate and do not require any modifications for normal operation. If the output capacitor closest to the regulator is of ceramic or film type, better transient response might be obtained by removing it from the circuit since ceramic and film capacitors will degrade the phase margin of the device. In these instances where the output capacitor is removed from the circuit, the internal 10 μ F tantalum polymer output capacitor will be sufficient as an output capacitor, and the device will operate with a higher phase margin and

less transient response ringing.

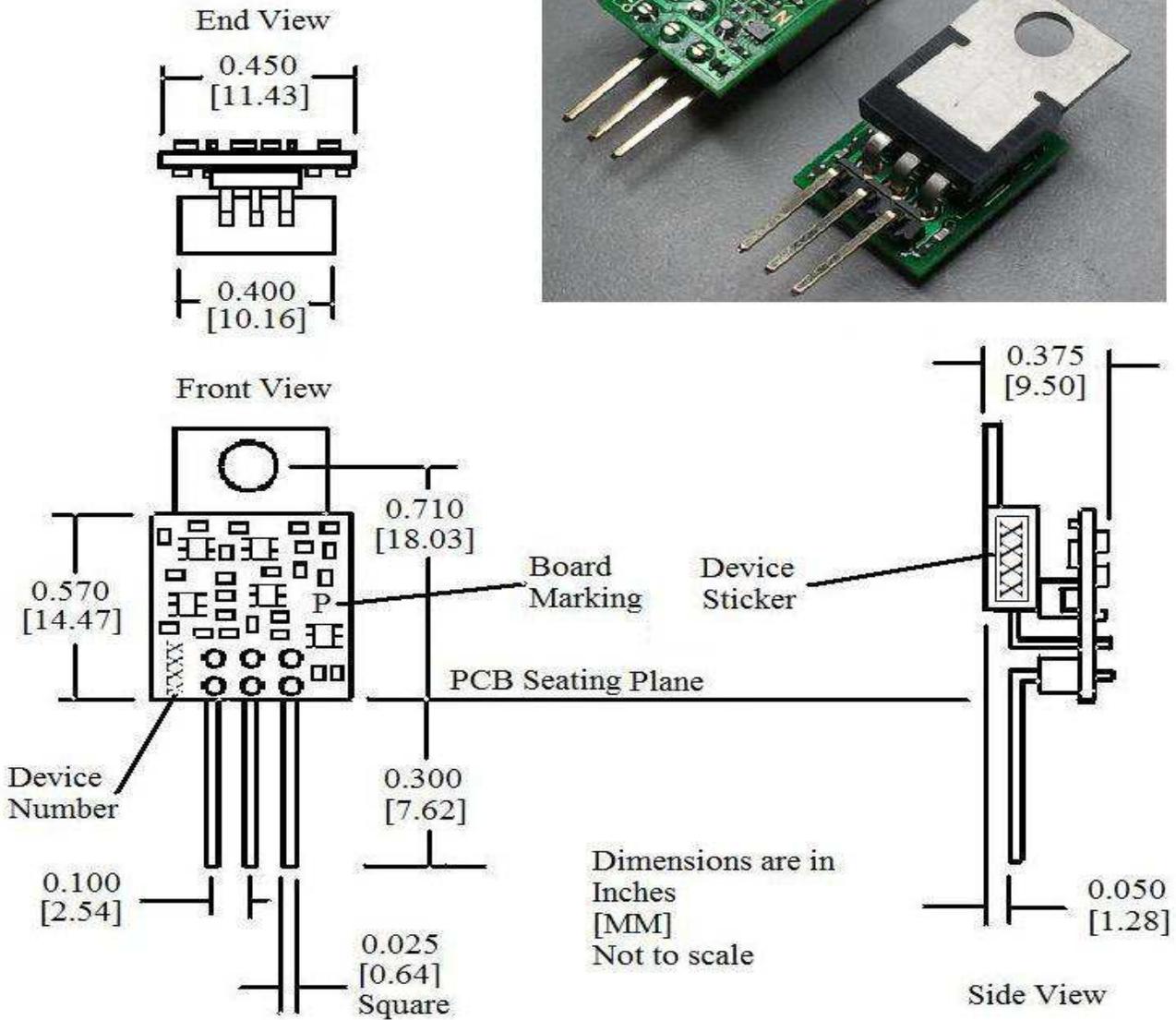
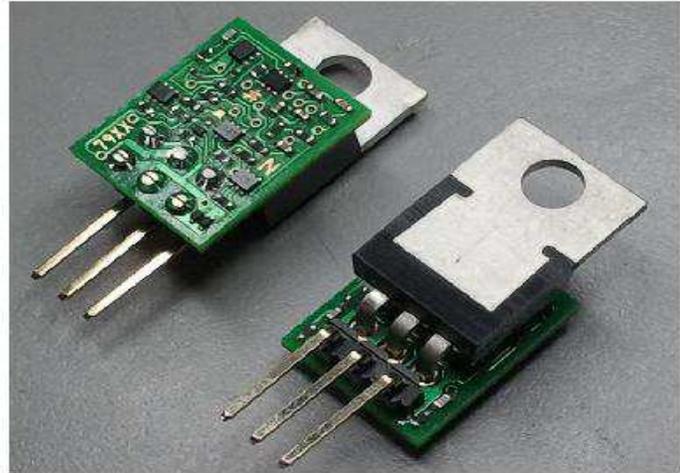
If one wishes to go all out, the best output capacitor is the Panasonic EEU - FR1H101B electrolytic capacitor (100 μ F 50V 65m Ω ESR) . This capacitor can be used to replace the existing output capacitor or it can be added in parallel with it. It should be noted that the correct polarity must be observed during the installation of these electrolytic capacitors.

The Panasonic EEU - FR1H101B capacitor can also be used for an input capacitor, and it can be added in parallel with the existing input capacitor, or be used to replace it. Using this capacitor as an input capacitor will likely hold up the input voltage better during load transients.

Using a socket with these discrete devices is not recommended in order to achieve the specified performance. It can be done, but the input rejection and transient response (load regulation) will suffer by about 10dB and 4mV respectively. The best performance is always obtained by soldering the device into place.

Mechanical And Packaging Data :

SS78XX / SS1117XX / SS79XX



Board Marking Indicates Pinout and Polarity

P = SS78XX
 A = SS17XX
 N = SS79XX

Device Sticker Indicates The Output Voltage

This package size and pin pitch are compatible with standard TO220 Packages

Important Notice:

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