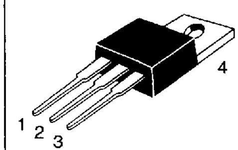
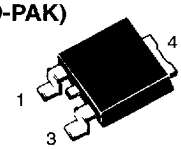
High Voltage Current Regulators

Current Regulator	BV_{DS} min. V	$I_{D(P)}$ typ. mA	TO-220 AB 	TO-252 AA (D-PAK) 
Non switchable regulators	350	10	IXCP 10M35	IXCU 10M35S
		20	IXCP 20M35	IXCU 20M35S
		35	IXCP 35M35	IXCU 35M35S
		100	IXCP 100M35	IXCU 100M35S
Switchable		10	IXCP 10M35S	IXCU 10M35SS
regulators	450	10	IXCP 10M45S	IXCU 10M45SS

Pin connections

1 = No Connection or CTL (Control for switchable regulator)
2 = 4 = (+) Pos. Terminal
3 = (-) Neg. Terminal

Features

- Extremely stable current characteristics 50 ppm/K
- Minimum of 350/450 V breakdown
- Easily configured for bi-directional current sourcing
- 40 W continuous dissipation
- International standard packages JEDEC TO-220 and TO-252
- On/Off switchable current source

Non switchable regulators

This is a family of extremely stable, high voltage current regulators. The temperature stability is based on a threshold compensation technique and uses IXYS' most recently developed high voltage process. The complete family will be capable of providing other intermediate current levels which can be programmed on-chip during the manufacturing phase.

Specific applications are current sourcing in PABX applications, telephone line terminations, surge protection and voltage supply protection. Two devices in a back-to-back configuration will give bi-directional operation. Specific bi-directional applications would be series surge protection and soft start-up applications from AC mains.

Switchable regulators

The IXYS Switchable Current Regulator with its 350/450 V minimum breakdown capability, is intended as a current source for off-line applications, such as switched mode power supply start-up circuits, where shutting the regulator down on demand is required to reduce standby power consumption. For additional design flexibility, the regulated current level can be reduced to values below nominal by adding a single resistor in series with the negative terminal.

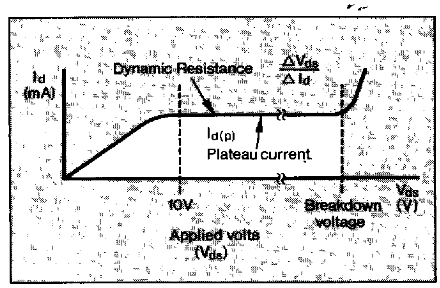


Fig. 3 Current regulator characteristics

Applications

- Start-up circuits for SMPS
- PABX current sources
- Telephone line terminations in PABXs and modems
- Highly stable voltage sources
- Surge limiters and protection (DC and AC)
- Instantaneously reacting indestructible fuses
- Waveform synthesizes
- Soft start-up circuits

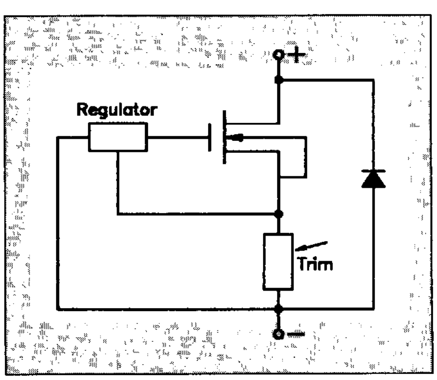


Fig. 1 Block diagram of non switchable regulator

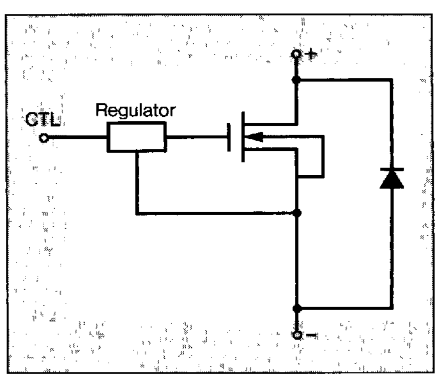


Fig. 2 Block diagram of switchable regulator

IXYS reserves the right to change limits, test conditions and dimensions.

Non Switchable Current Regulators

Symbol	Definition	Maximum Ratings	
V_{DS}	Drain Source Voltage	+350	V
P_D	Power Dissipation (T_C = 25°C)	40	W
I_{RM}	Maximum Reverse Current	1	A
T_J	Junction Operating Temperature	-55 to +150	°C
T_{stg}	Storage Temperature	-55 to +150	°C
T_L	Temperature for soldering (max. 10 s)	260	°C
M_D	Mounting torque with screw M3 (TO-220)	0.45/4	Nm/lb.in.
	with screw M3.5 (TO-220)	0.55/5	Nm/lb.in.

Symbol	Definition/Condition			Characteristic Values (T_J = 25°C, unless otherwise specified) min.	typ.	max.	
BV_{DS}	Breakdown voltage at operating current level	10M35	I_D = 20mA*	350			V
		20M35	I_D = 35mA*				
		35M35	I_D = 50mA*				
		100M35	I_D = 120mA*				
$I_{D(P)}$	Plateau Current	10M35	V_{DS} = 10 V	7	10	13	mA
		20M35		15	20	25	mA
		35M35		29	35	41	mA
		100M35		88	100	112	mA
$\Delta I_{D(P)}/\Delta T$	Plateau Current Shift with Temperature		V_{DS} = 10 V		50		ppm/K
$\Delta V_{DS}/\Delta I_{D(p)}$	Dynamic Resistance	10M35	V_{DS} = 10 V	20			kΩ
		20M35		10			kΩ
		35M35		6			kΩ
		100M35		2			kΩ
R_{thJC}	Thermal Resistance junction-to-case					3.1	K/W
R_{thJA}	Thermal Resistance junction-to-ambient, TO-220					80	K/W
	TO-252					100	K/W

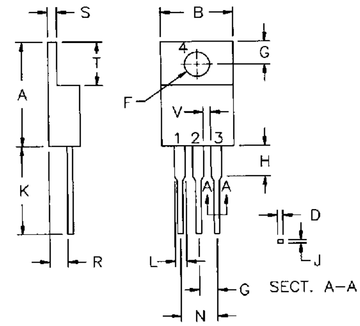
* Pulse test to limit power dissipation to within device capability.

Nomenclature of Current Regulators

IXCU 10M45SS **(Example)**

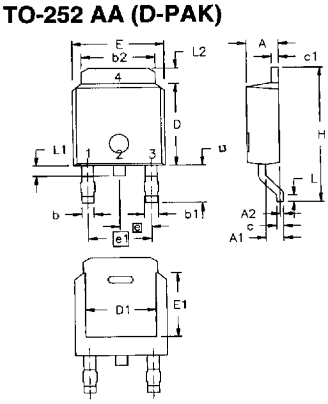
- **IX** —— IXYS
- **C** —— Current Regulator
- Package style
  - **U** —— TO-252 AA (D-PAK)
  - P —— TO-220 AB
- **10** —— Current Rating, 10 = 10 mA
- **M** —— Current Level
  A = Amps, M = mA, U = µA
- **45** —— Voltage rating, 45 = 450 V
- **S** —— Switchable regulator
- **S** —— Surface Mount Device

TO-220 AB



Dim.	Millimeter Min.	Max.	Inches Min.	Max.
A	14.23	16.51	560	.650
B	9.66	10.66	380	420
C	3.56	4.82	.140	190
D	0 64	0 89	.025	.035
F	3.54	4 06	139	.161
G	2 29	2.79	090	110
H	–	6 35	–	250
J	0 51	0.76	.020	030
K	12.70	14 73	500	580
L	1.15	1 77	045	.070
N	4.83	5.33	190	210
Q	2.54	3.42	100	.135
R	2.04	2.49	.080	.115
S	0.64	1 39	.025	055
T	5 85	6 85	2 30	2.70
V	1 15	–	045	–

TO-252 AA (D-PAK)



Dim.	Millimeter Min.	Max.	Inches Min.	Max.
A	2.19	2.38	0.086	0.094
A1	0.89	1.14	0.035	0.045
A2	0	0.13	0	0.005
b	0.64	0.89	0.025	0.035
b1	0.76	1.14	0.030	0.045
b2	5.21	5.46	0.205	0.215
c	0.46	0.58	0.018	0.023
c1	0.46	0.58	0.018	0.023
D	5.97	6.22	0.235	0.245
D1	4.32	5.21	0.170	0.205
E	6.35	6.73	0.250	0.265
E1	4.32	5.21	0.170	0.205
e	2.28 BSC		0.090 BSC	
e1	4.57 BSC		0.180 BSC	
H	9.40	10.42	0.370	0.410
L	0.51	1.02	0.020	0.040
L1	0.64	1.02	0.025	0.040
L2	0.89	1.27	0.035	0.050
L3	2.54	2.92	0.100	0.115

Switchable Current Regulators

Symbol	Test Condition		Maximum Ratings	
V_{AKR}	T_J = 25°C to 150°C	10M35S 10M45S	350 450	V V
V_{AGR} V_{AGR}	T_J = 25°C to 150°C	10M35S 10M45S	350 450	V V
V_{GK}			±20	V
I_D	T_C = 25°C		-0.3	A
P_D	T_C = 25°C		40	W
T_J T_{stg} T_L	 Temperature for Soldering (max. 10 s)		-55 ... +150 -55 ... +150 260	°C °C °C
M_D	Mounting torque with screw M3 (TO-220) with screw M3.5 (TO-220)		0.45/4 0.55/5	Nm/lb.in. Nm/lb.in.

Symbol	Test Condition		Characteristic Values (T_J = 25°C unless otherwise specified) min.	typ.	max.	
V_{AKR}	R_K = 300 Ω, (Fig. 4)	10M35S 10M45S	350 450			V V
$I_{D(P)}$	V_D = 10 V; R_K = 300 Ω; (Fig. 5)		7	10	15	mA
$V_{G(off)}$	I_D = 100 µA; V_D = 300 V I_D = 100 µA; V_D = 400 V Fig. 4	10M35S 10M45S	-5 -5			V V
I_{DV}	V_D = 300 V; V_{GK} = -10 V V_D = 400 V; V_{GK} = -10 V Fig. 4	10M35S 10M45S			25 25	µA µA
dv/di	Dynamic resistance; V_D = 10 V R_K = 300 Ω; (Fig. 4)		10			kΩ
R_{thJC} R_{thJA}	Thermal Resistance junction-to-case Thermal Resistance junction-to-ambient, TO-220 TO-252				3.1 80 100	K/W K/W K/W

Pin connections

1 = G, Control terminal
2 = 4 = A (+), Positive terminal
3 = K (-), Negative terminal

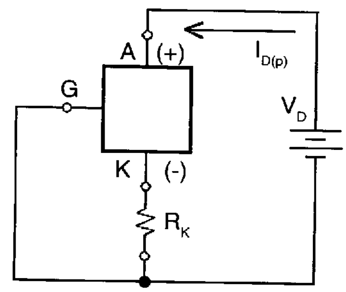


Fig. 4 Resistor "R_K" in series with negative pin to achieve different current levels

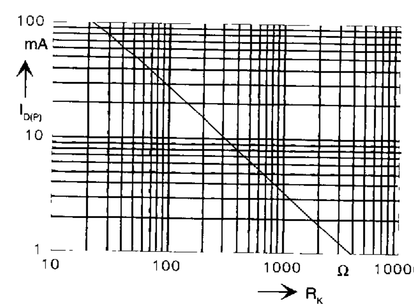


Fig. 5 Plateau current versus external resistance

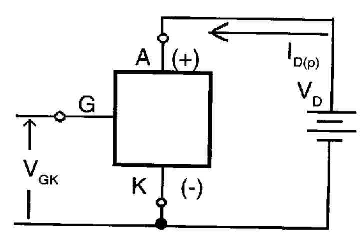


Fig. 6 Current regulator controlled by V_G

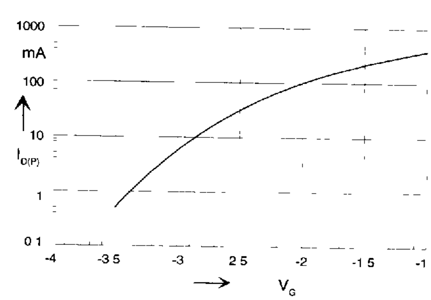


Fig. 7 Plateau current versus applied input voltage

Application examples with switchable regulator

Start-up Circuit

An often overlooked area in switch mode power supply (SMPS) designs is the start-up circuit (or housekeeping supply). A good start-up circuit should be inexpensive, require little space, be non-complex and should not lower the overall efficiency of the power supply. To maximize efficiency, it should switch off when the supply is in operation.

Fig. 8a shows a simple start-up circuit for a universal 96 to 264 V~ SMPS. Here R1, a 15 W/11 kΩ dropping resistor, provides the initial 10 mA or greater supply current required by the SMPS control IC. This circuit will consume up to 12.4 W of additional power, all of which must be dissipated and which reduces the overall SMPS design efficiency. Depending on the application, additional air space should be provided to adequately cool R1 and avoid damaging heat sensitive components.

Fig. 8b shows an SMPS start-up circuit using I1, the IXCP 10M45S switchable current regulator and M1, a 2N7000P MOSFET, to switch I1 on and off. Only during the first 10 ms to 20 ms of SMPS start-up does I1 need to be on to supply up to 10 mA, which is set by R1 = 300 Ω. It is commanded off during all other times. The additional average power dissipation due to this start-up circuit during normal operation, ie after M1 has turned I1 off, is proportional to the square of the voltage across R2.

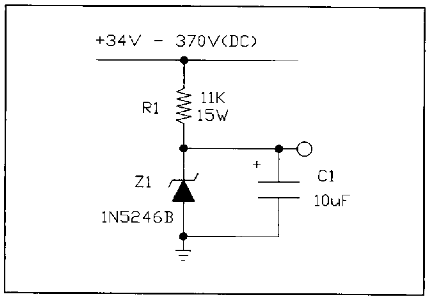


Fig. 8a Standard start-up circuit for SMPS

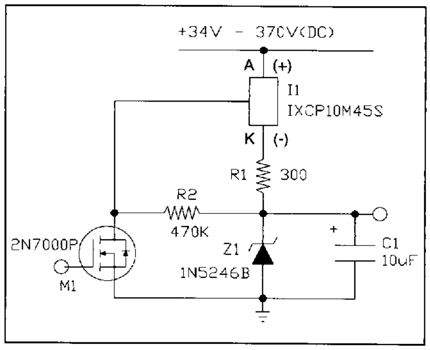


Fig. 8b SMPS start-up circuit using IXCP 10M45S

This approximately 0.5 mW, assuming V = 16 V and R2 = 470 kΩ. As such, minimal heat build-up will occur in the IXCP 10M45S, eliminating potential problems to heat sensitive components.

Any reduction in power dissipation in the start-up circuit translates directly into improved SMPS efficiency. Even though there may be more components required in Fig. 8b versus Fig. 8a, the absence of a heat generating component will serve to increase overall packing density and improve PCB layout flexibility.

Simple Off Line Power Supply with the IXCP 10M45S

In Fig. 9, the IXCP 10M45S, IC1, extends the input voltage range of a 5 V linear voltage regulator IC2, a 78L05 for example, to allow it to work off of 110 to 230 V~ mains. In fact, any three terminal linear regulator rated less than 50 mA (100 mA off 110 V mains) from 5 V to 22 V will work in this application. Assume that the rectified voltage across C2 is sufficiently positive to allow the output of 78L05 to supply I_L to the load with a regulated 5 V. Under steady state conditions the current output of IC1 (-) just matches the current input of IC2 (IN) with no current flow into or out of C2. Assume the current demanded by the load is such that I_L goes down. This will cause IC2 (IN) current to also go down resulting in excess current output from IC1 (-). This excess current will charge C2, resulting in IC1 (-) terminal voltage becoming more positive, which then reduces the IC1 output current until it matches the IC2 (IN) input current. If the current demanded by the load goes up increasing I_L, the IC2 (IN) input current will also go up. C2 will initially source the additional current by discharging itself. The reduction in C2 voltage causes IC1 (-) terminal to become more negative with respect to IC1 and results in IC1 output current increase. In steady state, IC1 will provide exactly the current required by IC2 - no more and no less. Note that IC1 must be heat sink since its average power dissipation is approximately peak input mains voltage multiplied by the output regulator current.

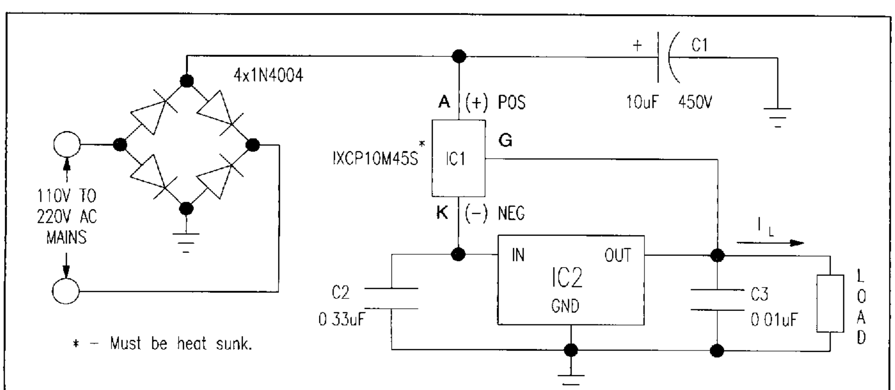


Fig. 9 Use of IXCP 10M45A to extend input voltage range to low voltage current regulators

Other Application

Current Regulator as a Current Source in PABXs

Telephone instruments need to take power from the telephone line when they are taken "off" hook; i.e., when the telephone is physically lifted by the user. The power is sourced for the PABX end, and in most cases, this is achieved by applying a differential DC voltage to the telephone lines via substantially sized inductors.

These inductors provide a very low resistance to the DC applied voltage while simultaneously presenting a high impedance to audio signals appearing on the line and ensuring that the signal is not routed to the voltage source under operating line conditions.

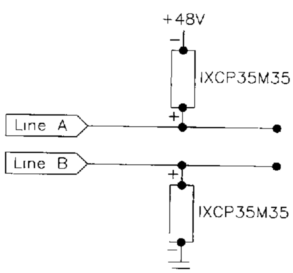


Fig. 10 Using two matched IXCP35M35 current regulators as current sources.

In addition to the inductor, some other components are generally necessary.

For example the IXCP35M35 current regulator could provide a cost-effective equivalent function in a single package. The IXCP35M35 has a 35 mA nominal value and is capable of acting as a constant current source for the line. It has a high dynamic impedance to AC signals under normal conditions when the DC operating voltage across it is greater than several volts. Although this device operates at a 35 mA nominal current, other current levels could be supplied to the end user.

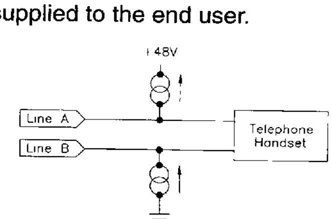


Fig. 11 PABX current sourcing with two current sources for longitudinal balance

Two current sources are needed, one in the "A" line and one in the "B" line. Their characteristics must have a high degree of matching. This provides the longitudinal balance that is needed. Longitudinal imbalance between the two lines will mean that there is likely to be unwanted pickup across the phone terminals. The circuit of Fig. 11 shows the two current sources in a PABX line. Applied voltage is around -48 V.

As well as longitudinal balance, each source must present a certain impedance value to AC speech signals on each line. The use of two current sources would provide an attractive cost-effective solution to PABX current

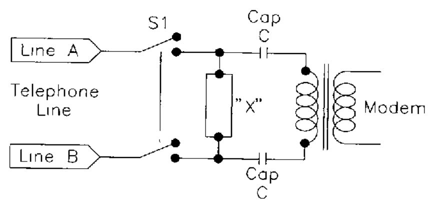


Fig. 12 Modem link-telephone line "X" is the line termination

sourcing applications (Fig. 11). The devices have a 350 V breakdown capability and can be utilized with voltage supplies substantially greater than -48 V, if required.

The 350 V capability also allows an extension of this current source approach to embrace other specific functions in a PABX system.

The important aspect of the current sources in the A and B lines is that the degree of matching should be high. The design of the current regulator embraces these features.

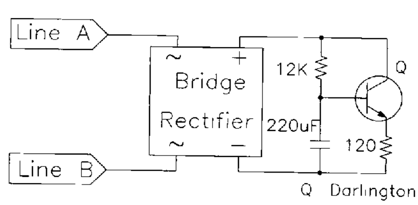


Fig. 13 Example of line terminating circuit

Devices can be matched to 0.1 mA at the operating voltage level by a combination of on-chip trimming at the pre-assembly stage or by a binning procedure during electrical test.

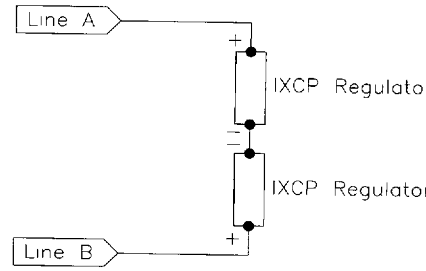


Fig. 14 Two current Regulators placed back-to-back

Telephone Line Termination

Fig. 12 shows a simple schematic of a modem interface in a telephone line at the subscriber end. Block "X" consists of a circuit which provides the end of line termination characteristics that are required.

Different countries may require different characteristics. The termination must provide specific DC characteristics as well as provide the dynamic impedance necessary between the A and B lines.

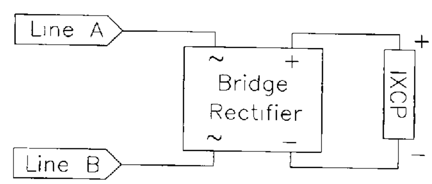


Fig. 15 Bi-directional Regulator (one package)

To input information into the line, switch SI will have to close. This initially means that ringing voltage will be imposed across the termination "X". Therefore, it not only has to provide the terminating characteristics under normal data transmission but has to be capable of withstanding the initially applied differential ringing voltage of the line when the switch SI is closed.

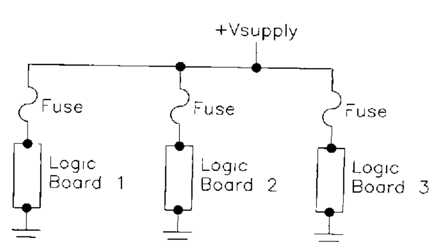


Fig. 16 Normal fusing links in series with each board

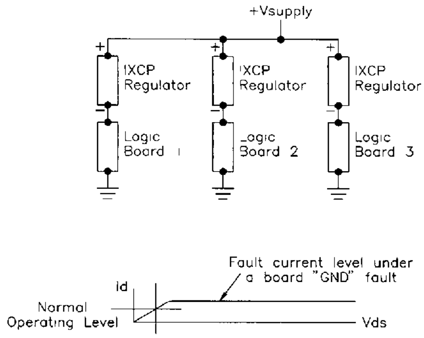


Fig.17 Low cost current regulators instead of fuses

The differential line voltage can be either polarity, therefore "X" also needs to cater for this potential bi-directionally.

An existing solution is illustrated in Fig. 13, an end-of-line termination in some countries. Fig. 14 and 15 show alternate solutions using the IXCP regulators.

Instantaneous "Fuse"

Another application would be protection against sudden voltage "droops" on voltage supply lines to logic cards in computing systems, resulting from one component suddenly shorting to ground. Normal fusing networks will draw considerable current during the time it takes for the fuse to clear. This could cause a sufficient dip in power rail voltage to cause malfunctions of the other logic cards, even with fast-blow fuses (Fig. 16). The current regulator in series with the logic card restricts the current to its own operating level (Fig. 17). Therefore the voltage supply does not become overloaded and the regulator remains intact.

R = 100 Ω V_{out} = 3.5 V nominal
R = 50 Ω V_{out} = 1.75 V nominal
R = 25 Ω V_{out} = 0.875 V nominal

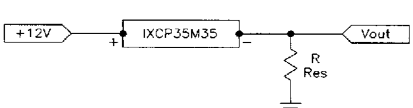


Fig. 18 Simple voltage source with high stability

The current regulator thus provides an "instantaneous fusing" function. When the logic component is replaced, the regulator to normal functioning mode.

The obvious advantages to having this regulator as fuse substitute are:

- Prevents a "dip" in the power supply during a fault condition
- Regulator remains intact
- Can be easily tied in with logic to indicate a "down state" board

Highly Stable Voltage Sources

An obvious application would be to use the current regulator as a source of a highly stable current to produce a stable voltage reference (Fig. 18). This would be effectively independent of temperature and a low cost approach. A high voltage reference is also possible, thanks to their high breakdown voltages.

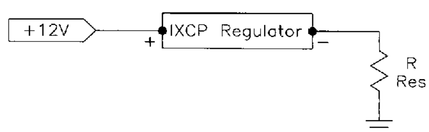


Fig. 19 DC surge suppression

DC and AC Overvoltage Suppression

The regulator can be used as a voltage surge suppressor. The device is again connected in series with the lead (Fig. 19) and would normally operate at a current level lower than the plateau (Fig. 20A). Any incoming voltage surge (Fig. 20b) less than the breakdown voltage of the regulator will be clamped by the IXCP regulator to voltage less than the plateau current times the effective resistance of the load.

Waveform Pattern Generation

Using a pair of matched current regulators, very linear and symmetrical waveforms can be generated. The temperature-stable characteristics of

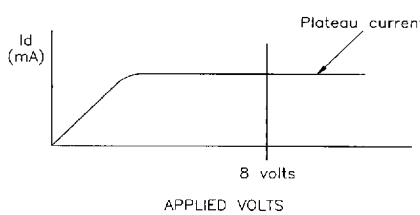


Fig. 20A DC surge suppression

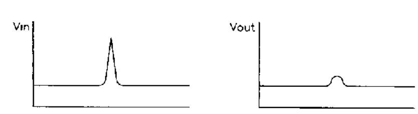


Fig. 20B Incoming surge/output surge across load

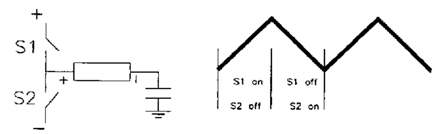


Fig. 21 Use of IXCP current regulators to generate linear waveforms.

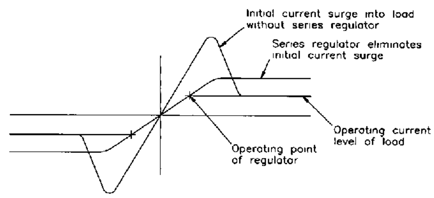


Fig. 22 Soft start on AC mains using a regulator in series with a load.

the current regulator provide a high degree of linearity and repeatability. Basically the circuit consists simply of one current regulator, two switches, and one capacitor (Fig. 21).
Switch S2 would be on the ground side and would operate from low voltage logic. Switch S1 would be driven from an isolated driver. With matched regulators, the upward and downward slopes match any requirement as dictated by the control logic timing.

Soft Start-Up Circuits

Here the regulator characteristic will clamp initial current surges which can occur when power is initially applied to a load. The device, with its 350 V capability could, for example, be used with a DC power supply or with AC mains to limit the initial high in-rush of current into lamp filaments, thereby increasing the filament life several times. It could, therefore, be used effectively in the lighting display and transportation lighting industries.

Testing & Handling Recommendations

- For initial assessment of the parts where the customer may test the device characteristics in free air without heat sinking, the continuous power dissipation should be kept within 1.5 W at ambient of 25°C. (R_{thJA} = 80 K/W for TO-220, and R_{thJA} = 100 K/W for TO-252))
- Normal electrostatic handling precautions for MOS devices should be adhered to.