Supertex inc. **HV320**

Initial Release

Demo Board Available!

Accurate, Re-Settable Electronic Circuit Breaker

(Negative Supply Rail)

Not Recommended For New Designs!

Features

- ❐ Differential 10V to 90V operation (+V_{IN} / -V_{EE})
- ❐ UV and OV Lock Out
- ❐ Power-On-Reset (POR) for debouncing
- ❐ Sense resistor programs circuit breaker
- ❐ Noise filter prevents false trip
- ❐ Programmable circuit breaker trip time
- ❐ Latched Operation
- ❐ Low Power, <0.4mA
- ❐ Small SO-8 package

Applications

- ❐ -48V Central Office Switching
- ❐ -24V Cellular and Fixed Wireless Systems
- ❐ -24V PBX Systems
- ❐ Telecom Line Cards
- ❐ -48V Powered Ethernet for VoIP
- ❐ Distributed Power Systems
- ❐ Power Supply Input/Output Fault Isolation
- ❐ Electronic Circuit Breakers
- ❐ Servers and SANS – replaceable modules
- ❐ Automotive and Industrial Circuit Breakers
- ❐ BUS Networks (CAN BUS, etc.)

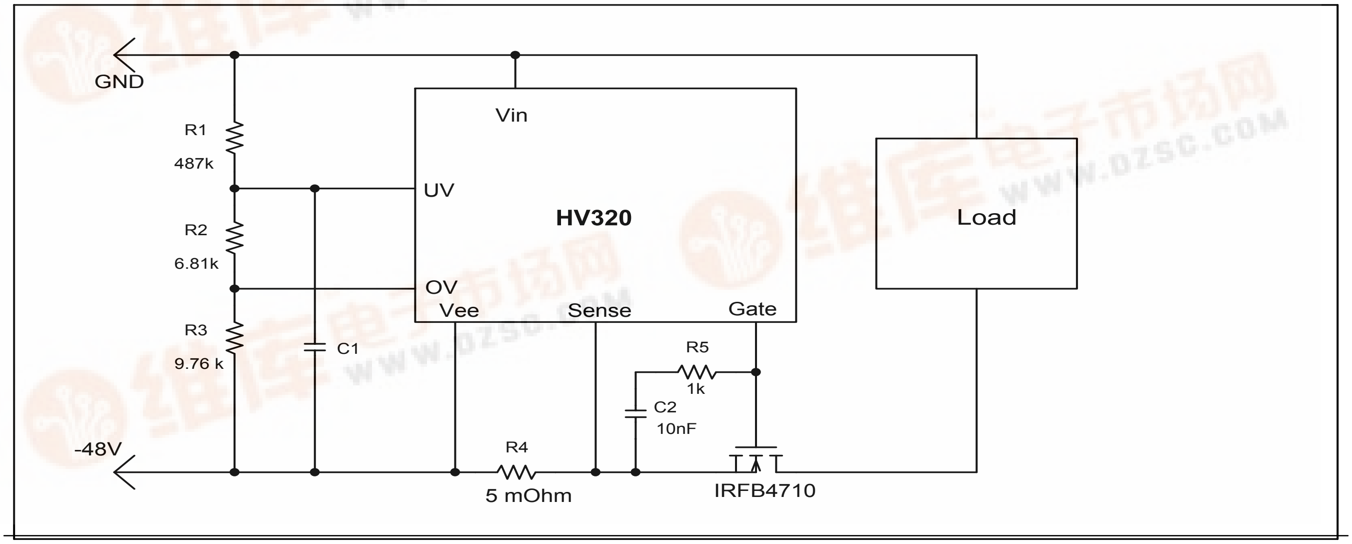
General Description

The Supertex HV320 re-settable electronic circuit breaker is designed to provide fast, consistent and accurate current limiting and load isolation during fault conditions. It may be used in a variety of applications in such markets as telecom, power, automotive, industrial, medical and security as well as in systems where active control is implemented in the negative supply lead. The current trip threshold is programmed by a sense resistor and operates from voltages varying from 10V to 90V differentially.

The HV320 can easily replace popular positive temperature coefficient (PTC) products such as Raychem™ PolySwitches™ or re-settable polyfuses. HV320 overcomes numerous performance shortcomings of existing PTC's, including trip point inaccuracy, increased device resistance after initial reset, slow response time, susceptibility to temperature variations and very high trip current to operating current.

During initial application of power, the gate of the external pass device is clamped low to suppress contact bounce glitches. Thereafter, the UV/OV supervisors and power-on reset work together to suppress gate turn on until the input power bounce ends. Once ON, HV320 continues to monitor the input voltage and the load current level. If a load fault occurs, the electronic circuit breaker will trip and the pass element will be turned off. To restart, the UV or OV pins must be toggled (for example by resetting the input voltage).

Typical Application Circuit



Ordering Information

DEVICE	Package Option
	8 Pin SO
HV320	HV320LG

Absolute Maximum Ratings*

Vee referenced to Vin pin	+0.3V to -100V
V_{UV} and V_{OV} referenced to Vee Voltage	-0.3V to +12V
Operating Ambient Temperature	-40°C to +85°C
Operating Junction Temperature	-40°C to +125°C
Storage Temperature Range	-65°C to +150°C

*Absolute Maximum Ratings are those values beyond which damage to the device may occur. Functional operation under these conditions is not implied. Continuous operation of the devide at the absolute rating level may affect device reliability. All voltages are referenced to device ground.

Electrical Characteristics (-10 • V_{EE} • -90V, -40°C • T • +85°C unless otherwise noted)

AC Characteristics

Symbol	Parameter	Min	Typ	Max	Units	Conditions

Supply (Referenced to Vin Pin)

Vee	Supply Voltage	-90		-10	V	
Iee	Supply Current		400	450	µA	V_{EE} = -48V

OV and UV Control (Referenced to V_{EE} pin)

V_{UVH}	UV High Threshold		1.26		V	Low to High Transition
V_{UVL}	UV Low Threshold		1.16		V	High to Low Transition
V_{UVHY}	UV Hysteresis		100		mV	
I_{UV}	UV Input Current			1.0	nA	Vuv = V_{EE} + 1.9V @ 25° C
V_{OVH}	OV High Threshold		1.26		V	Low to High Transition
V_{OVL}	OV Low Threshold		1.16		V	High to Low Transition
V_{OVHY}	OV Hysteresis		100		mV	
I_{OV}	OV Input Current			1.0	nA	V_{OV} = V_{EE} + 0.5V @ 25° C

Circuit Breaker (V_{UV} = V_{EE} + 1.9V, V_{OV} = V_{EE} + 0.5V, External MOSFET is IRFFR120N)

$V_{SENSE-CB}$	Circuit Breaker Threshold Voltage	80	100	120	mV	Referenced to V_{EE} pin @ 25° C
t_{CBTRIP}	Circuit Breaker Delay Time	2.0		5.0	µs	May be extended by external RC circuit
$I_{SENSE-CB}$				1.0	nA	$V_{SENSE-CB}$= 100mV @ 25° C

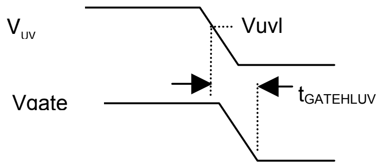
IRFB4710 and IRFFR120 are registered trademarks of International Rectifier.
Raychem and PolySwitch are registered trademarks of Tyco International.

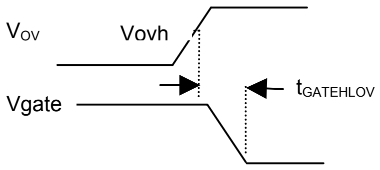
Gate Drive Output (Referenced to V_{EE} pin, External MOSFET is IRFB4710*)

V_{GATE}	Maximum Gate Drive Voltage	8.5	10	12	V	V_{UV} = Vee +1.9V, V_{OV} = Vee +0.5V
I_{GATEUP}	Gate Drive Pull-Up Current	500			µA	V_{UV} = Vee +1.9V, V_{OV} = Vee +0.5V
$I_{GATEDOWN}$	Gate Drive Pull-Down Current	40			mA	V_{UV} = Vee, V_{OV} = Vee +0.5V
$V_{GATELOW}$	Minimum Gate Drive Voltage		400		mV	V_{UV} = Vee, V_{OV} = Vee +0.5V, Igate = 5mA

Dynamic Characteristics (See timing below, External MOSFET is IRFB4710)

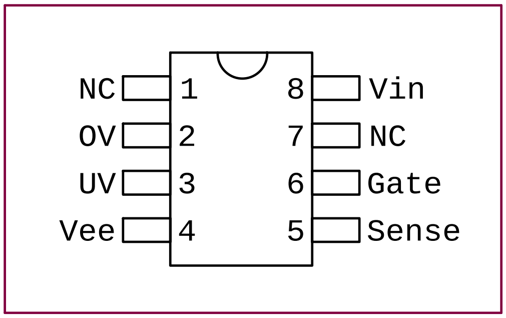
$t_{GATEHLOV}$	OV High to GATE Low			500	ns	Pulsed V_{OV} from V_{EE}+0.5V to V_{EE} +1.9V
$t_{GATEHLUV}$	UV Low to GATE Low			500	ns	Pulsed V_{UV} from V_{EE}+1.9V to V_{EE} +0.5V





Pinout for LG

Top View



Pin Description

OV – This Over Voltage (OV) sense pin, when raised above its high threshold limit, will immediately cause the GATE pin to be pulled low. The GATE pin will remain low until the voltage on this pin falls below the low threshold limit, initiating a new start-up cycle.

UV – This Under Voltage (UV) sense pin, when below its low threshold limit, will immediately cause the GATE pin to be pulled low. The GATE pin will remain low until the voltage on this pin rises above the high threshold limit, initiating a new start-up cycle.

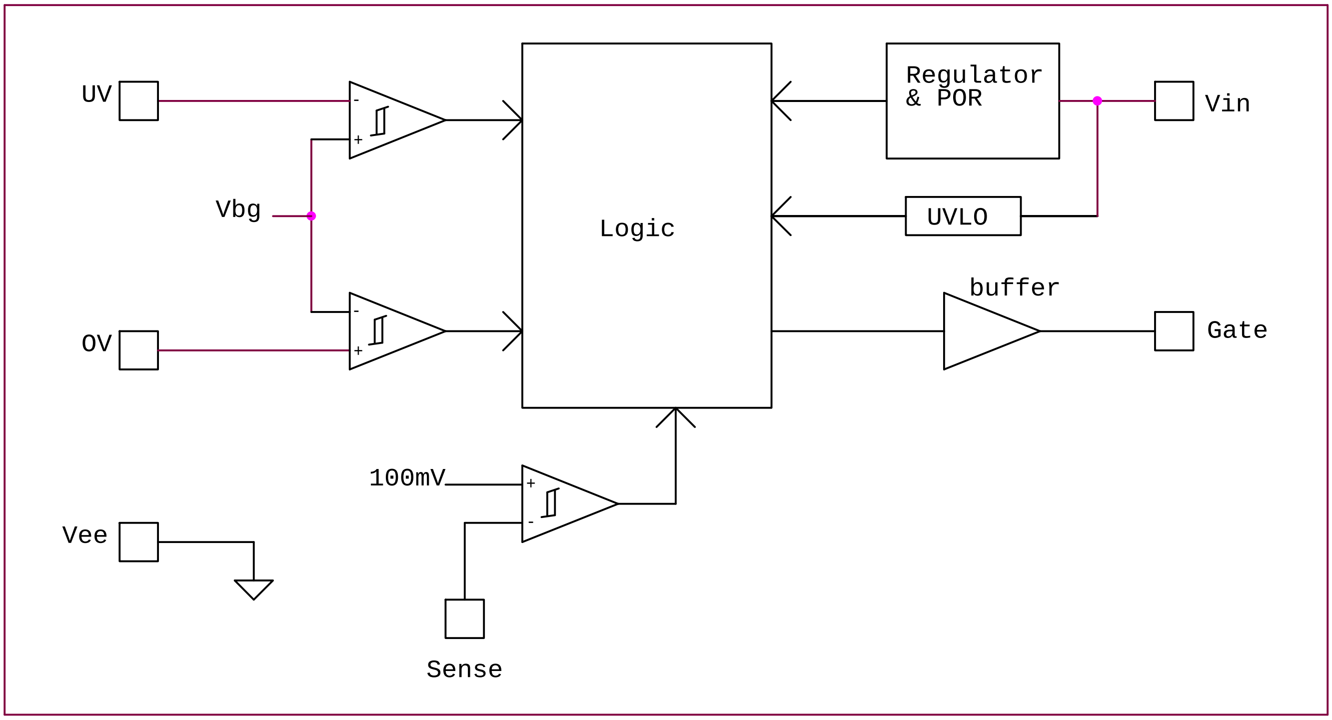
V_{EE} – This pin is the negative terminal of the power supply input to the circuit.

V_{IN} – This pin is the positive terminal of the power supply input to the circuit.

GATE – This is the Gate Driver Output for the external N-Channel MOSFET.

SENSE – The current sense resistor connected from this pin to the V_{EE} Pin programs the circuit breaker trip threshold.

Functional Block Diagram



Functional Description

HV320 as a fuse and circuit breaker replacement:
Telecom, data networks, automotive, industrial controls and some computer applications require the ability to isolate the power source from a load fault without having to physically replace a fuse or manually reset a mechanical circuit breaker. Traditionally a fast acting fuse or Positive Temperature Coefficient (PTC) device such as Raychem's PolySwitch or a manual / thermal circuit breaker have been used to limit the fault current.

The problems with PTCs are numerous. First, they are extremely temperature dependent. For example the required trip current can vary as high as 150% of nominal value at lower temperatures such as –40°C and as low as 50% of nominal value at higher temperatures such as +85°C.

Second, the ratio of trip current to steady state current can range from 7 to 70. This implies for an application where steady state current is 4A, traces must be over designed to withstand the trip current of 100A, a ratio of 25:1. Third, PTC's once tripped, require 20 seconds to minutes to reset and even when they are reset, the resistance value can permanently change as much as 240%. This implies PTC's are not suitable for repeated short circuit applications. Lastly the surface mount PTCs typically have large end cap terminations that absorb heat during the reflow process and can result in insufficient solder and cold solder joints. It is not uncommon for PCB surface contaminations to be present, thus resulting in poor solderability, hence loss of yield.

Typically, fuses are rated in Amp^2-seconds. For a SMT 1206 size fast-acting 2A, 63V fuse rated at 0.23 A - square second, it could take more than 200A for 5µs before the fusing element melts.

HV320 is an ideal alternative to thermal and manual circuit breakers in DC input applications. It has wide variety of uses in the automotive industry, such as PCB trace / device protection and DC motors and solenoid actuator current limit protection. These devices are typically used in windows and seat adjustment operations as well as automatic trunk opening mechanisms. Since these devices are operated manually, they can remain energized by the operator even after the mechanical lever has reached its end of travel. In this case, back EMF that normally opposes the supply voltage will drop to zero and a large current surge can begin to flow. HV320 can accurately be programmed to trip the current. In industrial applications, HV320 can offer broad solutions in DC solenoid-operated valves, DC motors and other electromagnetic loads.

Fault current magnitude can be scaled to different current ratings by proper selection of the sense resistor and the external N-Channel MOSFET. For higher current applications, IGBT devices may be considered. The HV320 is intended to provide this circuit breaker function on supply rails in the range of –10 to –90 Volts.

Description of Operation
During initial application of power, a unique proprietary circuit holds off the external MOSFET, preventing an input glitch while an internal regulator establishes an internal operating voltage of approximately 10V. Until the proper internal voltage is achieved, all circuits are held reset and the gate to source voltage of the external MOSFET is clamped low. Once the internal under voltage lock out

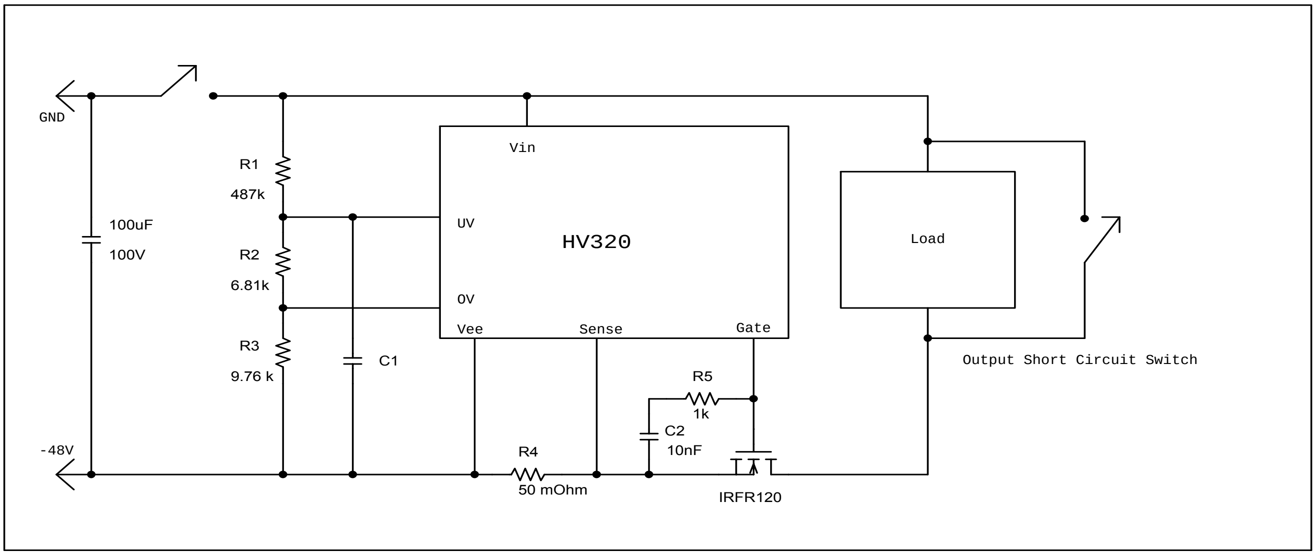
(UVLO) has been satisfied, the circuit checks the input supply under voltage (UV) and over voltage (OV) sense circuits to ensure that the input voltage is within programmed limits. These limits are determined by the selected values of resistors R1, R2 and R3 that form a voltage divider. Once the input voltage is within the programmed limits, the controller will force the GATE terminal to nominal 10V and the circuit breaker supervisor is enabled.

When the voltage on the SENSE pin rises to 100mV, indicating an over current condition, the circuit breaker will trip in less than 5µs. This time may be extended by the addition of external components (refer to Application Circuit 3 on page 9). The gate voltage is latched off when an over current condition is detected and is reset by removal and reapplication of input power.

At any time during the start up cycle or thereafter, crossing the UV and OV limits (including hysteresis) will cause an immediate reset of all internal circuitry. When the input supply voltage returns to a value within the programmed UV and OV limits, a new start up sequence will be initiated.

Safety recommendation: *For safety critical applications where UL, CSA or other safety agency approvals are required, a fuse must be placed in series with HV320. Although HV320 will protect a fuse from opening in many instances, from the safety agency point of view, ICs cannot displace a fuse.*

Test Set Up Circuit



Waveforms

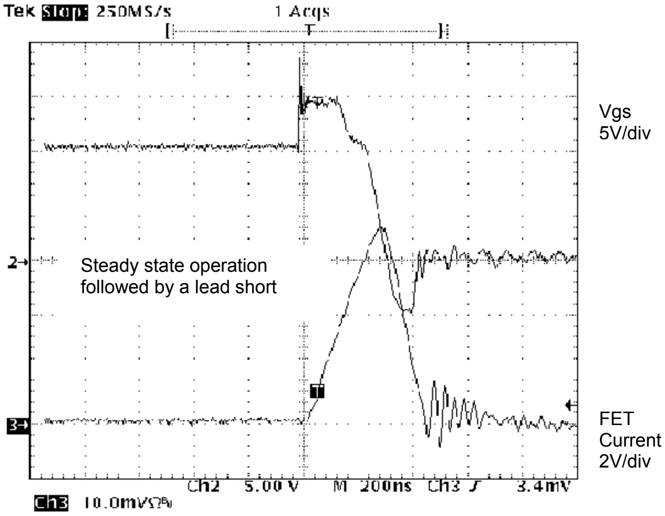


Figure 1

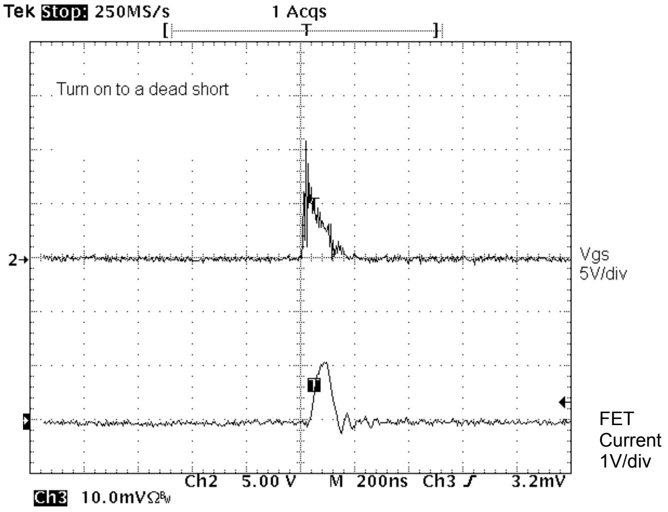


Figure 2

Design Information

Setting Under Voltage and Over Voltage Shut Down

The UV and OV pins are connected to comparators with typical 1.26V thresholds and 100mV of hysteresis. They are used to detect under voltage and over voltage conditions at the input to the circuit. Whenever the OV pin rises above its high threshold (1.26V) or the UV pin falls below its low threshold (1.16V), the GATE voltage is immediately pulled low.

Calculations can be based on either the desired input voltage operating limits or the input voltage shutdown limits. In the following equations the shutdown limits are assumed.

The under voltage and over voltage shut down thresholds can be programmed by means of the three resistor divider formed by R1, R2 and R3. Since the input currents on the UV and OV pins are negligible the resistor values may be calculated as follows:

$UV_{OFF} = V_{UVL} = 1.16 = \bullet V_{EEUV(off)} \bullet x\ (R2+R3)/(R1+R2+R3)$

$OV_{OFF} = V_{OVL} = 1.26 = \bullet V_{EEOV(off)} \bullet x\ R3/(R1+R2+R3)$

Where $\bullet V_{EEUV(off)} \bullet$ and $\bullet V_{EEOV(off)} \bullet$ relative to V_{EE} are Under and Over Voltage Shut Down Threshold points.

If we select a divider current of 100µA at a nominal operating input voltage of 50 Volts, then

R1+R2+R3 = 50V/100uA = 500k Ohm

From the second equation, for an OV shut down threshold of 65V, the value of R3 may be calculated.

$OV_{OFF} = 1.26 = (65xR3)/500k$

R3 = (1.26x 500k)/65 = 9.69k

The closest 1% value is 9.76k Ohm.

From the first equation, for a UV shut down threshold of 35V, the value of R2 can be calculated.

$UV_{OFF} = 1.16 = 35\ x\ (R2+R3) / 500k$

R2 = ((1.16 x 500k)/35) – 9.76k = 6.81k

The closest 1% value is 6.81k Ohm.

Then

R1 = 500k – R2 – R3 = 483k Ohm.

The closest 1% value is 487K Ohm.

From the calculated resistor values the OV and UV start up threshold voltages can be calculated as follows:

$UV_{ON} = V_{UVH} = 1.26 = \bullet V_{EEUV(on)} \bullet x\ (R2+R3)/(R1+R2+R3)$

$OV_{ON} = V_{OVL} = 1.16 = \bullet V_{EEOV(on)} \bullet x\ R3/(R1+R2+R3)$

Where $\bullet V_{EEUV(on)} \bullet$ and $\bullet V_{EEOV(on)} \bullet$ are Under and Over Voltage Start Up Threshold points relative to Vee.

Then

$\bullet V_{EEUV(on)} \bullet = 1.26\ x\ (R1+R2+R3)/(R2+R3)$

$\bullet V_{EEUV(on)} \bullet = 1.26\ x\ (487k+6.81k+9.76k)/(6.81k+9.76k\ ) = 38.29V$

and

$\bullet V_{EEOV(on)} \bullet = 1.16\ x\ (R1+R2+R3)/R3$

$\bullet V_{EEOV(on)} \bullet = 1.16\ x\ (487k +6.81k +9.76k)/9.76k = 59.85V$

Therefore, the circuit will start when the input supply voltage is in the range of 38.29V to 59.85V. To overcome longer bounce time during insertion, POR time must be extended. An additional cap C1 (Page 1) must be added from the UV pin to V_{EE}. The value of this cap can be calculated accordingly:

$$VC1\ (\ t\ ) = V_{IN}\ x\ \left(1 - e^{\left(\frac{-t_{POR}}{Req\ x\ C1}\right)}\right)$$

Where

VC1= 1.26
$V_{IN} = 1.60V$
t_{POR} = desired POR time to overcome the bounce
Req = R1 || (R2 + R3)

From the above C1 can be calculated:

$$C1 = \frac{t_{POR}}{Req\ x\ \ 1.60}$$

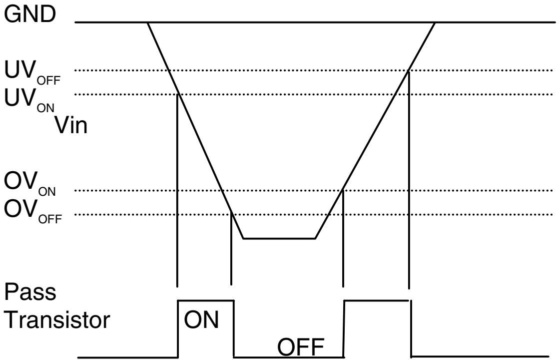
For example for t_{POR} = 10ms and
Values show on Page 1, the C1 calculates to be:

$$Req = \frac{487\ x\ (6.81 + 9.76)}{487 + 6.81 + 9.76} = 16K$$

$$C1 = \frac{10\ x\ 10^{-3}}{16000\ x\ \ 1.60}$$

C1 ≅ .39µF
a .47µF can be used.

Under Voltage/Over Voltage Operation



Start Up Overload Protection

If there is an output overload or short circuit during start up, the circuit breaker will trip when the voltage at the sense pin reaches 100mV. The gate is clamped low indefinitely until input power is cycled, the UV pin is pulsed low (<1.16V), or the OV pin is pulsed high (>1.26V). See Figure 2 on Page 5.

Circuit Breaker

The circuit breaker will trip in less than 5µs when the voltage on the SENSE pin reaches a nominal 100mV. A resistor in series with the SENSE pin and a capacitor connected between the SENSE and V_{EE} pins may be added to delay the rate of voltage rise on the SENSE pin, thus permitting a current overshoot and delaying Circuit Breaker activation. See Figure 1 on Page 5.

Selection of External R_sense

As a design example, consider a 500W load of a –48V rectifier: at a minimum regulation voltage of -42V, the input current is 11.9A, assuming that the trip point is set for 16A, the value of the sense resistor.

$R\_sense = 80mV / I_{TRIP} = 0.08/16 = 0.005$ Ohm

Where 80mV is the minimum circuit breaker trip level, the maximum circuit breaker threshold is 120mV. This will make the current trip level at 24A.

The power dissipation of the sense resistor is:

$P_{RSENSE} = (V_{SENSE\text{-}CB\ max})^2 / R\text{-}sense = (0.12)^2 / 0.005$
$= 2.88W$

Two 0.01 Ohm, 2W, 2512 size SMT resistor may be used in parallel. See Kelvin Connection to Sense Resistor.

Selection of External Pass Devices

The N-Channel may be selected based on maximum input operating voltage, RDS, maximum operating load current and peak short circuit current.

Continuing with the example, the lowest Rds(on) International Rectifier N-Channel MOSFET at 100V Vdss is 14 m-Ohm. The IRFB4710* (TO-220) may be used for this application.

FET Power Dissipation = $(I_{CBmax}\text{^}2)$ x Rds(on) x K = 24^2 x 0.014 x 1.4 = 11.3W

The K=1.4 factor is increased Rdson with respect to temperature rise. Assuming Rθjc = 0.74°C/W and Rθcs = 0.5°C/W and the maximum operating temperature being 55°C, then the needed heat sink thermal resistance can be calculated per:

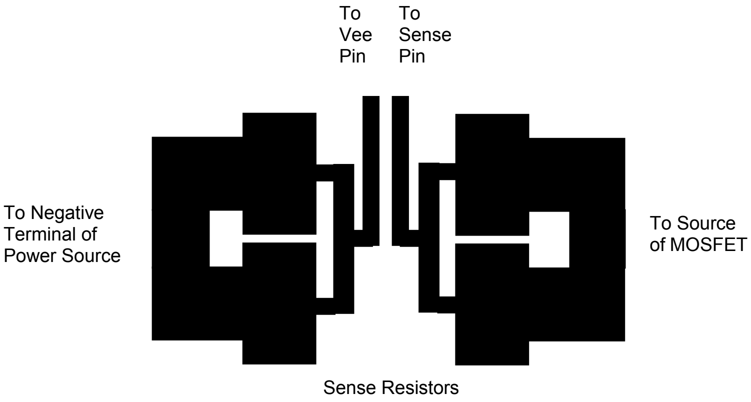
$Pd * (R\theta jc + R\theta cs + R\theta sa) + TA \le Tj\_derated$

$11.3 * (0.74 + 0.5 + R\theta sa) + 55°C \le 150°C$

$R\theta sa \le 7°C$

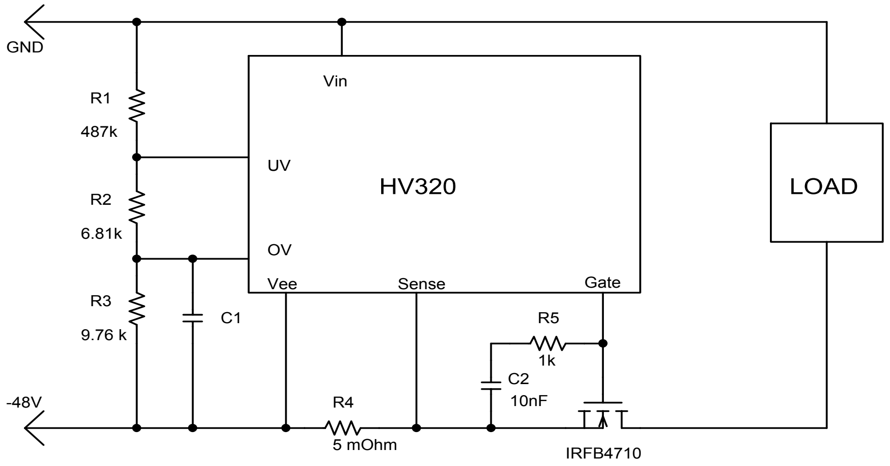
Kelvin Connection to Sense Resistor

Physical layout of the printed circuit board is critical for correct current sensing. Ideally trace routing between the current sense resistor and the V_{EE} and SENSE pins should be direct and as short as possible with zero current in the sense traces. The use of Kelvin Connection from SENSE pin and V_{EE} pin to the respective ends of the current sense resistor is recommended.



Filtering Voltage Spikes on the Input Supply

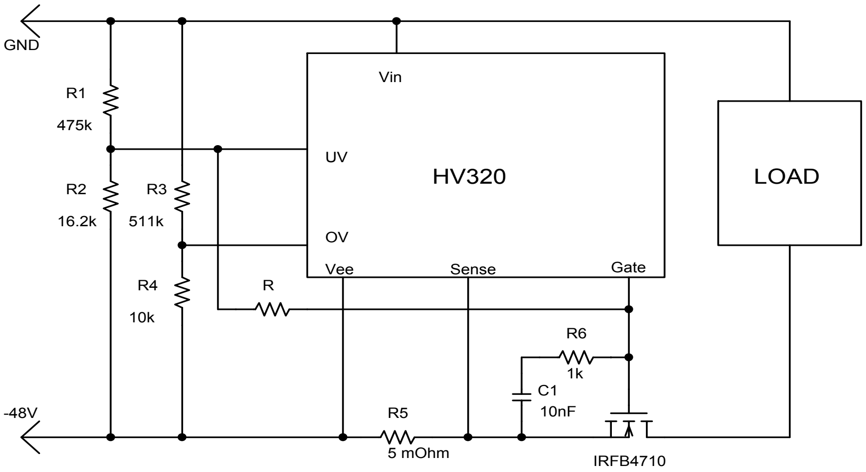
In some systems over voltage spikes of very short duration may exist and can prematurely trip the circuit breaker. For these systems a small capacitor may be added from the OV pin to the V_{EE} pin to filter the voltage spikes.



Application Circuit 1

Increasing Under Voltage Hysteresis

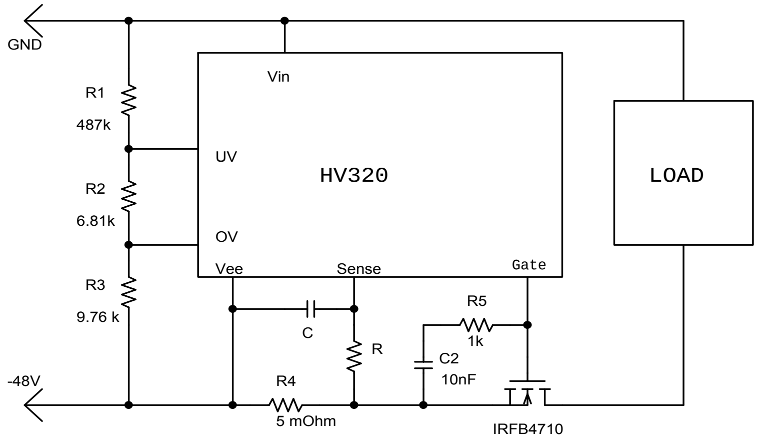
If the internally fixed under voltage hysteresis is insufficient for a particular system application, then it may be increased by using separate resistor dividers for OV and UV and providing a resistor feedback path from the gate pin to the UV pin.



Application Circuit 2

Extending Circuit Breaker Delay

Connecting a resistor in series with the SENSE pin and a capacitor between the SENSE and V_{EE} pins as shown in the following diagram may be used to extend the Circuit Breaker delay time beyond the 5µs internally set delay time.



Application Circuit 3