National Semiconductor

LM1951 Solid State 1 Amp Switch

General Description

The LM1951 is a high current, high voltage, high side (PNP) switch with a built-in error detection circuit.

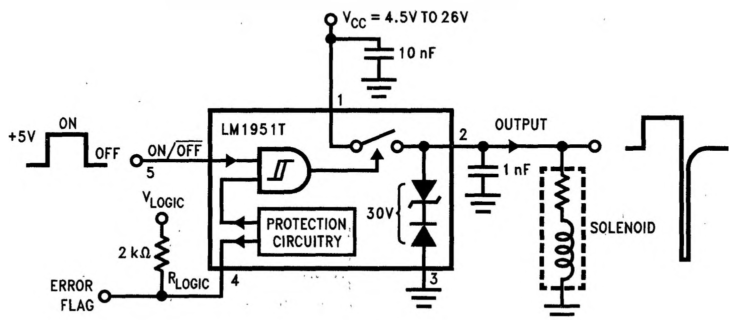
The LM1951 is guaranteed to deliver 1 Amp output current and is capable of withstanding up to ±85V transients. The built-in error detection provides an error flag output under the following fault conditions: output short to ground or supply, open load, current limit, overvoltage or thermal shutdown. The LM1951 will drive all types of resistive or inductive loads. The output has a built-in negative voltage clamp (≈ −30V) to provide a quick energy discharge path for inductive loads. The LM1951 features TTL and CMOS compatible logic input with hysteresis. Switching times, both turn on and turn off, are 2 μs (C_{load} < 0.005 μF). In addition, its quiescent current in the OFF state is typically less than 0.1 μA at room temperature and less than 10 μA over the entire operating temperature and voltage range.

The LM1951 features make it well suited for industrial and automotive applications.

Features

- 0.1 μA typical quiescent current (OFF state)
- 1 Amp output current guaranteed
- ±85V transient protection
- Reverse voltage protection
- Negative output voltage clamp
- Error flag output
- Internal overvoltage shutdown
- Internal thermal shutdown
- Short circuit proof
- High speed switching (up to 50 kHz)
- Inductive or resistive loads
- Low ON resistance (1Ω maximum)
- TTL, CMOS compatible input with hysteresis
- Plastic TO-220 5-lead package
- ESD protected
- 4.5V to 26V operation

Typical Application Circuit and Connection Diagram



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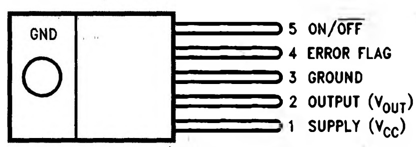
V_{IN}	Output
0	OFF
1	ON

TO-220, 5-Lead



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Front View
Order Number LM1951T
See NS Package Number T05A

Absolute Maximum Ratings

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

Supply Voltage	
Operational Voltage	26 V_{DC}
Sustained Voltage	$-40\ V_{DC} \geq V_{CC} \leq 85\ V_{DC}$
Transient Voltage Protection (τ = 100 ms, 1% Duty Cycle, $R_S \geq 10\Omega$)	±85V
Pins 4, 5	26 V_{DC}
Power Dissipation (Note 1)	Internally Limited
Load Inductance	1H
Operating Temperature Range (T_A)	−40°C to +125°C
Maximum Junction Temperature	150°C
Storage Temperature Range	−65°C to +150°C
Lead Temperature (Soldering, 10 sec.)	260°C
ESD Tolerance (Note 4):	2000V

Electrical Characteristics

V_{CC} = 12V, I_{out} = 500 mA, C_{out} = 0.001 μF, T_A = 25°C unless otherwise specified

Parameter	Conditions	Typical	Tested Limit (Note 2)	Design Limit (Note 3)	Units
Supply Voltage, V_{CC} Operational			4.5		V_{min}
			26		V_{max}
Transient	τ = 100 ms, 1% Duty Cycle, $R_{CC} \geq 10\Omega$		−85		V
			85		V
Supply Current	I_{out} = 0 mA, $V_{ON/\overline{OFF}}$ = 0.8V	0.1	10	100	μA_{max}
	I_{out} = 250 mA, $V_{ON/\overline{OFF}}$ = 2.0V	260	270		mA_{max}
	I_{out} = 600 mA, $V_{ON/\overline{OFF}}$ = 2.0V	630	650		mA_{max}
	I_{out} = 1A, $V_{ON/\overline{OFF}}$ = 2.0V	1.06	1.2		A_{max}
Voltage Drop ($V_{CC} - V_{OUT}$)	I_{out} = 600 mA, $V_{ON/\overline{OFF}}$ = 2.0V	400	600		mV_{max}
	I_{out} = 1A, $V_{ON/\overline{OFF}}$ = 2.0V	0.7	1.0		V_{max}
Short Circuit Current	V_{OUT} = 0V, $V_{ON/\overline{OFF}}$ = 2V	1.3	1.0		A_{min}
			2.5		A_{max}
Input Threshold, Pin 5	$4.5V \leq V_{CC} \leq 26V$, Turn ON	1.4	2.0	2.0	V_{max}
	Turn OFF	1.2	0.8	0.8	V_{min}
Input Current, Pin 5	$0.8V \leq V_{ON/\overline{OFF}} \leq 5.5V$	25	50		μA_{max}
			10		μA_{min}
Output Clamp	$I_{out} \leq 600$ mA	−30	−40		V_{min}
			−24		V_{max}
Delay Time t_d, ON	R_{load} = 20Ω, C_{load} = 0.001 μF	1	3		μs_{max}
Delay Time t_d, OFF		1	3		μs_{max}
Rise Time		1	3		μs_{max}
Fall Time		1	3		μs_{max}
Error Flag Characteristics: Output Voltage	Error Condition, Pin 4 Low, Sinking 10 mA	0.3	0.8		V_{max}
Sink Current	Error Condition, Pin 4 = 0.3V	10	3		mA_{min}
Output Leakage Current	No Error, Pin 4 = 26V	0.01	1		μA_{max}
Response Time	V_{LOGIC} = 5V, R_{LOGIC} = 2 kΩ, C_{LOGIC} = 0 μF	1			μs

Note 1: Thermal resistance junction-to-case is 3°C/W. Thermal resistance case-to-ambient is 50°C/W.

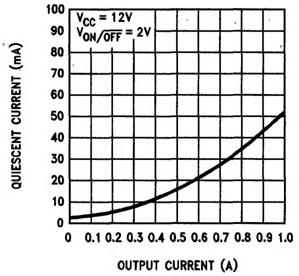
Note 2: Tested Limits are guaranteed and 100% production tested.

Note 3: Design Limits are guaranteed (but not 100% production tested) over the operating temperature and supply voltage range. These limits are not used to calculate outgoing quality levels.

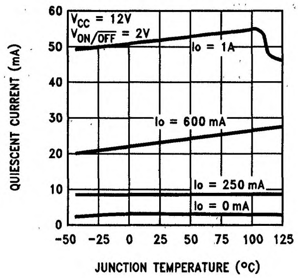
Note 4: Human body model, 100 pF discharged through a 1.5 kΩ resistor.

Typical Performance Characteristics

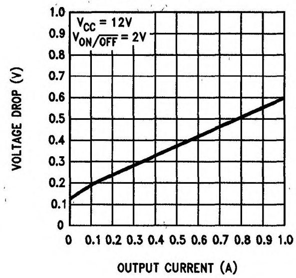
Quiescent Current



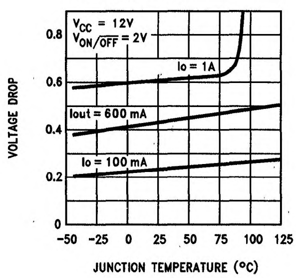
Quiescent Current



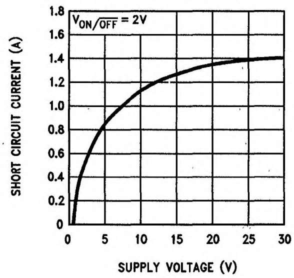
Voltage Drop



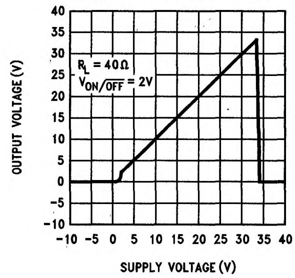
Voltage Drop



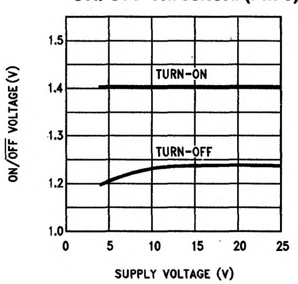
Short Circuit Current



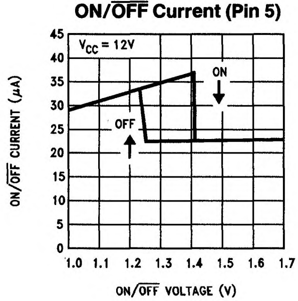
High Voltage Behavior



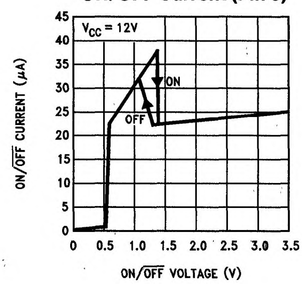
ON/OFF Threshold (Pin 5)



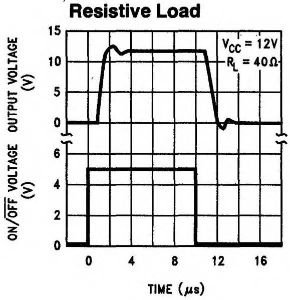
ON/OFF Current (Pin 5)



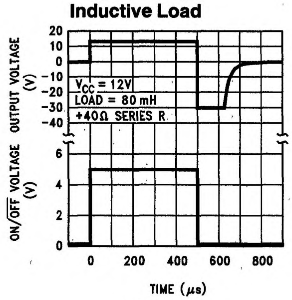
ON/OFF Current (Pin 5)



Output Voltage Resistive Load



Output Voltage Inductive Load



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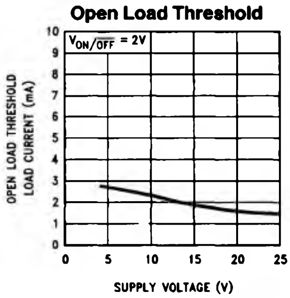
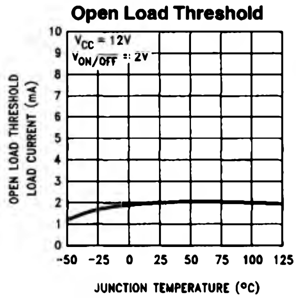
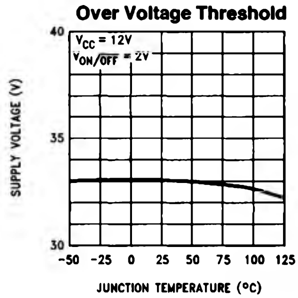
Error Flag Output Characteristics







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Truth Table

Fault Condition	$V_{ON/\overline{OFF}}$*	V_{out}	Error Flag
Normal	L	L	H
	H	H	H
Overvoltage	L	L	L
	H	L	L
Thermal Shutdown	L	L	L
	H	L	L
V_{OUT} Short to GND	L	L	H
	H	L	L
V_{OUT} Short to V_{supply}	L	H	L
	H	H	L
Open Load	L	L	H
	H	H	L
Current Limit	L	L	H
	H	H	L

* L ≅ $0 \le V_{ON/\overline{OFF}} \le 0.8V$ H ≅ $2V \le V_{ON/\overline{OFF}} \le 26V$

Typical Applications

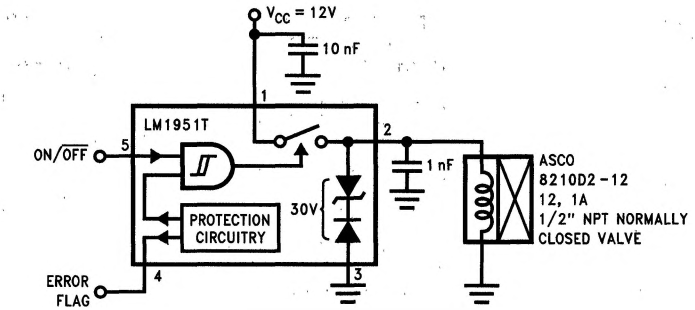

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FIGURE 1. Solenoid Actuated Valve

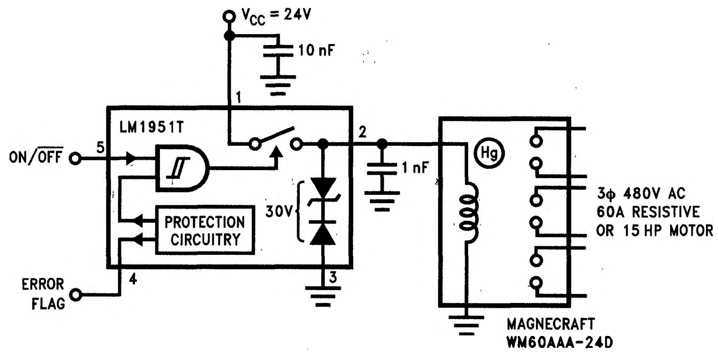

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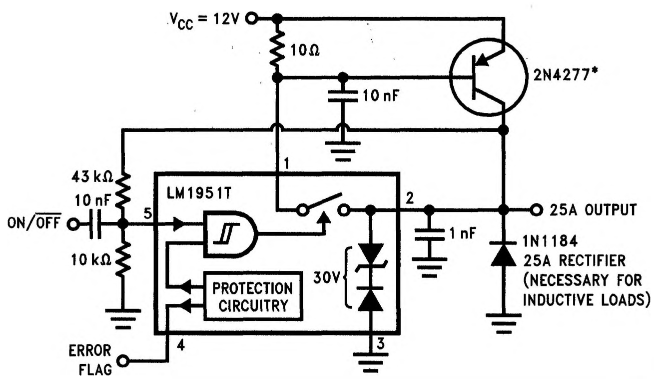
FIGURE 2. 60A 3-Phase Mercury Displacement Relay



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*Available from Germanium Power Devices, Andover, MA, Tel. (617) 475-5982

FIGURE 3. 25A Switch with Short Circuit Foldback

Typical Applications (Continued)

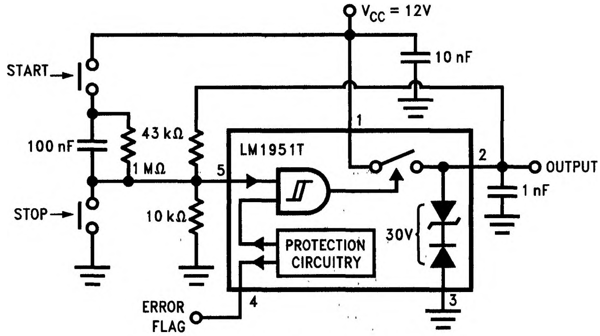

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FIGURE 4. Latching Switch

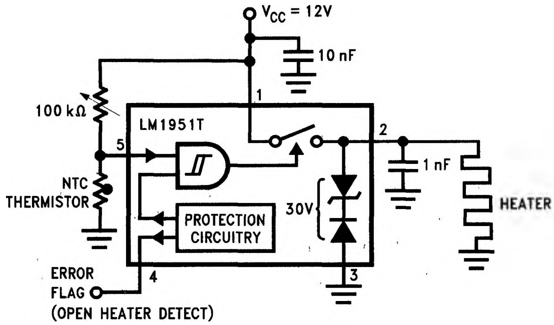

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FIGURE 5. Temperature Controller with Hysteresis

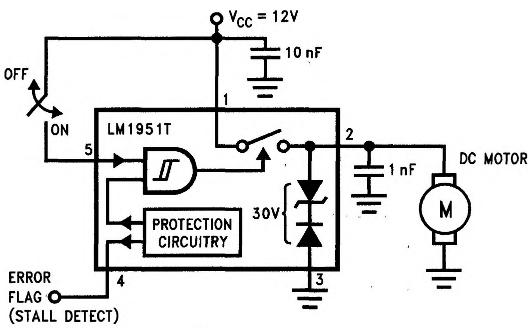

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FIGURE 6. DC Motor Driver

Typical Applications (Continued)

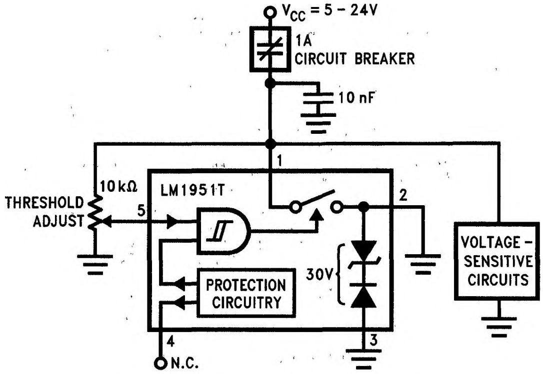

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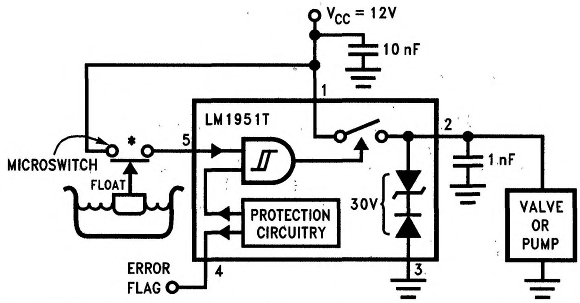
FIGURE 7. Over-Voltage Crowbar



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Operation	Switch Type
Empty	Normally Open
Fill	Normally Closed

FIGURE 8. Fluid Level Controller

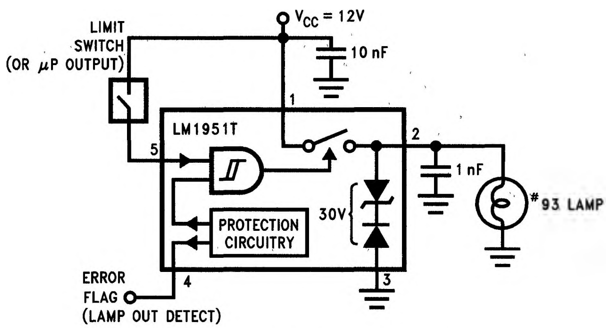

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FIGURE 9. Indicator Lamp Driver

Application Hints

When inductive loads are turned OFF, they produce a negative voltage spike. The LM1951 contains a voltage clamp that limits these spikes to approximately −30V, thus an external clamp is not necessary in most applications.

Loads with an inductance of greater than 1H, driven to full output current, may damage the clamp simply by exceeding the power capabilities of the LM1951. An LM1951 can dissipate 25W continuous at 25°C ambient when mounted on a large heatsink. If the load current is limited to 800 mA, the sustained spike from an infinitely large inductance can be handled. Sustained spikes produced by higher currents and high inductances will exceed the 25W limit.

For inductances above 1H, care should be taken to see that the output current does not exceed a value that could damage the clamp. While 800 mA is acceptable for the device running at 25°C ambient on a heatsink, derate this current for smaller heatsinks or higher ambient temperatures to limit the junction temperature to 150°C. Alternatively, an external clamp or resonating capacitor can be added to handle any combination of load inductance, load current, and device temperature. This is especially important if the output current is boosted, such as the application shown in *Figure 3*. A peak power of 750W could be developed in the internal clamp if an inductive load is switched without external clamping.

Another case where the clamp's power capability may be exceeded is when driving a solenoid. The inductance of a solenoid is greatest when energized, with the plunger pulled in. As the plunger is pulled out of the solenoid, the inductance goes down. Under certain conditions of high solenoid inductance and fast mechanical time constants, the current may actually **increase** when the solenoid is turned OFF. Since the energy stored in an inductor cannot change instantaneously, the current must increase to conserve energy when the inductance decreases. This condition is traced by observing the load current with a current probe and storage oscilloscope.

Load capacitances larger than 1 nF will slow rise and fall times. Inductive loads having a capacitive component larger than 1 nF will also exhibit overshoot. Furthermore, ringing may be evident in a combination inductive/capacitive load, or in an inductive load with supply decoupling capacitors in the range of 100 nF to 1 μF. For fast rise and fall times and minimum ringing with inductive loads, a supply decoupling capacitor of 10 nF and an output capacitor of 1 nF is recommended. These should be located as close to the IC pins as possible.

The error flag is an open collector output that pulls low under certain fault conditions. These errors include overvoltage (V_{CC} > 26V), overcurrent (I_{OUT} > 1.3A), undercurrent (I_{OUT} < 2 mA), output short circuit to ground, output short circuit to supply, and junction temperature greater than 150°C. By connecting a 2 kΩ resistor from the error flag output to a 5V supply a logic output to a microprocessor is provided.

The error flag can give seemingly false indications in a number of situations. Slewing large capacitive loads (>100 nF) can drive the LM1951 into temporary current limit, producing a momentary error indication. Incandescent lamps and DC motors require an inrush current that will also cause a temporary current limit and error indication. Large inductive loads (>50 mH) initially appear as open circuits, falsing the error flag. The error flag pulses for about 1 μs when any load is turned ON since the output is initially at ground. In microprocessor systems these false indications are easily ignored in software. In discrete logic circuits utilizing a latch at the error flag output, some filtering may be required.

An internal current sink (10 μA minimum) is connected to the input, pin 5. If this pin is left open it is guaranteed to pull low, switching the LM1951 OFF. This characteristic is important under certain fault conditions such as when the control line fails open cirucit.

Although the input threshold has hysteresis, the switch points are derived from a very stable band-gap reference. In many applications, such as *Figures 5* and *7*, the LM1951 input can replace an extenal reference and comparator.

The input (pin 5) is clamped at −0.7V and includes a series resistance of approximately 30 kΩ. This pin tolerates negative inputs of up to 1 mA without affecting the performance of the chip.