PWR-SMP220

PWM Power Supply IC

85-265 VAC Input
Isolated, Regulated DC Output

POWER INTEGRATIONS, INC.

Product Highlights

Integrated Power Switch and CMOS Controller

- Output power up to 20 W from rectified 220 VAC input, 12 W from rectified universal (85 to 265 VAC) input
- External transformer provides isolated output voltages
- Configurable for transformer winding or optocoupler feedback

High-voltage, Low-capacitance MOSFET Output

- Designed for 120/220 V off-line applications
- Can also be used with DC inputs from 36 V to 400 V
- Low capacitance allows for high frequency operation

High-speed Voltage-mode PWM Controller

- Internal pre-regulator self-powers the IC on start-up
- Wide V_{BIAS} voltage range
- Optimized for optocoupler feedback

Built-In Self-protection Circuits

- Cycle-by-cycle current limit
- Output overvoltage protection
- Shutdown/auto-restart cycling
- Input undervoltage lockout
- Thermal shutdown

Description

The PWR-SMP220, intended for 220 V or universal off-line isolated power supply applications, combines a high voltage power MOSFET switch with a switchmode power system controller in a monolithic integrated circuit. Few external components are required to implement a small, low-cost, isolated, off-line power supply.

The PWR-SMP220 has been designed for maximum flexibility in feedback techniques. An error amplifier has been included for use with feedback winding regulation, or it can be bypassed for direct optical feedback to the PWM comparator.

The controller section of the PWR-SMP220 contains all the blocks required to drive and control the power stage: off-line pre-regulator, oscillator, bandgap reference, error amplifier, gate driver, and circuit protection. This voltage-mode Pulse Width Modulation control circuit is optimized for flyback topologies, but may be used with other topologies as well.

The PWR-SMP220 is available in a 20-pin batwing SOIC package.

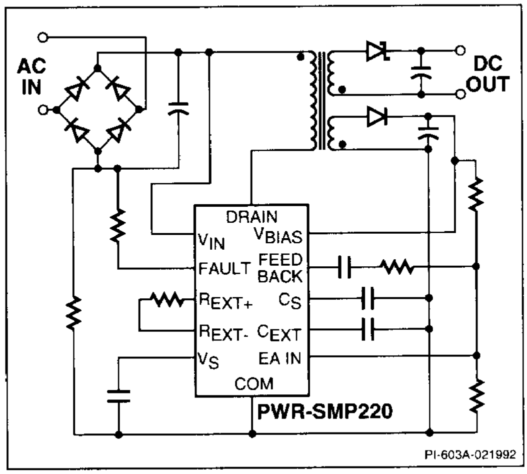

Figure 1. Typical Application

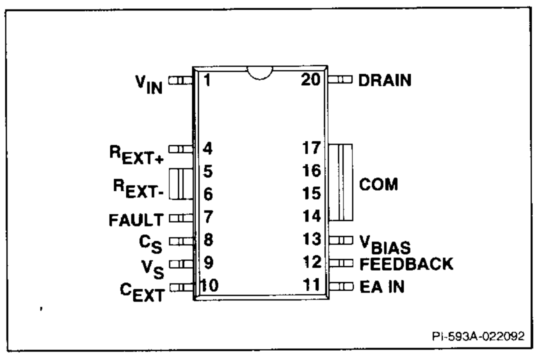

Figure 2. Pin Configuration

ORDERING INFORMATION		
PART NUMBER	PACKAGE	TEMP RANGE
PWR-SMP220SRI	20-pin PWR SOIC	-40 to 85°C

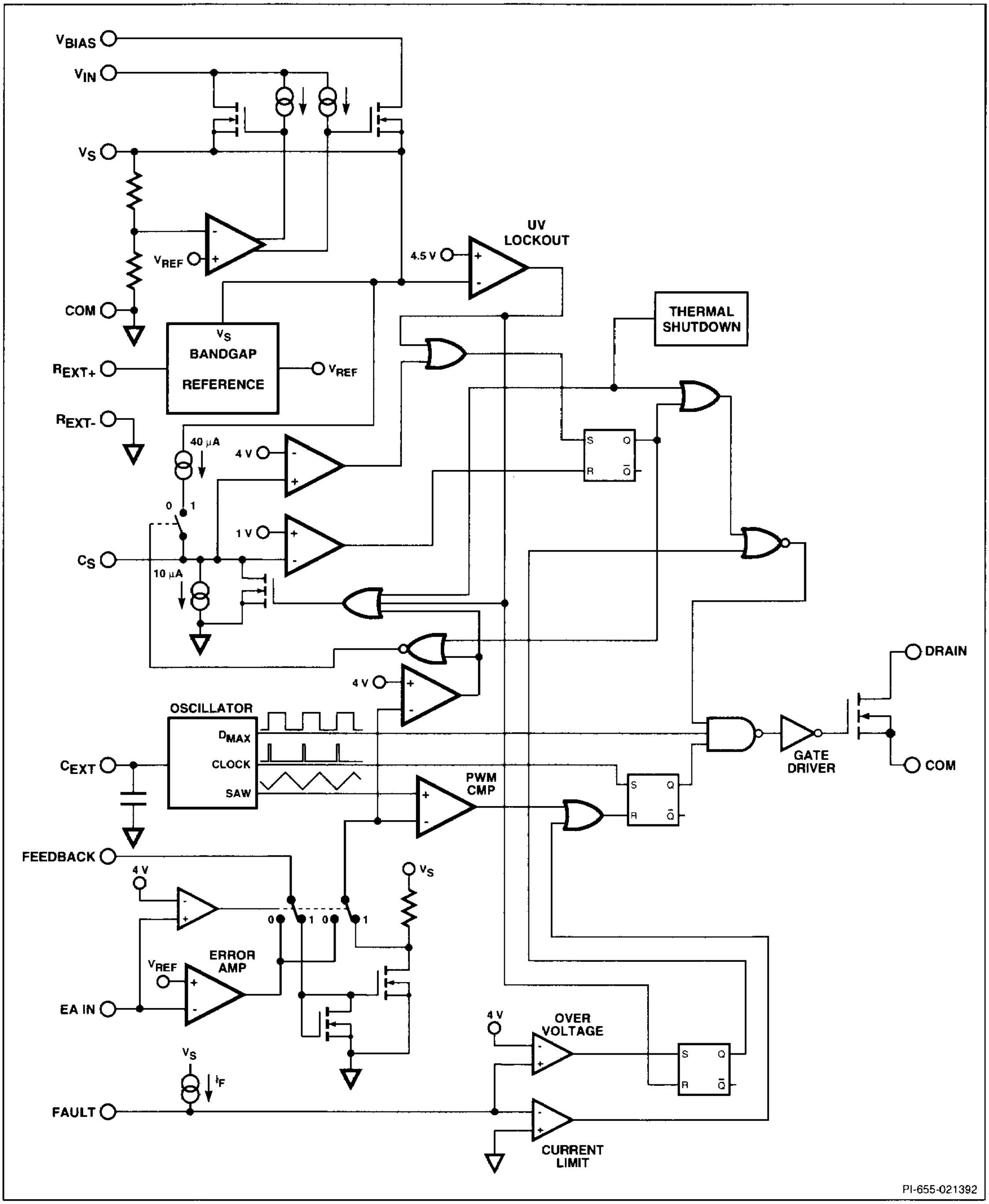

Figure 3. Functional Block Diagram of the PWR-SMP220.

Pin Functional Description

Pin 1:
High voltage V_{IN} for connection to the high voltage pre-regulator used to self-power the device during start-up.

Pin 4:
A resistor placed between R_{EXT+} and R_{EXT-} sets the internal bias currents.

Pin 5, 6:
R_{EXT-} is the return for the reference current. Do not connect to ground plane.

Pin 7:
The **FAULT** pin is used with an external resistor to provide protection of the output during overcurrent and overvoltage conditions.

Pin 8:
C_S is used to set the shutdown/auto-restart cycle time.

Pin 9:
Connection for a bypass capacitor for the internally generated V_S supply.

Pin 10:
C_{EXT} is used to set the oscillator frequency. Adding external capacitance lowers the PWM frequency.

Pin 11:
EA IN is the error amplifier inverting input for connection to the external feedback and compensation networks. Connecting this pin to V_S disables the error amplifier when using optocoupler feedback.

Pin 12:
FEEDBACK can be driven directly by an optocoupler output, bypassing the internal error amplifier. When using transformer winding feedback control, this pin is used as the error amplifier output for connection to the external compensation network.

Pin 13:
V_{BIAS} is the bootstrap voltage used to self-power the device once the supply is operating.

Pin 14, 15, 16, 17:
COM connections. Ground or reference point for the circuit.

Pin 20:
Open **DRAIN** of the output MOSFET.

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PWR-SMP220 Functional Description

Bias Regulator
The onboard supply voltage (V_S) is supplied from either of two high-voltage linear regulators. The V_{IN} linear regulator draws current from the high-voltage bus while the V_{BIAS} regulator draws current from a voltage generated from a transformer winding. The V_{IN} regulator dissipates significant power levels and should be cut off during normal operation for improved efficiency. The V_S error amplifier has a built-in preference for generating V_S from the V_{BIAS} regulator, which automatically cuts off the V_{IN} regulator during normal operation. During start-up and under power supply fault conditions, the bias error amplifier generates V_S from the V_{IN} regulator.

V_S is the supply voltage for the controller and driver circuitry. An external bypass capacitor connected to V_S is required for filtering and noise immunity. The value of V_S also determines when the internal undervoltage lockout is enabled. Undervoltage lockout disables the power MOSFET until V_S is within its normal operating range.

Bandgap Reference
V_{REF} is a 1.25 V reference voltage generated by the temperature compensated bandgap reference. This reference voltage is used for setting thresholds for comparators, amplifiers, and the thermal shutdown circuit. The external resistor connected between R_{EXT+} and R_{EXT-} and the bandgap reference set the proper internal bias current levels for the various internal circuits.

Oscillator
The oscillator linearly charges and discharges the combined internal and external capacitance between two different voltage levels to create a sawtooth waveform for the pulse width modulator. Two digital signals, D_{MAX} and CLOCK are also generated. D_{MAX} corresponds to the rising portion of the sawtooth waveform, and is used to gate the MOSFET driver. A short CLOCK pulse is used to reset the current limit comparator at the beginning of each cycle. The maximum duty cycle is equal to the ratio of the charge time to the total period of the oscillator waveform.

PWR-SMP220 Functional Description (cont.)

Optional Error Amplifier Circuitry
The control loop circuitry is configurable for either secondary-referenced optocoupler control or primary-referenced feedback winding control. In both cases, a control voltage is generated and sent to the pulse width modulator for conversion to a duty cycle.

Connecting the EA IN input to V_S configures the control loop for connection to an external optocoupler. In this mode the internal error amplifier is disabled. The optocoupler output transistor emitter connects directly to FEEDBACK, which is configured as an N-channel MOSFET transistor "diode". This connection presents a low impedance and wide collector-emitter voltage to the optocoupler transistor for improved frequency response and speed. The diode current is converted to the control voltage by a mirror transistor and resistor.

For primary-referenced feedback winding control, the EA IN input is simply connected through a resistor divider to the feedback voltage. The internal error amplifier is automatically configured and connected to the pulse width modulator. EA IN is the inverting input to the error amplifier. The non inverting input is internally connected to the 1.25 V bandgap reference. FEEDBACK is connected to an external feedback compensation network for tailoring the frequency response for proper bandwidth, gain margins, and phase margins.

Pulse Width Modulator
The pulse width modulator implements a voltage mode control loop by driving the power MOSFET with a duty cycle proportional to a control voltage. The duty cycle signal is generated by a comparator which compares the control voltage with a sawtooth waveform. A clock signal from the oscillator sets a latch which turns on the power MOSFET. The pulse width modulator resets the latch turning off the power MOSFET. The D_{MAX} signal from the oscillator limits the maximum duty cycle by gating the driver.

Fault Protection
The FAULT pin is used to implement both cycle-by-cycle MOSFET transistor current limiting and latching output overvoltage protection.

The FAULT pin latches off the power switch when an overcurrent condition causes the voltage on this pin to drop to zero. The DRAIN current is sensed by an external resistor. An internal current source biases the FAULT signal during normal operation. During an overcurrent condition, current flows in the current sense resistor, causing the voltage on the FAULT pin to decrease. If the voltage on the FAULT pin falls below COM for longer than the delay time, the power switch will be latched off until the beginning of the next clock cycle. If this condition persists, the output voltage will fall out of regulation, triggering a shutdown/auto-restart cycle.

For latching overvoltage protection, an external optocoupler can be used to drive the FAULT pin above the 4 V threshold of the overvoltage comparator. This comparator sets a latch that will turn off the power MOSFET until the latch is reset by removing and restoring input power.

Shutdown/Auto-restart
The PWR-SMP220 contains an auto-restart function which will shut off the power supply if the output voltage falls out of regulation. The PWR-SMP220 will try to restart and will test the output after a delay. The PWR-SMP220 will remain shut off for the amount of time determined by the value of C_S, and will then begin the auto-restart cycle. The power supply will resume normal operation if the fault condition has been removed. The power supply will continuously cycle if the output is not regulated within the turn-on delay as determined by C_S. During normal operation, C_S is quickly discharged to 0 V. This function can be disabled by connecting the C_S pin to COM.

Overtemperature Protection
Temperature protection is provided by a precision analog circuit that turns the power switch off and reduces supply current when the switch junction gets too hot (typically 140°C). When the circuit has cooled past the hysterisis temperature, normal operation resumes.

12 W Universal Off-line Power Supply with Optocoupler Feedback

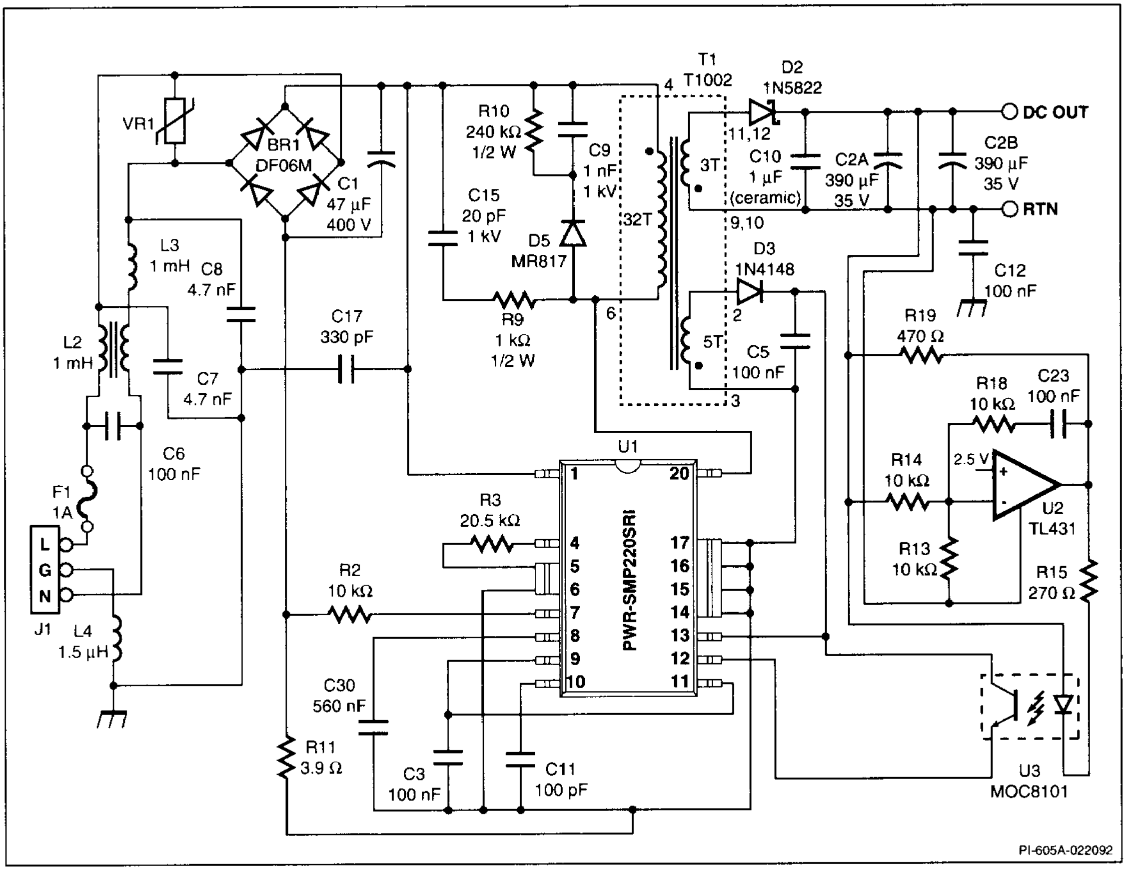


Figure 4. Schematic Diagram of a 5 V, 12 W Universal Input Power Supply Utilizing the PWR-SMP220.

General Circuit Operation

The flyback power supply circuit shown in Figure 4, when operated with the T1002 standard transformer (see DA-3), will produce a 5 volt, 12 watt power supply that will operate from 85 to 265 V(rms) AC input voltage. The output voltage is directly sensed and accurately regulated by a secondary-referenced error amplifier. The error amplifier drives an error signal through an optocoupler to the PWR-SMP220, which directly controls the duty cycle of the integrated high voltage MOSFET switch.

The effective output voltage can be fine-tuned by adjusting the resistive divider formed by R13 and R14. Other output voltages are possible by adjusting the transformer turns ratios as well as the resistor divider.

AC power is rectified and filtered by BR1 and C1 to create the high voltage DC bus applied to the primary winding of transformer T1. The other side of the transformer primary is driven by the integrated high voltage MOSFET transistor within the PWR-SMP220. The clamp circuit implemented by R10, C9, and D5 clamps the leading edge voltage spike caused by transformer leakage inductance to a safe value. Ringing caused by parasitic capacitance and leakage inductance is damped by C15 and R9. The power secondary winding is rectified and filtered by D2, C2A, C2B, and C10 to create the desired output voltage. The bias winding is rectified and filtered by D3 and C5 to create a bias voltage to the PWR-SMP220, which

General Circuit Operation (cont.)

effectively cuts off the high voltage internal linear regulator. Common mode emission currents which flow between the primary windings of the transformer and the secondary output circuitry are attenuated by C12, C17, C7, C8, and L2. Differential mode emission currents caused by pulsating currents at the input of the power supply are attenuated by C6 and L3. Voltage spikes on the AC line are clamped by VR1.

Internal bias currents are accurately set by R3. Bypass capacitor C3 filters current spikes on the internally generated voltage source V_S. The oscillator frequency is determined by C11. Transistor switch current is sensed by resistor R11. The initial voltage level at the fault pin is determined by resistor R2. C30 determines the auto-restart time interval.

The secondary-referenced error amplifier control system is implemented with the TL431 shunt regulator (U2). This device consists of an accurate 2.5 V bandgap reference , error amplifier, and driver. The output voltage is sensed , divided by R13 and R14, and applied to the inverting input of the error amplifier. The non-inverting input of the error amplifier is internally connected to the bandgap reference voltage. The frequency response of the error amplifier is determined by the compensation network consisting of R18, C23, and the high frequency gain setting resistor R14. Bias current of 2 mA minimum for U2 is provided by resistor R19. The LED current in the optocoupler is limited by resistor R15. Optocoupler U3 drives the error signal into the FEEDBACK pin of the PWR-SMP220. Note that the EA IN pin must be connected to the V_S pin to properly configure the PWR-SMP220 for this type of control.

To reduce device power dissipation and temperature rise during normal operation, the voltage applied to V_{BIAS} must be greater than the minimum specified value to ensure complete cutoff of the high voltage linear regulator. Ensure that the maximum specified voltage on the V_{BIAS} pin is not exceeded when adjusting the value of the output voltage.

Implementing Output Overvoltage Protection

If the load is extremely sensitive to overvoltage conditions, an overvoltage shutdown function can be implemented as shown in Figure 5. The output voltage is fed back to the PWR-SMP220 via an op amp and optocoupler. If the voltage at pin 7 is greater than 4 V, the internal latch will shut off the output. The PWR-SMP220 must be restarted by removing the input voltage and then reapplying it, causing the latch to reset and the circuit to begin a new startup cycle.

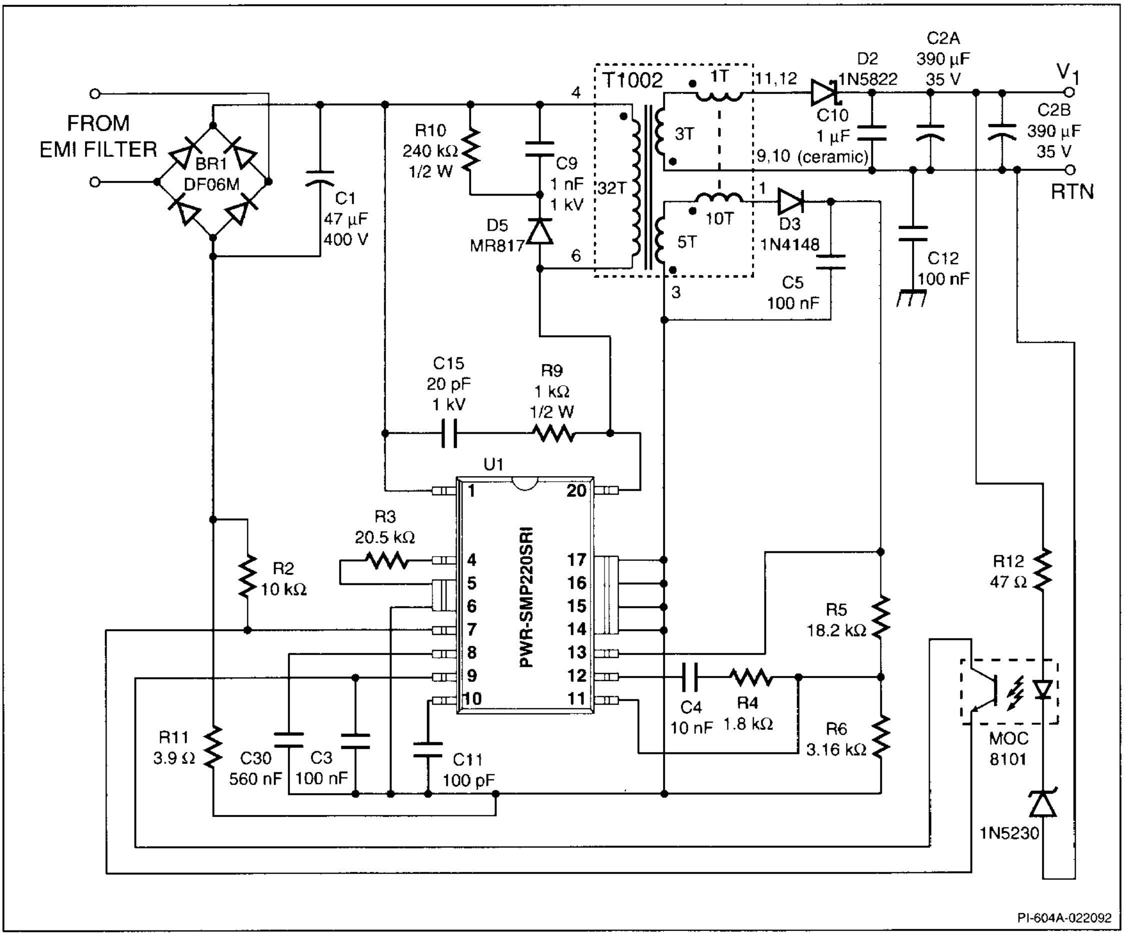


Figure 5. Implementing Feedback Winding Regulation and Output Overvoltage Protection.

ABSOLUTE MAXIMUM RATINGS[1]

Drain Voltage .... 700 V
V_{IN} Voltage .... 500 V
V_{BIAS} Voltage .... 35 V
Drain Current[2] .... 1.3 A
Input Voltage[3] .... - 0.3 V to V_S + 0.3 V
Storage Temperature .... –65 to 125°C
Ambient Temperature .... -40 to 85°C
Junction Temperature[4] .... 150°C
Lead Temperature[5] .... 260°C

Power Dissipation (T_A = 25°C) .... 3.0 W
(T_A = 70°C) .... 1.5 W
Thermal Impedance (θ_{JA}) .... 30°C/W
Thermal Impedance (θ_{JC})[6] .... 6°C/W

1. Unless noted, all voltages referenced to COM, T_A = 25°C
2. 300 µs, 2% duty cycle.
3. Does not apply to V_{IN} or DRAIN.
4. Normally limited by internal circuitry.
5. 1/16" from case for 5 seconds.
6. Measured at pin 15/16.

Specification	Symbol	Test Conditions, Unless Otherwise Specified: V_{IN} = 325 V, V_{BIAS} = 8.5 V, COM = 0 V, R_{EXT} = 20.5 kΩ, C_S = 560 nF, T_A = -40 to 85°C (See Note 1)	Test Limits MIN	TYP	MAX	Units
OSCILLATOR						
Output Frequency	f_{OSC}	C_{EXT} = Open	650	750	850	kHz
PULSE WIDTH MODULATOR						
Duty Cycle Range	DC	C_{EXT} = Open	0-35	0-40		%
		f_{OSC} = 200 kHz	0-48	0-50		
Optocoupler Output Current	I_C	EA IN = V_S, Maximum Duty Cycle	400		600	µA
Dynamic Control Current	i_C	0 to Maximum Duty Cycle	50	100	200	µA
CIRCUIT PROTECTION						
FAULT Offset Current				100		µA
FAULT OV Threshold	V_{OV}			4		V
FAULT Current Limit Threshold	V_{ILIMIT}			0		V

Specification	Symbol	Test Conditions, Unless Otherwise Specified: V_{IN} = 325 V, V_{BIAS} = 8.5 V, COM = 0 V R_{EXT} = 20.5 kΩ, C_S = 560 nF T_A = -40 to 85°C (See Note 1)	Test Limits MIN	TYP	MAX	Units
CIRCUIT PROTECTION (cont.)						
Current Limit Delay Time	$t_{d(off)}$	See Figure 6	75	150	250	ns
Thermal Shutdown Temperature			125	140		°C
Thermal Shutdown Hysteresis				15		°C
SHUTDOWN/AUTO-RESTART						
ON Time	t_{ON}	See Figure 7		38		ms
OFF Time	t_{OFF}	See Figure 7		150		ms
Reset Time	t_{RESET}	See Figure 7		12.5		ms
Charge/Discharge Ratio				4:1		
Upper Threshold Voltage	V_{THU}			4.0		V
Lower Threshold Voltage	V_{THL}			1.0		V
ERROR AMPLIFIER						
Reference Voltage	V_{REF}		1.21	1.25	1.29	V
Reference Voltage Temperature Drift	ΔV_{REF}			50		ppm/°C
Gain-Bandwidth Product				500		kHz
DC Gain	A_{VOL}		60	80		dB
Output Impedance	Z_{OUT}			1.5		kΩ

Specification	Symbol	Test Conditions, Unless Otherwise Specified: V_{IN} = 325 V, V_{BIAS} = 8.5 V, COM = 0 V R_{EXT} = 20.5 kΩ, C_S = 560 nF T_A = -40 to 85°C (See Note 1)		Test Limits MIN	TYP	MAX	Units
OUTPUT (cont.)							
ON-State Resistance	$R_{DS(ON)}$	I_D = 200 mA	T_j = 25°C			7.2	Ω
			T_j = 115°C			13	
ON-State Current	$I_{D(ON)}$	V_{DS} = 10 V	T_j = 25°C	0.7	1.0		A
			T_j = 115°C	0.5	0.7		
OFF-State Current	I_{DSS}	V_{DRAIN} = 560 V, T_A = 115°C			10	50	μA
Breakdown Voltage	BV_{DSS}	I_{DRAIN} = 100 μA, T_A = 25°C		700			V
Output Capacitance	C_{OSS}	V_{DRAIN} = 25 V, f = 1 MHz			150		pF
Output Stored Energy	E_{OSS}	V_{DRAIN} = 400 V			2000		nJ
Rise Time	t_r	See Figure 6			70	150	ns
Fall Time	t_f	See Figure 6			70	150	ns
SUPPLY							
Pre-regulator Voltage	V_{IN}			36		500	V
Off-line Supply Current	I_{IN}	V_{BIAS} not connected, C_{EXT} = Open			3	4.5	mA
		V_{BIAS} > 8.25 V				0.1	
		Thermal Shutdown ON				2	
V_{BIAS} Supply Voltage	V_{BIAS}	V_{BIAS} externally supplied		8.25		30	V
V_{BIAS} Supply Current	I_{BIAS}	V_{BIAS} externally supplied			3	4.5	mA
V_S Source Voltage	V_S			5.1		6.0	V
V_S Source Current	I_S					400	μA

NOTES:

1. Applying >3.5 V to the C_{EXT} pin activates an internal test circuit that turns on the output switch continuously. Destruction of the part can occur if the output of the PWR-SMP220 is connected to a high voltage power source when the test circuit is activated.

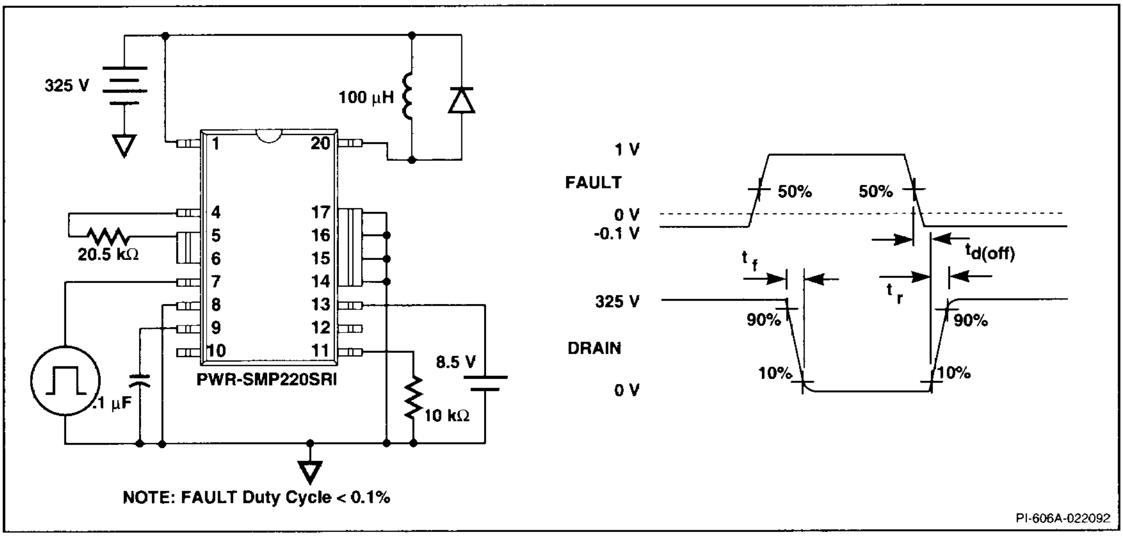


Figure 6. Current Limit Delay/Switching Time Test Circuit.

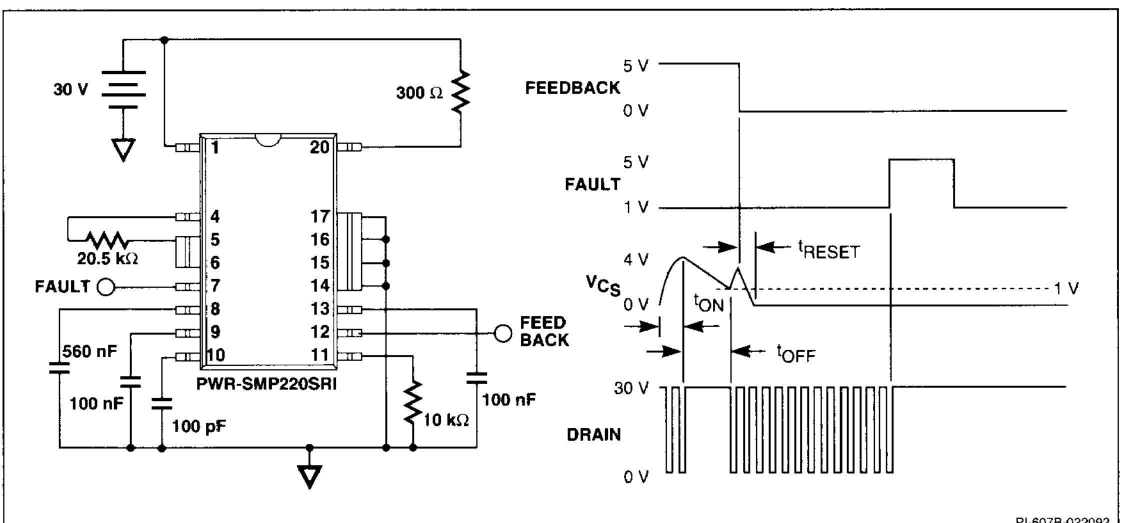
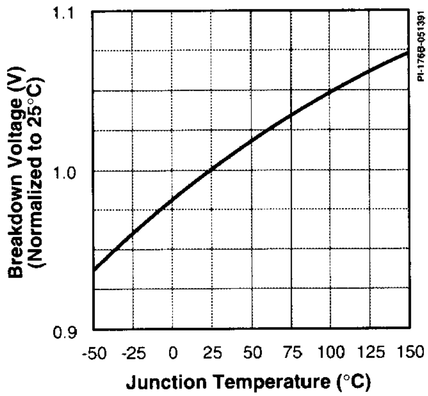
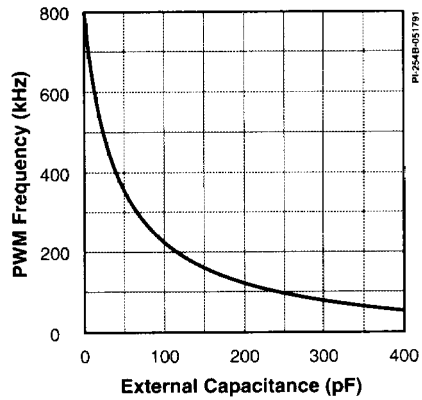


Figure 7. Auto-restart Test Circuit.

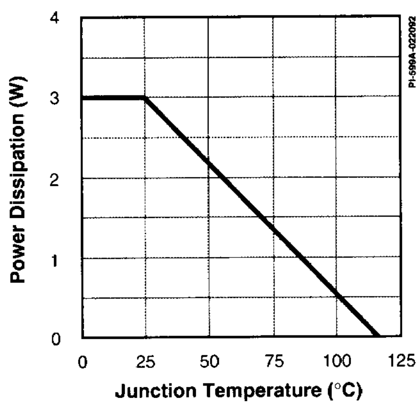
BREAKDOWN vs. TEMPERATURE



fPWM vs. EXTERNAL CAPACITANCE



PACKAGE POWER DERATING



TRANSIENT THERMAL IMPEDANCE