



High-Voltage Current Mode PWM Controller for ISDN Power Supplies

FEATURES

- BiC/DMOS Technology
- Current Mode Control
- Max 50% Duty Cycle Operation
- 1.3-MHz Error Amp
- Up to 500-kHz Internal Oscillator
- Soft-Start
- 0.6-V Fast Over-Current Protection
- $<5\text{-}\mu\text{A}$ Supply Current for $+V_{IN} < 18\text{ V}$
- 23.5-V to 200-V Input Voltage Range
- Programmable Start/Stop Capability
- Internal Start-Up Circuit
- Power_Good Output

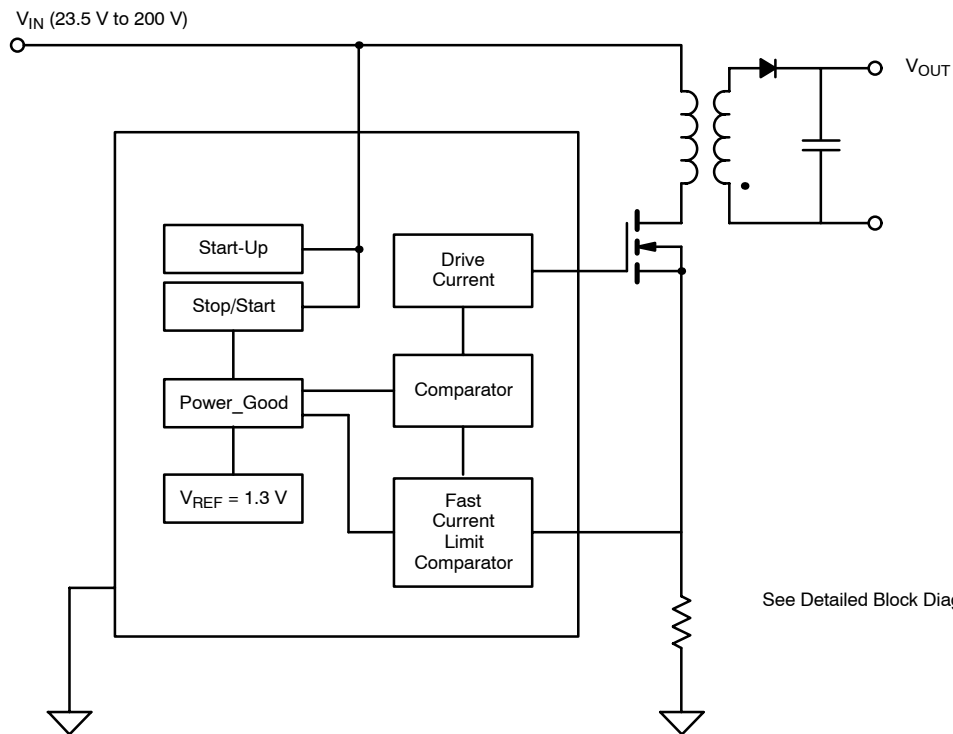
DESCRIPTION

Si9113 is a current mode PWM controller for ISDN power supplies. In a 14-pin SOIC package, it provides all necessary functions to implement a single-switch PWM with a minimum of external parts. To maximize the circuit integration, the Si9113 is designed with a 200-V depletion mode MOSFET capable of powering directly off the high input bus without an external start-up circuit. The Start and Stop input voltage thresholds can be programmed within the operating input voltage range by means of a resistor divider, provided $+V_{IN}$

(Start) $> +V_{IN}$ (Stop). The internal clock frequency is set with a single external resistor and is capable of capacitor-coupled external synchronization. In order to satisfy the stringent ambient temperature requirements, the Si9113 is rated to handle the industrial range of -40°C to 85°C .

The Si9113 is available in both standard and lead (Pb)-free packages.

FUNCTIONAL BLOCK DIAGRAM



Applications information see AN728.

A Demonstration Board data sheet is available for this product.

Vishay Siliconix

ABSOLUTE MAXIMUM RATINGS

| | |
|---|--|
| V_{IN} | 220 V |
| V_{CC} | 18 V |
| Logic Inputs (OSC IN, OSC OUT, PWR_GOOD) | -0.3 V to $V_{CC} + 0.3$ V or ± 10 mA |
| Linear Inputs (FB, V_{REF} , SENSE, SS) | -0.3 V to $V_{CC} + 0.3$ V |
| Storage Temperature | -65 to 150°C |
| Operating Temperature | -40 to 85°C |

| | |
|--|---------|
| Junction Temperature | 150°C |
| Power Dissipation (Package) ^a | |
| 14-Pin SOIC (Y Suffix) ^b | 900 mW |
| Thermal Impedance (θ_{JA}) | |
| 14-Pin SOIC | 140°C/W |

Notes

- a. Device mounted with all leads soldered or welded to PC board.
b. Derate 7.2 mW/°C above 25°C.

Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

RECOMMENDED OPERATING RANGE

| | |
|----------------------|-----------------|
| V_{IN} | 23.5 V to 200 V |
| V_{CC} | 10 V to 14 V |
| Digital Inputs | 0 V to V_{CC} |

| | |
|----------------------|-----------------------|
| Linear Outputs | 0 V to $V_{CC} - 3$ V |
| f_{OSC} | 30 kHz to 500 kHz |

| SPECIFICATIONS ^a | | | | | | | |
|--------------------------------------|------------------|--|-------------------|-----------------------|------------------|------------------|---------|
| Parameter | Symbol | Test Conditions Unless Otherwise Specified $V_{CC} = 10$ V, $+V_{IN} = 48$ V, $R_{OSC} = 390$ k Ω | Temp ^b | Limits -40 to 85°C | | | Unit |
| | | | | Min ^c | Typ ^d | Max ^c | |
| Reference | | | | | | | |
| Output Voltage | V_{REF} | $OSC_{IN} = -V_{IN}$ (OSC Disabled) $R_L = 10$ M Ω | Room Full | 1.275 1.26 | 1.3 1.3 | 1.325 1.34 | V |
| Short Circuit Current | I_{SREF} | $V_{REF} = -V_{IN}$ | Room | | -25 | -10 | mA |
| Load Regulation | ΔV_{REF} | $I_{REF} = 0$ to -0.5 mA | Full | | ± 10 | 40 | mV |
| Line Regulation | | $V_{CC} = 10$ to 14 V | Full | | ± 2 | 5 | |
| UVLO | | | | | | | |
| Under Voltage Lockout | $V_{UVSTART}$ | Turn-On | Full | 8.10 | 8.8 | 9.50 | V |
| | V_{UVSTOP} | Turn-Off | Full | 8.10 | 8.8 | 9.50 | |
| Input Bias Current | I_{START} | $V_{STOP} = 8$ V, $V_{START} = 8$ V | Room | | | 0.05 | μ A |
| | I_{STOP} | | Room | | | 0.05 | |
| Pre-Regulated V_{CC} | V_{REG} | | Room | 8.5 | 9.0 | 9.5 | V |
| UVLO for V_{CC} | V_{CCUV} | | Room | 7.9 | 8.4 | 8.9 | |
| $V_{REG} - V_{CCUV}$ | V_{Δ} | | Room | 0.3 | 0.6 | | |
| PWR_Good Comparator | | | | | | | |
| Rise Time | t_{rpg} | $C_{PWR_Good} = 100$ nF | Room | | 35 | | mS |
| Fall Time | t_{fpg} | | Room | | 25 | | μ S |
| Output Logic Low | | $I_{SINK} = 2.5$ mA | Room | | 0.4 | 0.8 | V |
| Soft-Start | | | | | | | |
| SS Current | I_{SS} | | Room | | 11 | | μ A |
| Output Inhibit Voltage | V_{SS} | | Room | | 3.3 | | V |
| Oscillator | | | | | | | |
| Maximum Frequency ^e | f_{MAX} | $R_{OSC} = 0$ | Room | 500 | | | kHz |
| Initial Accuracy | f_{OSC} | $R_{OSC} = 390$ k (Note f) | Room | 80 | 100 | 120 | |
| | | $R_{OSC} = 180$ k (Note f) | Room | 160 | 200 | 240 | |
| Voltage Stability | $\Delta f/f$ | $\Delta f/f = (f [14$ V] - $f [10$ V]) / $f [10$ V] | Room | | 10 | 15 | % |
| Temperature Coefficient ^e | T_{OSC} | | Full | | 450 | 650 | ppm/°C |
| Maximum Duty Cycle | D_{MAX} | $f_{OSC} = 100$ kHz | Room | | 50 | | % |



| SPECIFICATIONS ^a | | | | | | | |
|---------------------------------------|--------------|--|-------------------|-----------------------|------------------|------------------|---------------|
| Parameter | Symbol | Test Conditions Unless Otherwise Specified $V_{CC} = 10\text{ V}$, $+V_{IN} = 48\text{ V}$, $R_{OSC} = 390\text{ k}\Omega$ | Temp ^b | Limits -40 to 85°C | | | Unit |
| | | | | Min ^c | Typ ^d | Max ^c | |
| Error Amplifier | | | | | | | |
| Open Loop Voltage Gain ^e | A_{VOL} | OSC IN = - V_{IN} | Room | 50 | 60 | | dB |
| Input BIAS Current | I_{BIAS} | $V_{FB} = 1.3\text{ V}$ | Room | -1 | | 1 | μA |
| Feedback Input Voltage | V_{FB} | FB Tied to COMP, OSC IN = - V_{IN} | Full | 1.28 | | 1.32 | V |
| Dynamic Output Impedance ^e | Z_{OUT} | | Room | | 1 | 2 | k Ω |
| Unity Gain Bandwidth ^e | BW | | Room | 1 | 1.3 | | MHz |
| Output Current | I_{OUT} | Source $V_{FB} = 0.8\text{ V}$ | Room | | -5 | -1 | mA |
| | | Sink $V_{FB} = 1.8\text{ V}$ | Room | 0.12 | 0.15 | | |
| Power Supply Rejection ^e | PSRR | | Room | 50 | 70 | | dB |
| Current Limit Comparator | | | | | | | |
| Threshold Voltage | V_{SOURCE} | $V_{FB} = 0\text{ V}$ | Full | 0.5 | 0.6 | 0.7 | V |
| Delay to Output ^e | t_d | $V_{SENSE} = 0.85\text{ V}$, See Figure 1 | Full | | 100 | 150 | ns |
| Output Drive | | | | | | | |
| Output High Voltage | V_{OH} | $I_{OUT} = -10\text{ mA}$ | Room Full | 9.7 9.5 | | | V |
| Output Low Voltage | V_{OL} | $I_{OUT} = 10\text{ mA}$ | Room Full | | | 0.3 0.5 | |
| Rise Time | t_r | $C_L = 500\text{ pF}$ (10% to 90%) | Room | | 40 | 75 | ns |
| Fall Time | t_f | | Room | | 40 | 75 | |
| Supply | | | | | | | |
| Supply Current | I_{CC} | $V_{CC} = 10\text{ V}$, $R_{OSC} = 390\text{ k}\Omega$ $V_{UVUP} \leq V_{IN} \leq 200\text{ V}$ | Full | | 1 | 1.4 | mA |
| | I_{VIN} | Excluding I From Resistive Divider of Stop and Start Pins | Room | | 75 | 100 | μA |
| Supply Current UVLO Mode | I_{VIN} | $+V_{IN} \leq 18\text{ V}$, V_{START} (Pin 14) < 8.8 V | Room | | 2 | 5 | |

Notes

- a. Refer to PROCESS OPTION FLOWCHART for additional information.
- b. Room = 25°C, Full = -40 to 85°C.
- c. The algebraic convention whereby the most negative value is a minimum and the most positive a maximum.
- d. Typical values are for DESIGN AID ONLY, not guaranteed nor subject to production testing.
- e. Guaranteed by design, not subject to production test.
- f. C_{STRAY} Pin 8 = $\leq 5\text{ pF}$.

TIMING WAVEFORMS

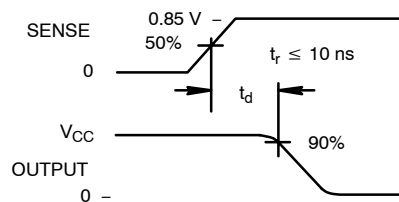
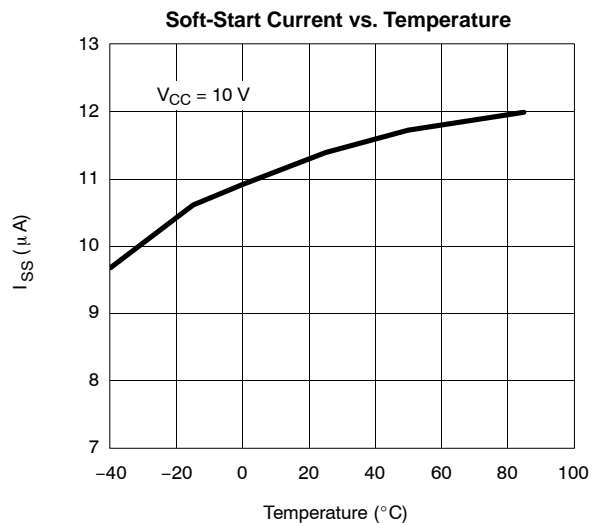
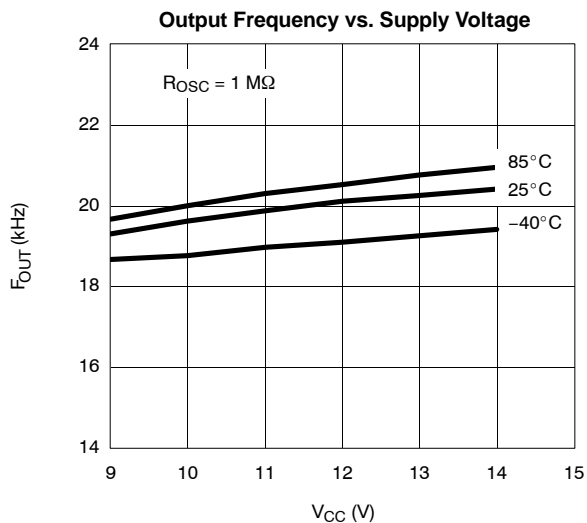
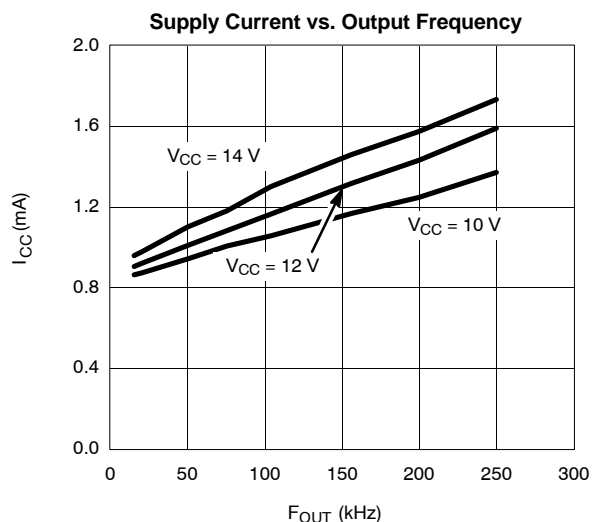
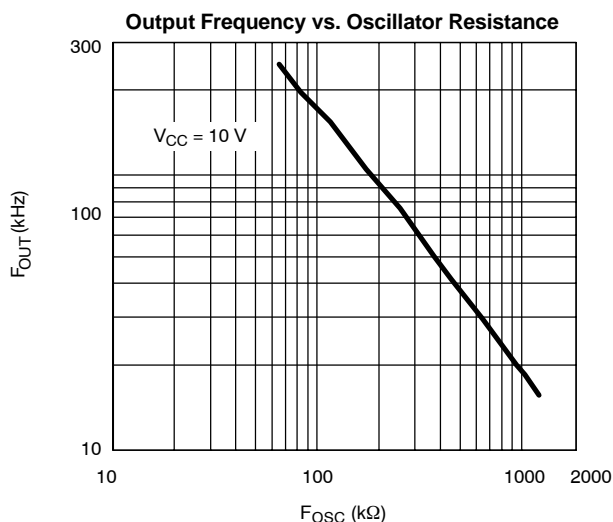
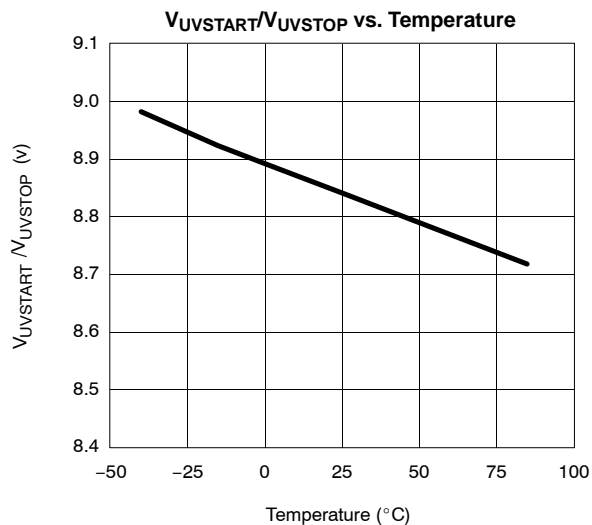
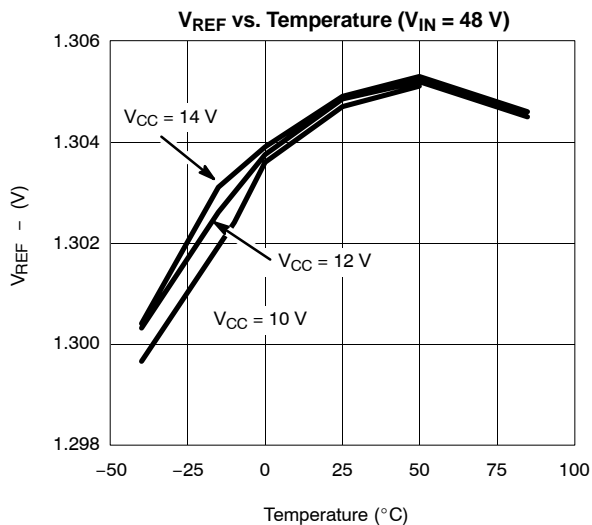


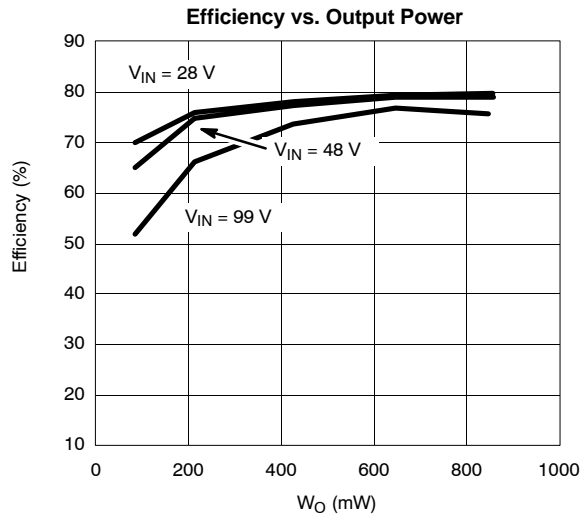
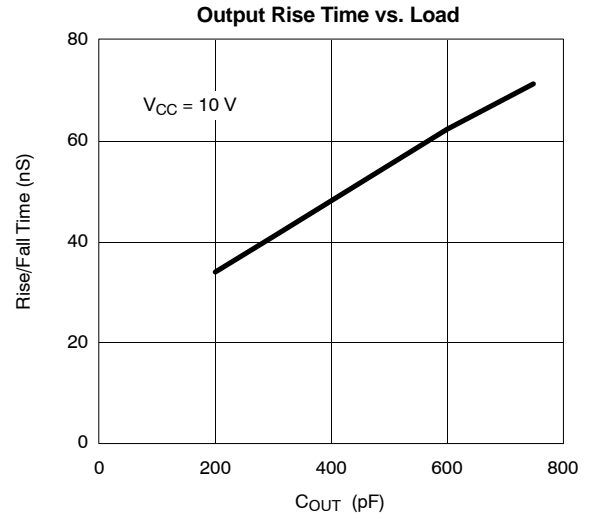
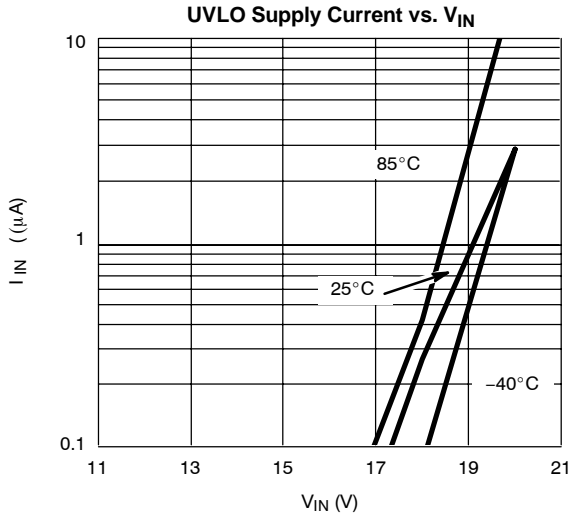
FIGURE 1. Delay Time for Current Sense

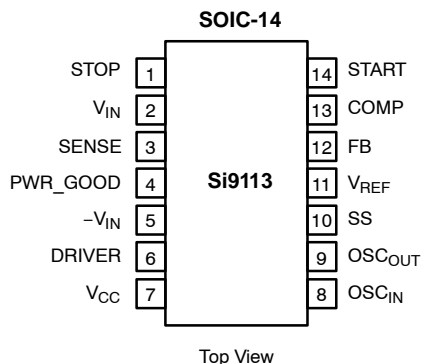
TYPICAL CHARACTERISTICS (25 °C UNLESS NOTED)





TYPICAL CHARACTERISTICS (25°C UNLESS NOTED)



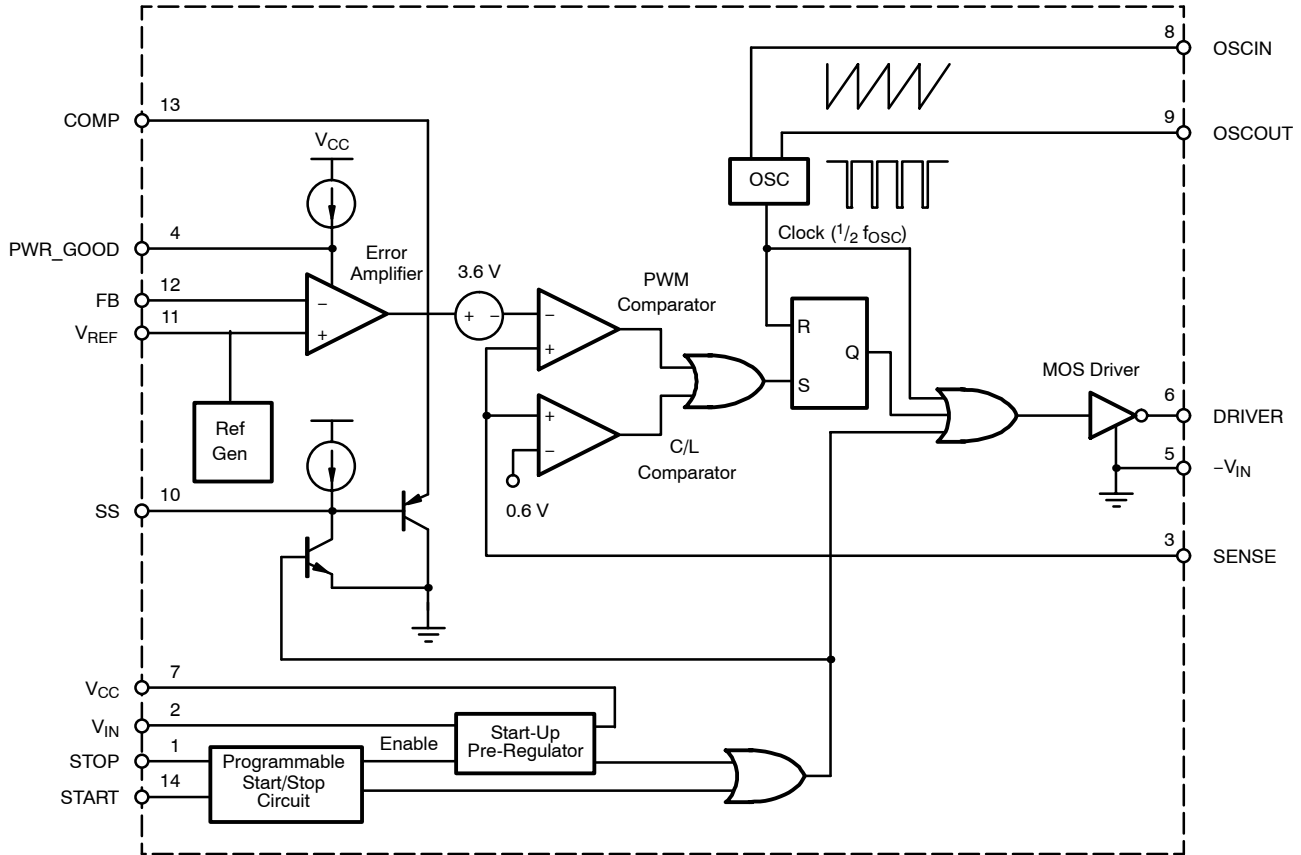
PIN CONFIGURATION

ORDERING INFORMATION

| Part Number | Temperature Range | Package |
|----------------|-------------------|---------------|
| Si9113DY | -40 to 85°C | Bulk |
| Si9113DY-T1 | | Tape and Reel |
| Si9113DY-T1—E3 | | |

| Eval Kit | Temperature Range | Board Type |
|----------|-------------------|-----------------------------|
| Si9113D1 | -10 to 70°C | Surface Mount and Thru-Hole |
| Si9113D2 | | |

PIN DESCRIPTION

| Pin Number | Name | Function |
|------------|--------------------|---|
| 1 | STOP | Set up the stop threshold of $+V_{IN}$ for V_{CC} via resistive dividers |
| 2 | $+V_{IN}$ | Input voltage to UVLO and Start-Up circuitry |
| 3 | SENSE | Current sense amplifier input for current mode control and OCP. |
| 4 | PWR_GOOD | Logic high PWR_Good signal indicates FB voltage is within regulation. |
| 5 | $-V_{IN}$ | Ground pin |
| 6 | DRIVER | MOSFET gate drive signal. |
| 7 | V_{CC} | Supply voltage to internal circuitry and MOSFET gate drive. |
| 8 | OSC _{IN} | R _{OSC} terminal |
| 9 | OSC _{OUT} | R _{OSC} terminal, square waveform output |
| 10 | SS | Soft-Start, time programmed by capacitor value. |
| 11 | V _{REF} | 1.3-V reference. Decoupled with 0.1- μ F capacitor. |
| 12 | FB | Inverting input of an error amplifier. |
| 13 | COMP | Error amplifier output for external compensation network. |
| 14 | START | Set up the start threshold of $+V_{IN}$ for V_{CC} via resistive dividers |

DETAILED BLOCK DIAGRAM

DETAILED DESCRIPTION
Start-Up

The Si9113 start-up circuit prevents the internal circuits from turning on until the voltage on the +V_{IN} pin, via the resistor divider R₃, R₄, R₅, is sufficiently positive such that the voltage across R₃ (V_{START}) is >8.8 V (typical value for the internal reference V_{UVSTART} [see Figure 2]). When this occurs, the internal 1.3-V reference, soft-start and oscillator circuits are enabled. A constant current source provides the current to the external soft-start capacitor, which allows the output voltage to rise gradually without overshoot. The output drive circuit is disabled until the soft-start voltage reaches 3.3 V. The controller is continuously powered in the state until the V_{IN} voltage falls and V_{STOP} drops below 8.8 V (the typical value for

the internal reference V_{UVSTOP}). The user can program the +V_{IN} START and +V_{IN} STOP voltage with the external resistor divider R₃–R₅ (see Figure 2) as follows:

$$V_{IN(START)} = \left(\frac{R_3 + R_4 + R_5}{R_5} \right) \times V_{UVSTART} \quad (1)$$

$$V_{IN(STOP)} = \left(\frac{R_3 + R_5}{R_5} \right) \times V_{UVSTOP} \quad (2)$$

Since V_{UVSTART} = V_{UVSTOP} = 8.8 V (typical) the hysteresis voltage can be expressed as:

$$\Delta V_{IN} = \left(\frac{R_4}{R_5} \right) \times V_{UVSTART} \quad (3)$$

V_{CC} Circuit

The depletion MOSFET process allows the Si9113 controller to power directly from the high input bus voltage. Once $V_{UVSTART}$ is met, the pre-regulator start-up circuit generates the 9.0-V V_{CC} voltage. The V_{CC} voltage is used internally to power the IC as well as providing the drive current for the external MOSFET. An internal V_{CC} circuit is disabled once a higher external voltage (~ 10 V) is applied to this pin. If V_{CC} is below V_{CCUV} , the Si9113 will inhibit the driver output switching.

REF

The reference voltage of Si9113 is set at 1.3 V. The reference voltage is internally connected to the non-inverting input of error amplifier. The reference is decoupled with 0.1- μ F capacitor.

Soft-Start

The soft-start circuit provides a constant 10- μ A current to external capacitor attached to SS pin. A constant soft-start current forces a gradual increase in duty cycle which in turn ensures gradual output voltage rise without overshooting. The soft-start time is programmed by the capacitance value.

Oscillator

The oscillator consists of a ring of CMOS inverters, capacitors, and a capacitor discharge switch. An external resistor, R_{OSC} , between the OSC_{IN} and OSC_{OUT} pins sets the frequency. The maximum frequency is obtained when $R_{OSC} = 0 \Omega$. A frequency divider in the logic section limits the switch duty cycle to 50% by locking the switching frequency to one-half of the oscillator frequency.

PWM Mode

As the load and line voltage vary, the switching frequency remains constant. The switching frequency is programmed by the R_{OSC} value as shown by the oscillator curve. In the PWM mode, a duty cycle pulse is generated for each switching

period eliminating any chance of undesirable noise frequency. When the output load current decreases to 0 A, the controller is forced to enter the pulse skipping mode. This is a natural phenomenon for all controllers since the duty cycle cannot decrease linearly to 0%.

Error Amplifier

The error amplifier gain-bandwidth product and slew rate are critical parameters which determine the transient response of converter. The transient response is the function of both small and large signal responses. The small signal response is determined by the converter closed loop bandwidth and phase margin while the large signal is determined by the error amplifier dv/dt and the inductor di/dt slew rate. Besides the inductance value, the error amplifier determines the converter response time. In order to minimize the response time, the Si9113 is designed with 1.3-MHz error amplifier gain-bandwidth product to generate the widest converter bandwidth.

Current Limit

Over current protection circuit is provided by monitoring the voltage on the Sense pin. Once the current sense voltage reaches 0.6V peak, the output drive stage is disabled for the remainder of the clock cycle.

Power_Good Comparator

The PWR_Good signal indicates the status of output voltage. If the output voltage and V_{CC} are within regulation, the PWR_Good signal generates a logic high output by monitoring the voltage on COMP and V_{CC} pins. If either one is out of regulation, a logic low PWR_Good signal is generated. The capacitor at the PWR_Good pin determines the rise time of the power good signal, once all the conditions are met for power good. The PWR_Good signal is an open collector output capable of sinking 2.5 mA.

MOSFET Gate Drive

The DRIVER pin is designed to drive the low-side n-channel MOSFET. Typically, the driver stage is sized to sink and source 200-mA of peak current when $V_{CC} = 12$ V.

TYPICAL APPLICATION CIRCUITS

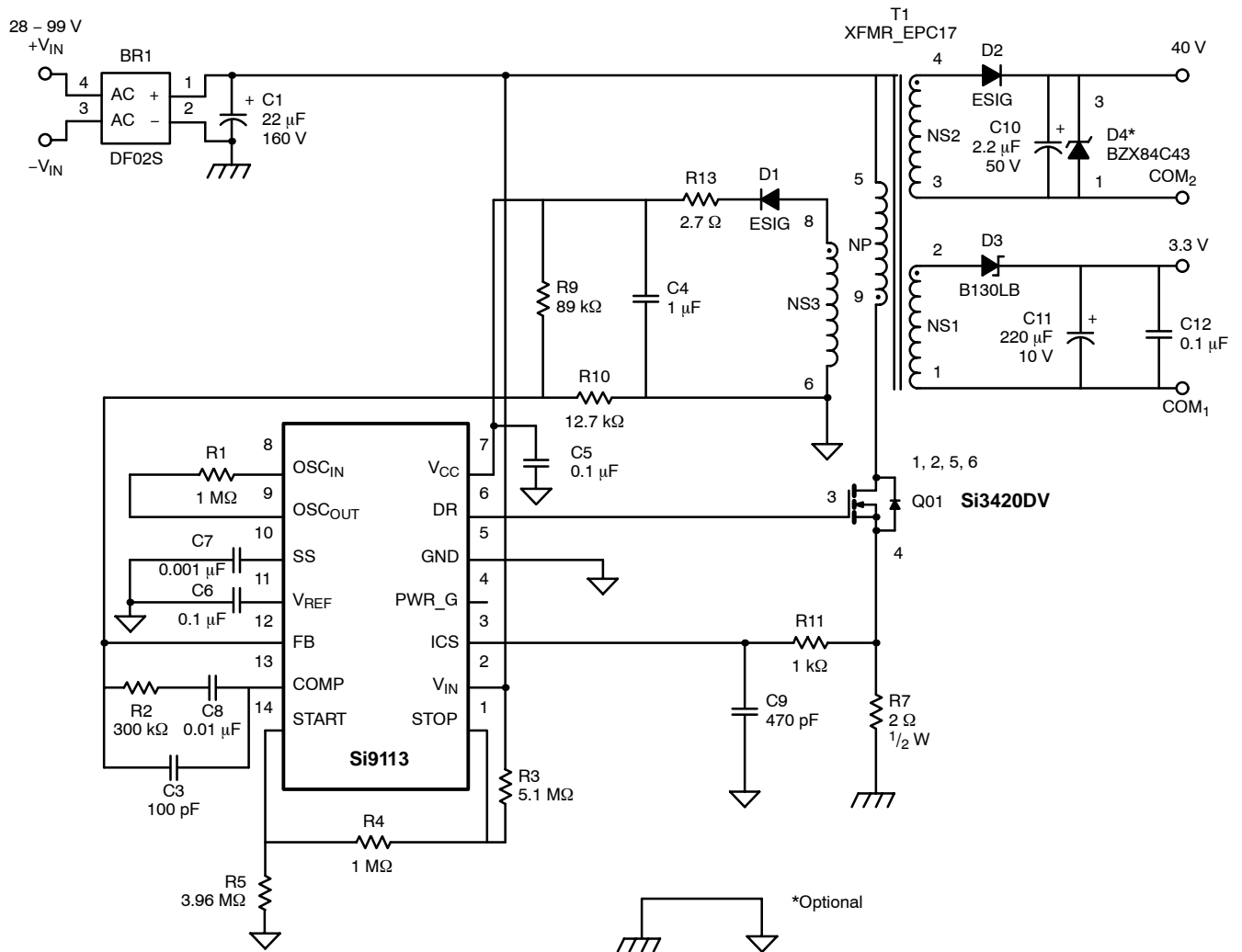


FIGURE 3. Dual Output Flyback Converter with Moderately Regulated Outputs
(As used on Demo Board DB-2)



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