

## SMARTRECTIFIER™ CONTROL IC

### Features

- Secondary side high speed SR controller
- DCM, CrCM and CCM flyback topologies
- 200 V proprietary IC technology
- Max 500 KHz switching frequency
- Anti-bounce logic and UVLO protection
- 4 A peak turn off drive current
- Micropower start-up & ultra low quiescent current
- 10.7 V gate drive clamp
- 50 ns turn-off propagation delay
- Vcc range from 11.3 V to 20 V
- Direct sensing of MOSFET drain voltage
- Minimal component count
- Simple design
- Lead-free
- Compatible with 1 W Standby, Energy Star, CECP, etc.

### Typical Applications

- LCD & PDP TV, Telecom SMPS, AC-DC adapters, ATX SMPS, Server SMPS

### Product Summary

|  |             |
|--|-------------|
| Topology                                 | Flyback     |
| VD                                       | 200 V       |
| V <sub>OUT</sub>                         | 10.7 V      |
| I <sub>o+</sub> & I <sub>o-</sub> (typ.) | +1 A & -4 A |
| Turn on Propagation Delay (typ.)         | 52 ns       |
| Turn off Propagation Delay (typ.)        | 35 ns       |

### Package Options

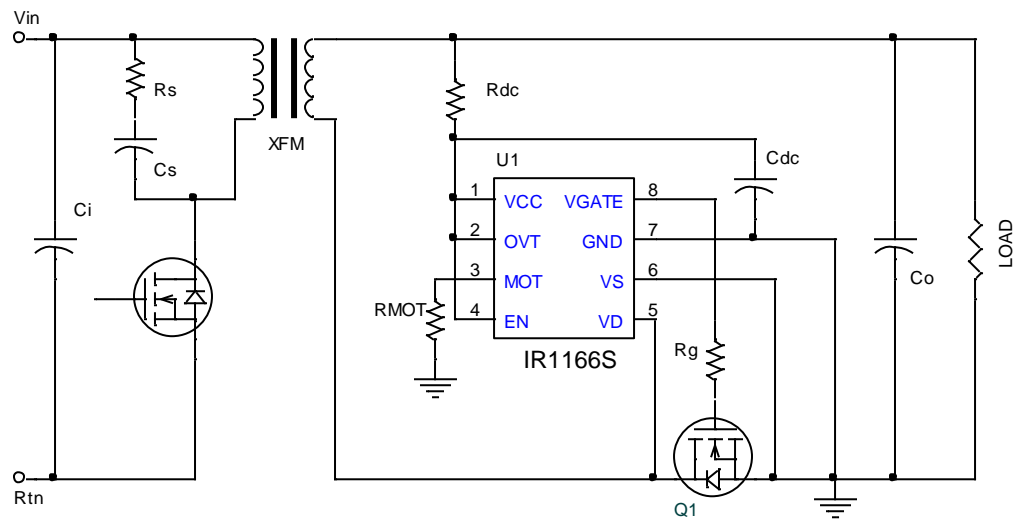


8-Lead SOIC

### Ordering Information

| Base Part Number | Package Type | Standard Pack |          | Complete Part Number |
|------------------|--------------|---------------|----------|----------------------|
|                  |              | Form          | Quantity |                      |
| IR1166S          | SOIC8N       | Tape and Reel | 2500     | IR1166STRPBF         |

## Typical Connection Diagram



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## Description

IR1166S is a smart secondary side driver IC designed to drive N-Channel power MOSFETs used as synchronous rectifiers in isolated Flyback converters. The IC can control one or more paralleled N-MOSFETs to emulate the behavior of Schottky diode rectifiers. The drain to source voltage is sensed differentially to determine the polarity of the current and turn the power switch on and off in proximity of the zero current transition. Ruggedness and noise immunity are accomplished using an advanced blanking scheme and double-pulse suppression which allow reliable operation in continuous, discontinuous and critical current mode operation and both fixed and variable frequency modes.

## Absolute Maximum Ratings

Stress 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 conditions are not implied. All voltages are absolute voltages referenced to GND. Thermal resistance and power dissipation are measured under board mounted and still air conditions.

| Parameters                     | Symbol          | Min. | Max. | Units | Remarks                       |
|--------------------------------|-----------------|------|------|-------|-------------------------------|
| Supply Voltage                 | $V_{CC}$        | -0.3 | 20   | V     |                               |
| Enable Voltage                 | $V_{EN}$        | -0.3 | 20   |       |                               |
| Cont. Drain Sense Voltage      | $V_D$           | -3   | 200  |       |                               |
| Pulse Drain Sense Voltage      | $V_D$           | -5   | 200  |       |                               |
| Source Sense Voltage           | $V_S$           | -3   | 20   |       |                               |
| Gate Voltage                   | $V_{GATE}$      | -0.3 | 20   |       | $V_{CC}=20V$ , Gate off       |
| Operating Junction Temperature | $T_J$           | -40  | 150  | °C    |                               |
| Storage Temperature            | $T_S$           | -55  | 150  |       |                               |
| Thermal Resistance             | $R_{\theta JA}$ |      | 128  | °C/W  | SOIC-8                        |
| Package Power Dissipation      | $P_D$           |      | 970  | mW    | SOIC-8, $T_{AMB}=25^{\circ}C$ |
| ESD Protection                 | $V_{ESD}$       |      | 1.5  | kV    | Human Body Model <sup>†</sup> |
| Switching Frequency            | fsw             |      | 500  | kHz   |                               |

<sup>†</sup> Per EIA/JESD22-A114-B (discharging a 100pF capacitor through a 1.5kΩ series resistor).

## Electrical Characteristics

The electrical characteristics involve the spread of values guaranteed within the specified supply voltage and junction temperature range  $T_J$  from  $-25^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . Typical values represent the median values, which are related to  $25^{\circ}\text{C}$ . If not otherwise stated, a supply voltage of  $V_{CC}=15\text{V}$  is assumed for test condition.

### Supply Section

| Parameters   | Symbol        | Min. | Typ. | Max. | Units         | Remarks   |
|--|---------------|------|------|------|---------------|---|
| Supply Voltage Operating Range                       | $V_{CC}$      | 11.4 |      | 18   | V             |   |
| $V_{CC}$ Turn On Threshold                           | $V_{CCON}$    | 9.8  | 10.6 | 11.3 |               |   |
| $V_{CC}$ Turn Off Threshold (Under Voltage Lock Out) | $V_{CCUVLO}$  | 8.4  | 9    | 9.7  |               |   |
| $V_{CC}$ Turn On/Off Hysteresis                      | $V_{CCHYST}$  | 1.4  | 1.57 | 1.7  |               |   |
| Operating Current                                    | $I_{CC}$      |      | 8    | 10   | mA            | $C_{LOAD}=1\text{nF}$ , $f_{sw} = 400\text{kHz}$  |
|  |               |      | 47   | 65   |               | $C_{LOAD}=10\text{nF}$ , $f_{sw} = 400\text{kHz}$ |
| Quiescent Current                                    | $I_{QCC}$     |      | 1.7  | 2.2  |               |   |
| Start-up Current                                     | $I_{CCSTART}$ |      | 92   | 200  | $\mu\text{A}$ | $V_{CC}=V_{CCON} - 0.1\text{V}$                   |
| Sleep Current  | $I_{SLEEP}$   |      | 145  | 200  |               | $V_{EN}=0\text{V}$ , $V_{CC}=15\text{V}$          |
| Enable Voltage High                                  | $V_{ENHI}$    | 2.15 | 2.71 | 3.2  | V             |   |
| Enable Voltage Low                                   | $V_{ENLO}$    | 1.2  | 1.6  | 2    |               |   |
| Enable Pull-up Resistance                            | $R_{EN}$      |      | 1.5  |      | M $\Omega$    | GBD   |

### Comparator Section

| Parameters              | Symbol       | Min.  | Typ.  | Max. | Units         | Remarks                             |
|-------------------------|--------------|-------|-------|------|---------------|-------------------------------------|
| Turn-off Threshold      | $V_{TH1}$    | -7    | -3    | 0    | mV            | $OVT = 0\text{V}$ , $V_S=0\text{V}$ |
|                         |              | -15   | -10.3 | -7   |               | $OVT$ floating, $V_S=0\text{V}$     |
|                         |              | -23   | -18.7 | -15  |               | $OVT = V_{CC}$ , $V_S=0\text{V}$    |
| Turn-on Threshold       | $V_{TH2}$    | -150  |       | -50  |               |                                     |
| Hysteresis              | $V_{HYST}$   |       | 63    |      |               |                                     |
| Input Bias Current      | $I_{BIAS1}$  |       | 1     | 7.5  | $\mu\text{A}$ | $V_D = -50\text{mV}$                |
|                         | $I_{BIAS2}$  |       | 23    | 100  |               | $V_D = 200\text{V}$                 |
| Comparator Input Offset | $V_{OFFSET}$ |       |       | 2    | mV            | GBD                                 |
| Input CM Voltage Range  | $V_{CM}$     | -0.15 |       | 2    | V             |                                     |

### One-Shot Section

| Parameters              | Symbol      | Min. | Typ. | Max. | Units         | Remarks                   |
|-------------------------|-------------|------|------|------|---------------|---------------------------|
| Blanking pulse duration | $t_{BLANK}$ | 9    | 15   | 25   | $\mu\text{s}$ |                           |
| Reset Threshold         | $V_{TH3}$   |      | 2.5  |      | V             | $V_{CC}=10\text{V}$ - GBD |
|                         |             |      | 5.4  |      |               | $V_{CC}=20\text{V}$ - GBD |
| Hysteresis              | $V_{HYST3}$ |      | 40   |      | mV            | $V_{CC}=10\text{V}$ - GBD |

## Electrical Characteristics

The electrical characteristics involve the spread of values guaranteed within the specified supply voltage and junction temperature range  $T_J$  from  $-25^{\circ}\text{C}$  to  $125^{\circ}\text{C}$ . Typical values represent the median values, which are related to  $25^{\circ}\text{C}$ . If not otherwise stated, a supply voltage of  $V_{CC}=15\text{V}$  is assumed for test condition.

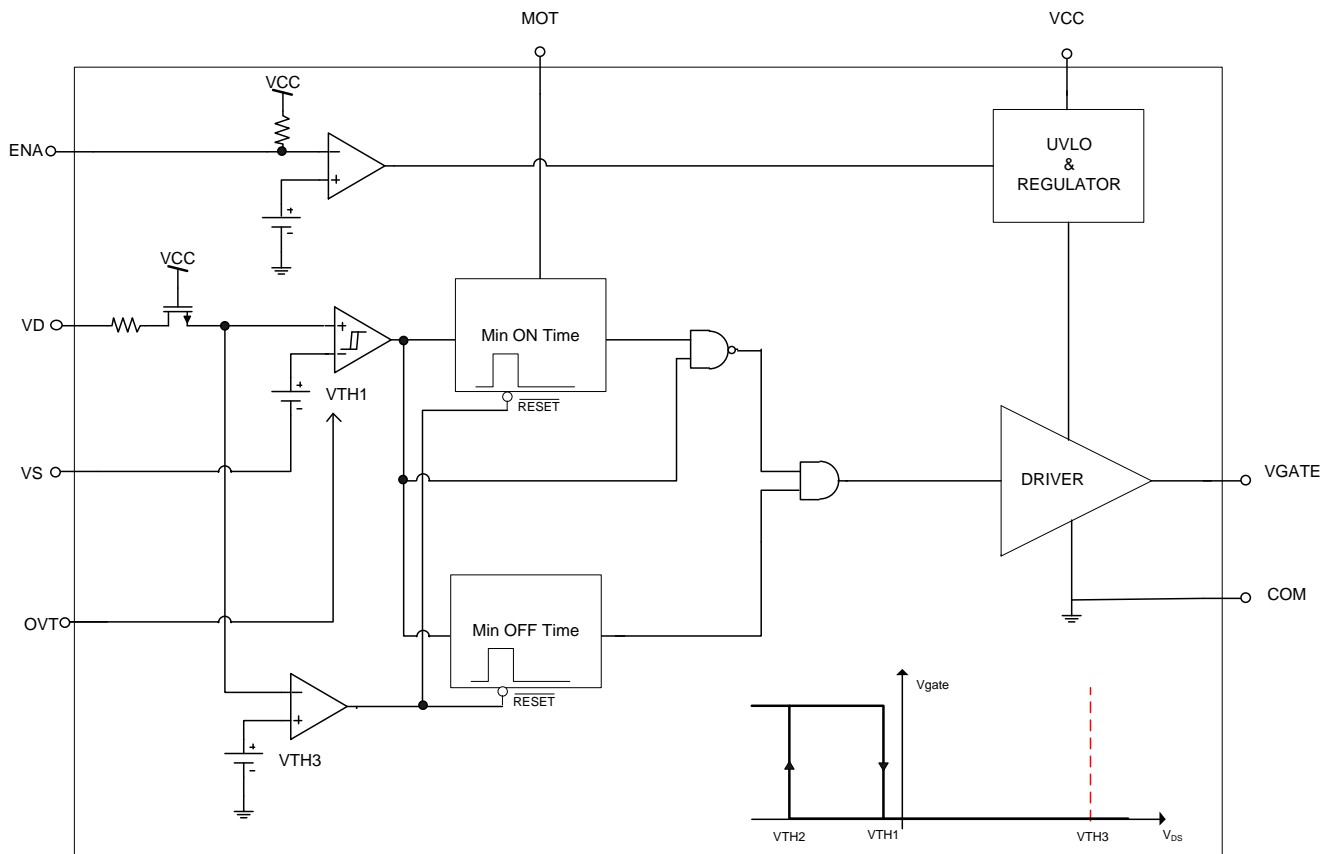
### Minimum On Time Section

| Parameters      | Symbol      | Min. | Typ. | Max. | Units         | Remarks                                   |
|-----------------|-------------|------|------|------|---------------|---|
| Minimum on time | $T_{ONmin}$ | 190  | 251  | 290  | ns            | $R_{MOT}=5k\Omega$ , $V_{CC}=12\text{V}$  |
|                 |             | 2.4  | 3    | 3.6  | $\mu\text{s}$ | $R_{MOT}=75k\Omega$ , $V_{CC}=12\text{V}$ |

### Gate Driver Section

| Parameters                   | Symbol          | Min. | Typ. | Max. | Units    | Remarks   |
|------------------------------|-----------------|------|------|------|----------|---|
| Gate Low Voltage             | $V_{GLO}$       |      | 0.2  | 0.5  | V        | $I_{GATE}=200\text{mA}$                             |
| Gate High Voltage            | $V_{GTH}$       | 9    | 10.7 | 12.5 |          | $V_{CC}=12\text{V}-18\text{V}$ (internally clamped) |
| Rise Time                    | $t_{r1}$        |      | 21   |      | ns       | $C_{LOAD}=1\text{nF}$ , $V_{CC}=12\text{V}$         |
|                              | $t_{r2}$        |      | 181  |      |          | $C_{LOAD}=10\text{nF}$ , $V_{CC}=12\text{V}$        |
| Fall Time                    | $t_{f1}$        |      | 10   |      |          | $C_{LOAD}=1\text{nF}$ , $V_{CC}=12\text{V}$         |
|                              | $t_{f2}$        |      | 44   |      |          | $C_{LOAD}=10\text{nF}$ , $V_{CC}=12\text{V}$        |
| Turn on Propagation Delay    | $t_{Don}$       |      | 52   | 80   |          | $V_{DS}$ to $V_{GATE}$ -100mV overdrive             |
| Turn off Propagation Delay   | $t_{Doff}$      |      | 35   | 65   |          |   |
| Pull up Resistance           | $r_{up}$        |      | 5    |      | $\Omega$ | $I_{GATE}=1\text{A}$ - GBD                          |
| Pull down Resistance         | $r_{down}$      |      | 1.2  |      |          | $I_{GATE}=-200\text{mA}$                            |
| Output Peak Current (source) | $I_{O\ source}$ |      | 1    |      | A        | $C_{LOAD}=10\text{nF}$ - GBD                        |
| Output Peak Current (sink)   | $I_{O\ sink}$   |      | 4    |      |          |   |

## Functional Block Diagram

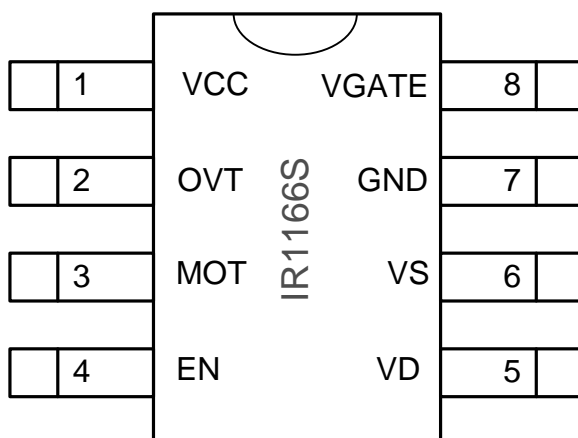




### Lead Definitions

| PIN# | Symbol | Description             |
|------|--------|-------------------------|
| 1    | VCC    | Supply Voltage          |
| 2    | OVT    | Offset Voltage Trimming |
| 3    | MOT    | Minimum On Time         |
| 4    | EN     | Enable                  |
| 5    | VD     | FET Drain Sensing       |
| 6    | VS     | FET Source Sensing      |
| 7    | GND    | Ground                  |
| 8    | GATE   | Gate Drive Output       |

### Lead Assignments



## Detailed Pin Description

### VCC: Power Supply

This is the supply voltage pin of the IC and it is monitored by the under voltage lockout circuit. It is possible to turn off the IC by pulling this pin below the minimum turn off threshold voltage, without damage to the IC.

To prevent noise problems, a bypass ceramic capacitor connected to Vcc and GND should be placed as close as possible to the IR1166S. This pin is internally clamped.

### OVT: Offset Voltage Trimming

The OVT pin will program the amount of input offset voltage for the turn-off threshold  $V_{TH1}$ .

The pin can be optionally tied to ground, to VCC or left floating, to select 3 ranges of input offset trimming.

This programming feature allows for accommodating different  $R_{DSon}$  MOSFETs.

### MOT: Minimum On Time

The MOT programming pin controls the amount of minimum on time. Once  $V_{TH2}$  is crossed for the first time, the gate signal will become active and turn on the power FET. Spurious ringings and oscillations can trigger the input comparator off. The MOT blanks the input comparator keeping the FET on for a minimum time.

The MOT is programmed between 200ns and 3 $\mu$ s (typ.) by using a resistor referenced to GND.

### EN: Enable

This pin is used to activate the IC "sleep" mode by pulling the voltage level below 2.5V (typ). In sleep mode the IC will consume a minimum amount of current. However all switching functions will be disabled and the gate will be inactive. The EN pin voltage cannot linger between the Enable low and Enable high thresholds. The pin is intended to operate as a switch with the pin voltage either above or below the threshold range. The Enable control pin (EN) is not intended to operate at high frequency. For proper operation, EN positive pulse width needs to be longer than 20 $\mu$ s, EN negative pulse width needs to be longer than 10 $\mu$ s.

Please refer to Figure 22B for the definition of EN pulse switch.

### VD: Drain Voltage Sense

VD is the voltage sense pin for the power MOSFET Drain. This is a high voltage pin and particular care must be taken in properly routing the connection to the power MOSFET drain.

Additional filtering and or current limiting on this pin is not recommended as it would limit switching performance of the IC.

### VS: Source Voltage Sense

VS is the differential sense pin for the power MOSFET Source. This pin must not be connected directly to the power ground pin (7) but must be used to create a Kelvin contact as close as possible to the power MOSFET source pin.

### GND: Ground

This is ground potential pin of the integrated control circuit. The internal devices and gate driver are referenced to this point.

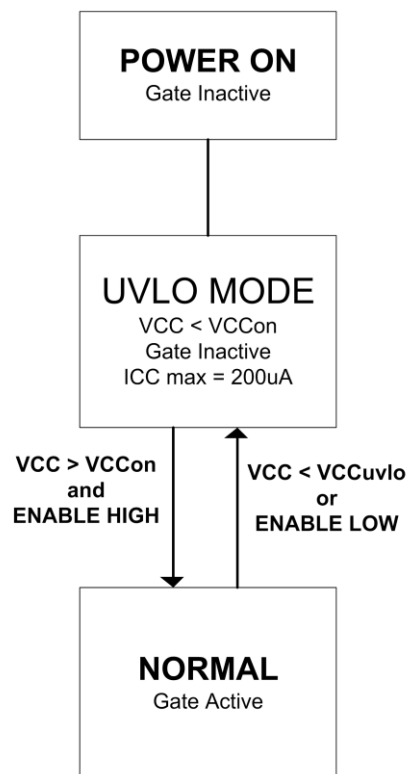
### GATE: Gate Drive Output

This is the gate drive output of the IC. Drive voltage is internally limited and provides 1A peak source and 4A peak sink capability. Although this pin can be directly connected to the power MOSFET gate, the use of minimal gate resistor is recommended, especially when putting multiple FETs in parallel.

Care must be taken in order to keep the gate loop as short and as small as possible in order to achieve optimal switching performance.

## Application Information and Additional Details

### State Diagram



#### UVLO/Sleep Mode

The IC remains in the UVLO condition until the voltage on the VCC pin exceeds the VCC turn on threshold voltage,  $V_{CCON}$ . During the time the IC remains in the UVLO state, the gate drive circuit is inactive and the IC draws a quiescent current of  $I_{CC \text{ START}}$ . The UVLO mode is accessible from any other state of operation whenever the IC supply voltage condition of  $V_{CC} < V_{CC \text{ UVLO}}$  occurs.

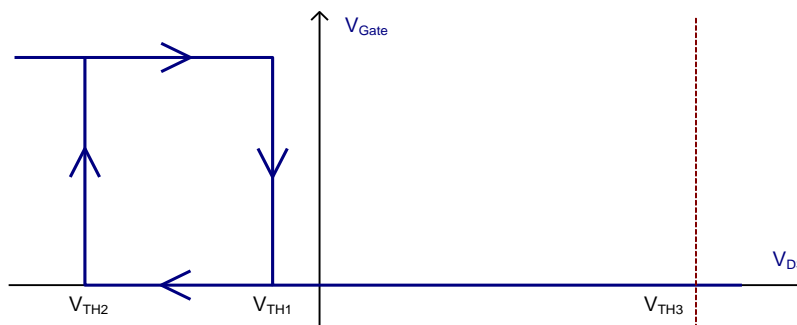
The sleep mode is initiated by pulling the EN pin below 2.5V (typ). In this mode the IC is essentially shut down and draws a very low quiescent supply current.

#### Normal Mode

The IC enters in normal operating mode once the UVLO voltage has been exceeded. At this point the gate driver is operating and the IC will draw a maximum of  $I_{CC}$  from the supply voltage source.

## General Description

The IR1166 Smart Rectifier IC can emulate the operation of diode rectifier by properly driving a Synchronous Rectifier (SR) MOSFET. The direction of the rectified current is sensed by the input comparator using the power MOSFET  $R_{DS(on)}$  as a shunt resistance and the GATE pin of the MOSFET is driven accordingly. Internal blanking logic is used to prevent spurious transitions and guarantee operation in continuous (CCM), discontinuous (DCM) and critical (CrCM) conduction mode.



**Figure 1: Input comparator thresholds**

## Flyback Application

The modes of operation for a Flyback circuit differ mainly for the turn-off phase of the SR switch, while the turn-on phase of the secondary switch (which corresponds to the turn off of the primary side switch) is identical.

### Turn-on phase

When the conduction phase of the SR FET is initiated, current will start flowing through its body diode, generating a negative  $V_{DS}$  voltage across it. The body diode has generally a much higher voltage drop than the one caused by the MOSFET on resistance and therefore will trigger the turn-on threshold  $V_{TH2}$ .

At that point the IR1166 will drive the gate of MOSFET on which will in turn cause the conduction voltage  $V_{DS}$  to drop down. This drop is usually accompanied by some amount of ringing, that can trigger the input comparator to turn off; hence, a Minimum On Time (MOT) blanking period is used that will maintain the power MOSFET on for a minimum amount of time.

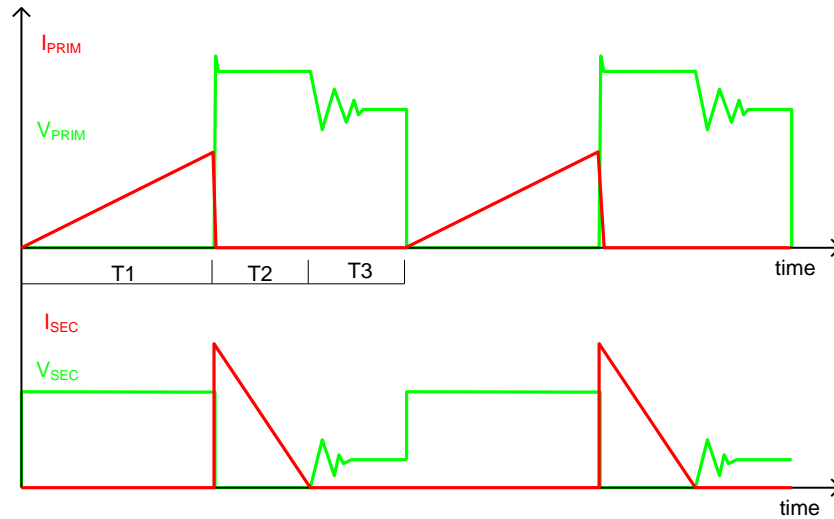
The programmed MOT will limit also the minimum duty cycle of the SR MOSFET and, as a consequence, the max duty cycle of the primary side switch.

### DCM/CrCM Turn-off phase

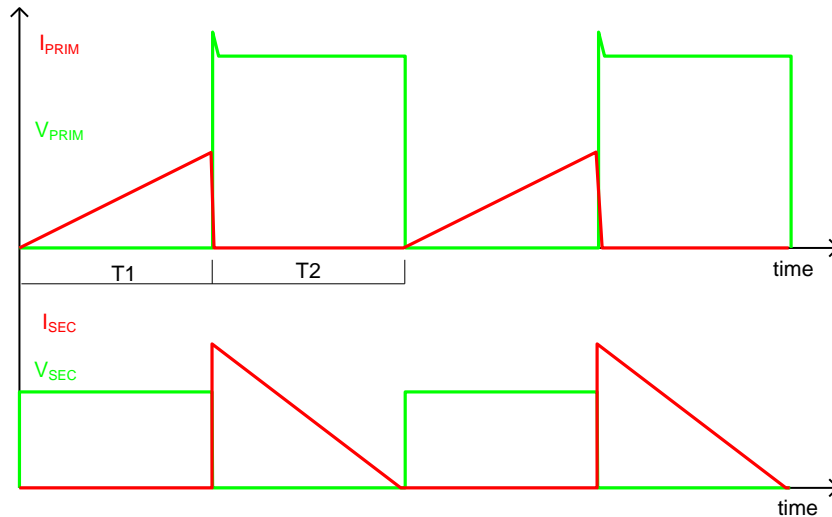
Once the SR MOSFET has been turned on, it will remain on until the rectified current will decay to the level where  $V_{DS}$  will cross the turn-off threshold  $V_{TH1}$ . This will happen differently depending on the mode of operation.

In DCM the current will cross the threshold with a relatively low  $dI/dt$ . Once the threshold is crossed, the current will start flowing again through the body diode, causing the  $V_{DS}$  voltage to jump negative. Depending on the amount of residual current,  $V_{DS}$  may trigger once again the turn on threshold: for this reason  $V_{TH2}$  is blanked for a certain amount of time ( $T_{BLANK}$ ) after  $V_{TH1}$  has been triggered.

The blanking time is internally set. As soon as  $V_{DS}$  crosses the positive threshold  $V_{TH3}$  also the blanking time is terminated and the IC is ready for next conduction cycle.



**Figure 2: Primary and secondary currents and voltages for DCM mode**



**Figure 3: Primary and secondary currents and voltages for CrCM mode**

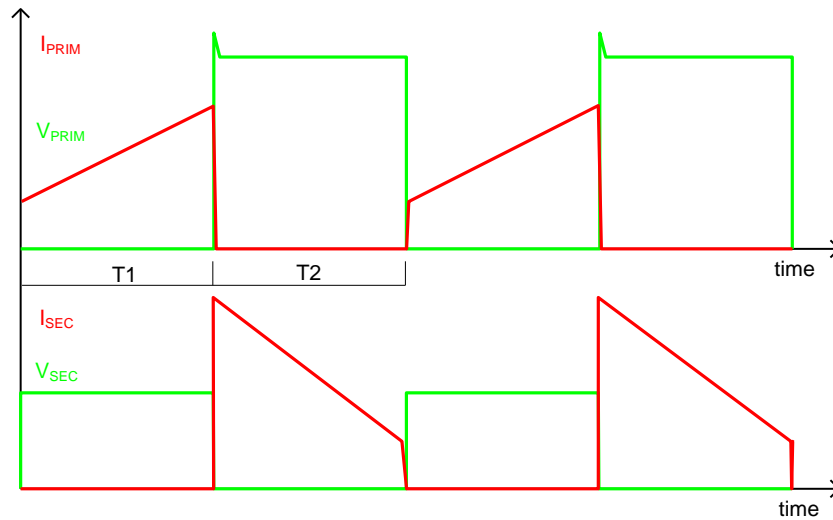
### CCM Turn-off phase

In CCM mode the turn off transition is much steeper and  $di/dt$  involved is much higher. The turn on phase is identical to DCM or CrCM and therefore won't be repeated here.

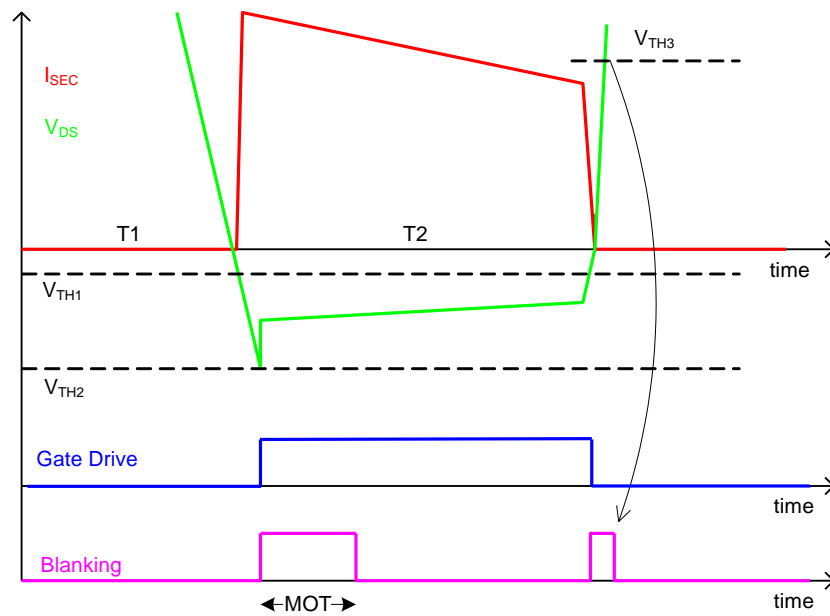
During the SR FET conduction phase the current will decay linearly, and so will  $V_{DS}$  on the SR FET.

Once the primary switch will start to turn back on, the SR FET current will rapidly decrease crossing  $V_{TH1}$  and turning the gate off. The turn off speed is critical to avoid cross conduction on the primary side and reduce switching losses.

Also in this case a blanking period will be applied, but given the very fast nature of this transition, it will be reset as soon as  $V_{DS}$  crosses  $V_{TH3}$ .



**Figure 4: Primary and secondary currents and voltages for CCM mode**



**Figure 5: Secondary side CCM operation**

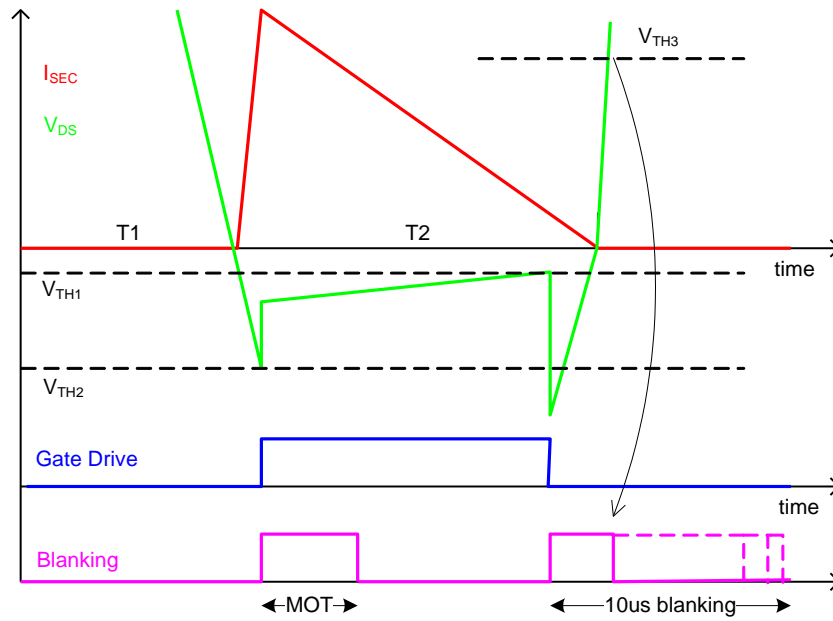
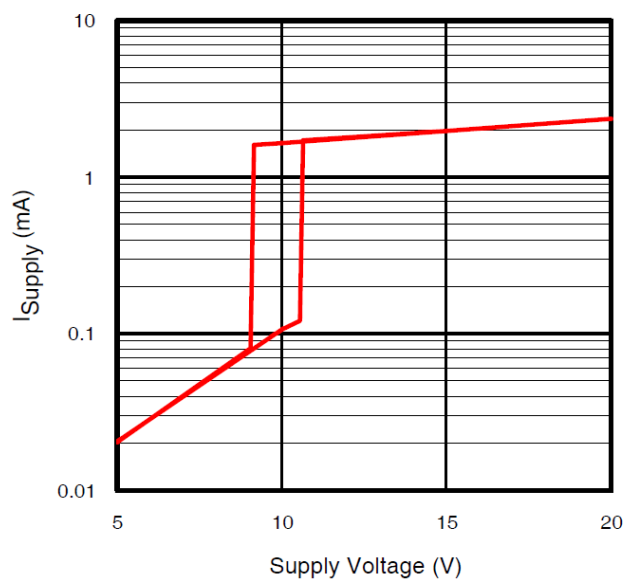
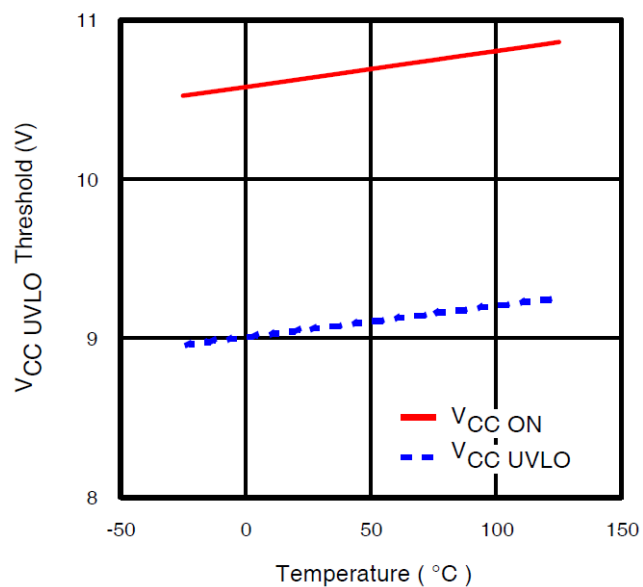
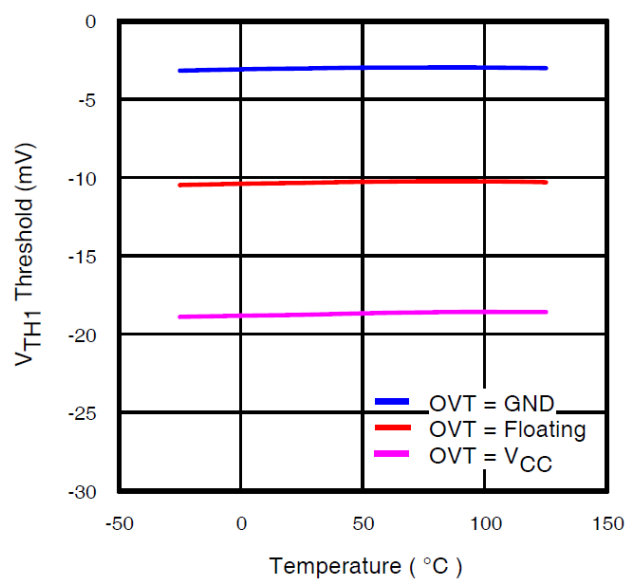
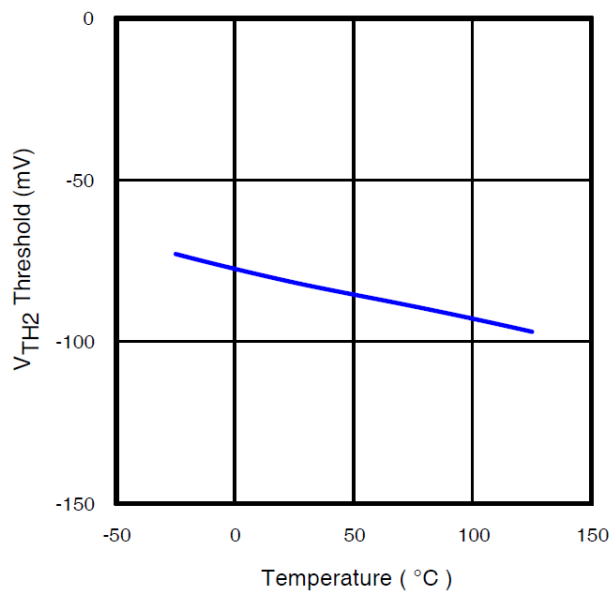
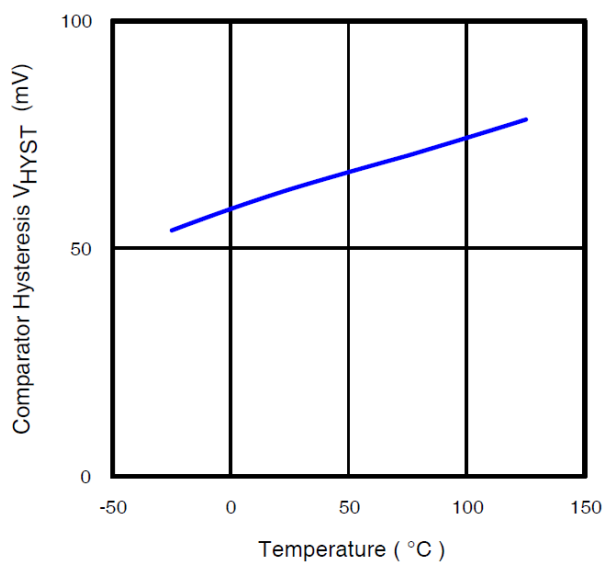


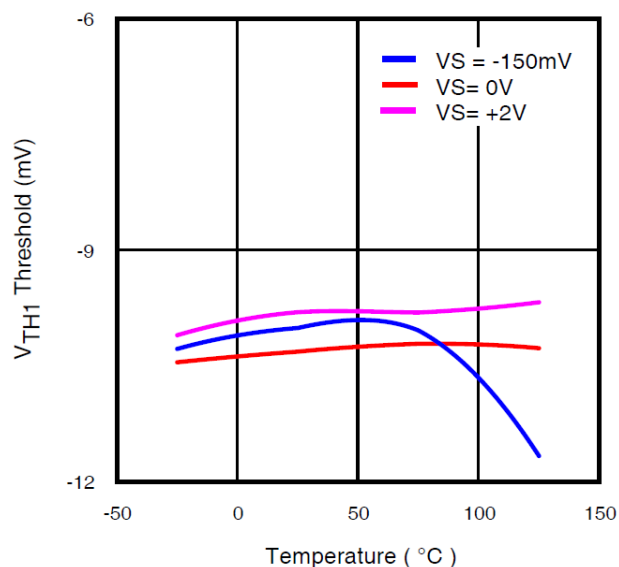
Figure 6: Secondary side DCM/CrCM operation


**Figure 7: Supply Current vs. Supply Voltage**

**Figure 8: Undervoltage Lockout vs. Temperature**

**Figure 9: V<sub>TH1</sub> vs. Temperature**

**Figure 10: V<sub>TH2</sub> vs. Temperature**

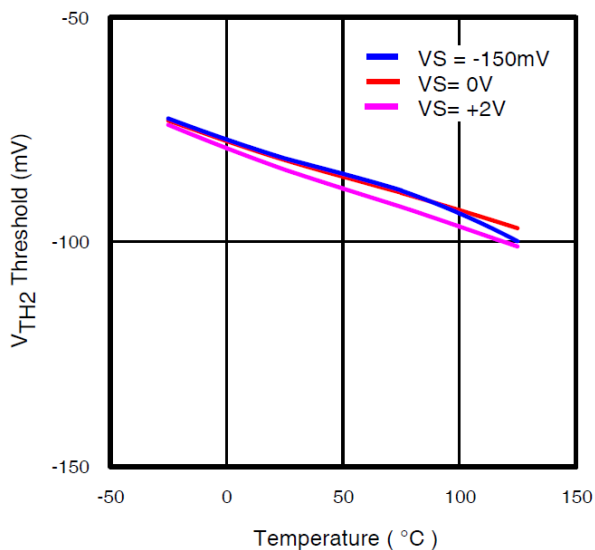




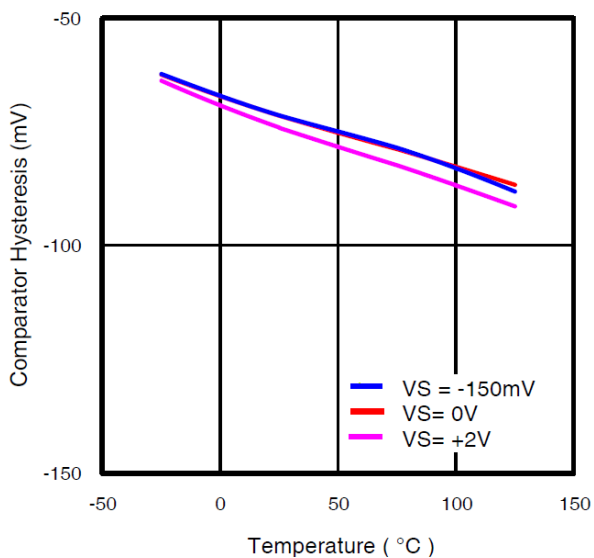
**Figure 11: Comparator Hysteresis vs. Temperature**



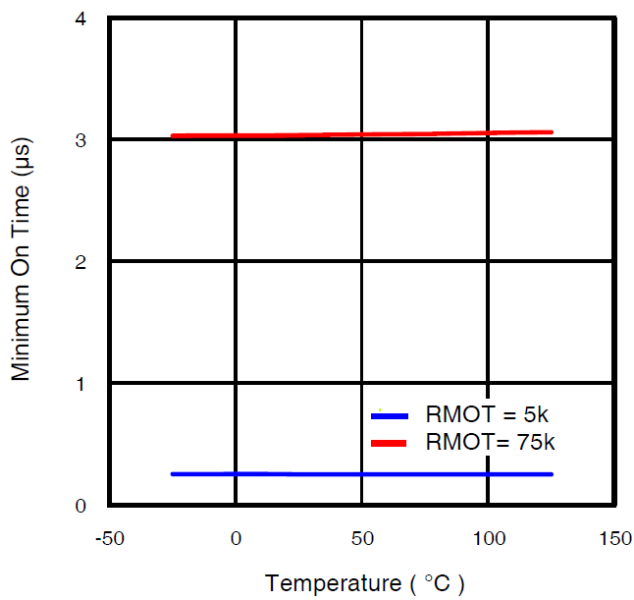
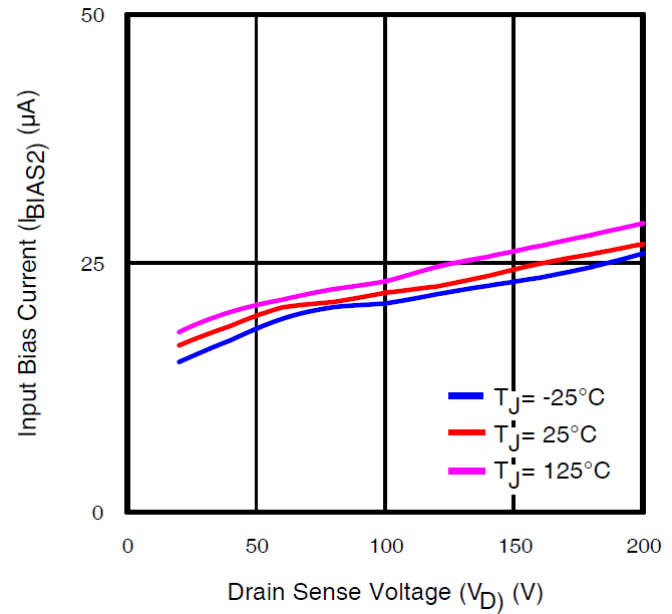
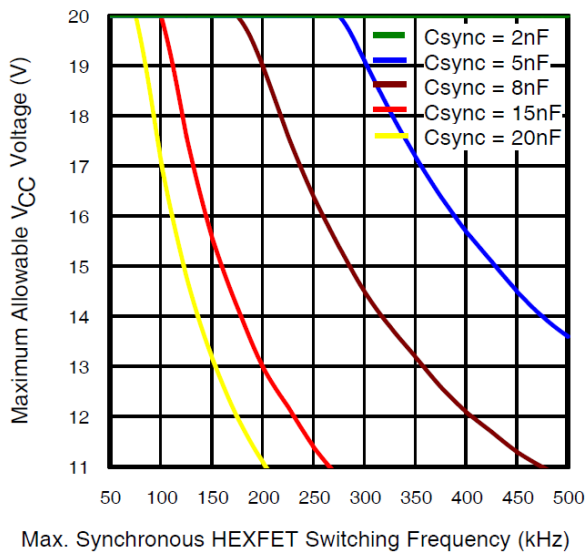
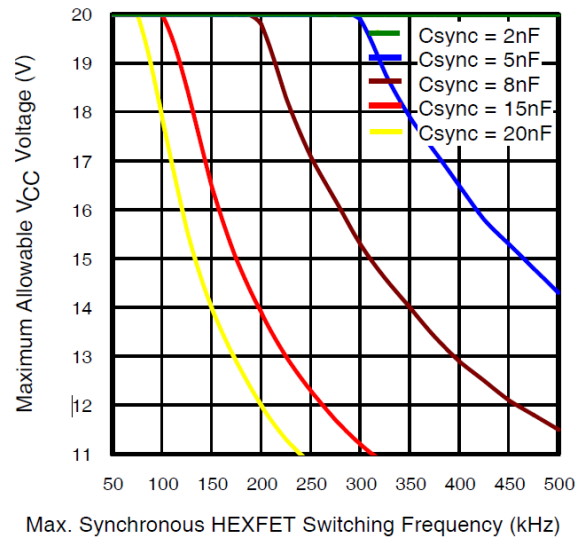
**Figure 12:  $V_{TH1}$  vs. Temperature and Common Mode (OVT = Floating)**

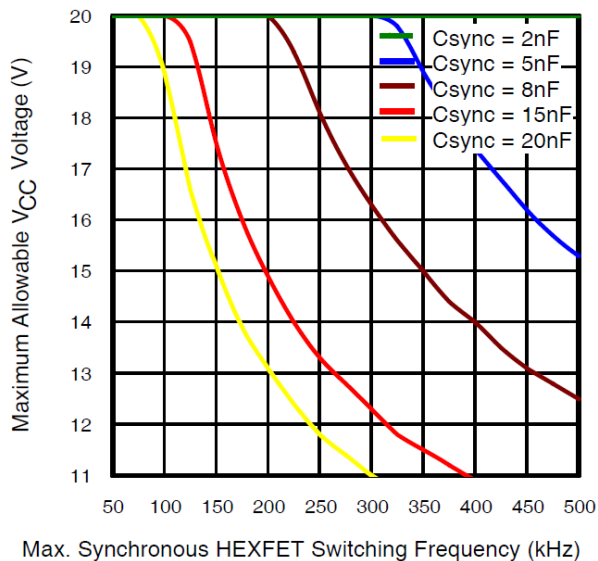


**Figure 13:  $V_{TH2}$  vs. Temperature and Common Mode (OVT = GND)**

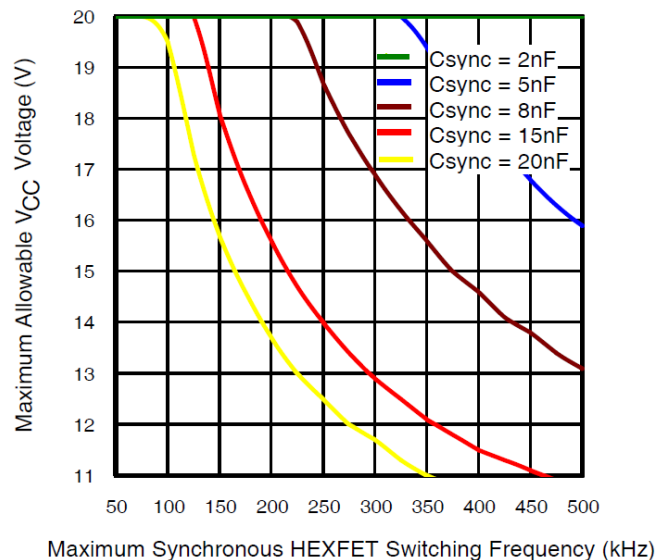


**Figure 14: Comparator Hysteresis vs. Temperature and Common Mode (OVT = GND)**


**Figure 15: MOT vs. Temperature**

**Figure 16: Input Bias Current vs.  $V_D$** 

**Figure 17: Max.  $V_{CC}$  Voltage vs. Synchronous Rectifier Switching Freq,  $T_J = 125^\circ\text{C}$ ,  $T_{IC} = 85^\circ\text{C}$ , external  $R_G = 1\Omega$ ,  $1\Omega$  HEXFET Gate Resistance Included**

**Figure 18: Max.  $V_{CC}$  Voltage vs. Synchronous Rectifier Switching Freq,  $T_J = 125^\circ\text{C}$ ,  $T_{IC} = 85^\circ\text{C}$ , external  $R_G = 2\Omega$ ,  $1\Omega$  HEXFET Gate Resistance Included**



**Figure 19: Max.  $V_{CC}$  Voltage vs. Synchronous Rectifier Switching Freq,  $T_J = 125^\circ\text{C}$ ,  $T_{IC} = 85^\circ\text{C}$ , external  $R_G = 4\Omega$ ,  $1\Omega$  HEXFET Gate Resistance Included**



**Figure 20: Max.  $V_{CC}$  Voltage vs. Synchronous Rectifier Switching Freq,  $T_J = 125^\circ\text{C}$ ,  $T_{IC} = 85^\circ\text{C}$ , external  $R_G = 6\Omega$ ,  $1\Omega$  HEXFET Gate Resistance Included**

Figures 17 – 20 show the maximum allowable  $V_{CC}$  voltage vs. maximum switching frequency for different loads which are calculated using the design methodology discussed in AN1087

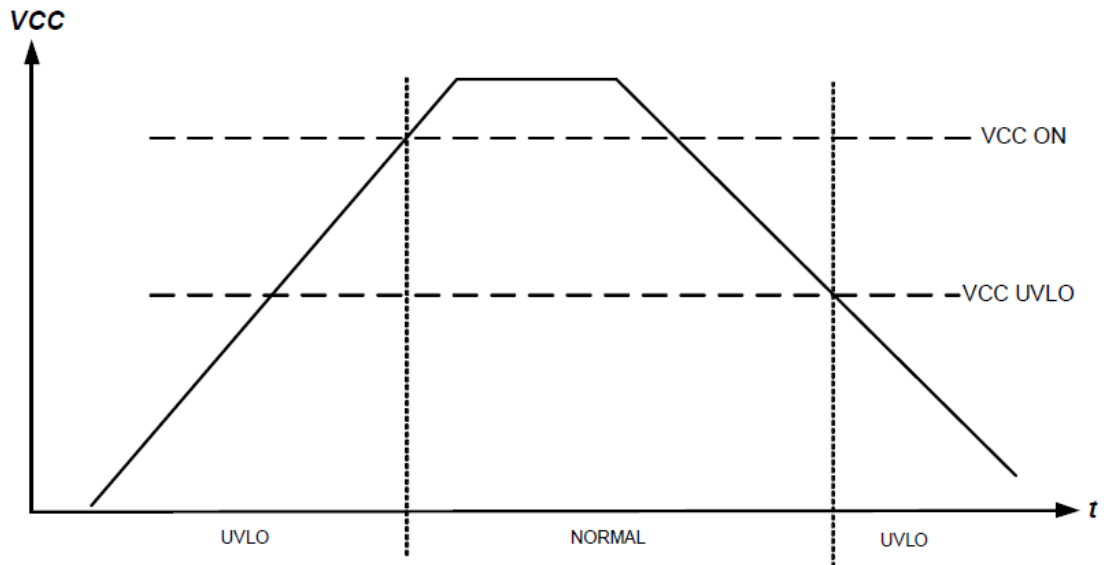


Figure 21:  $V_{CC}$  Under Voltage Lockout

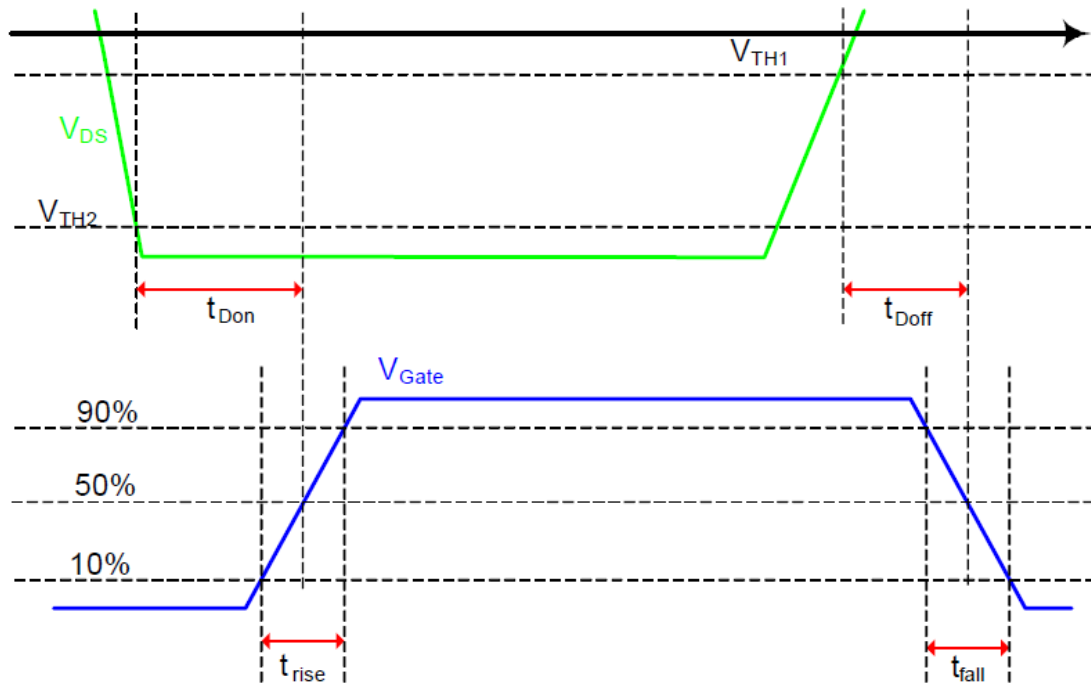


Figure 22A: Timing Diagrams

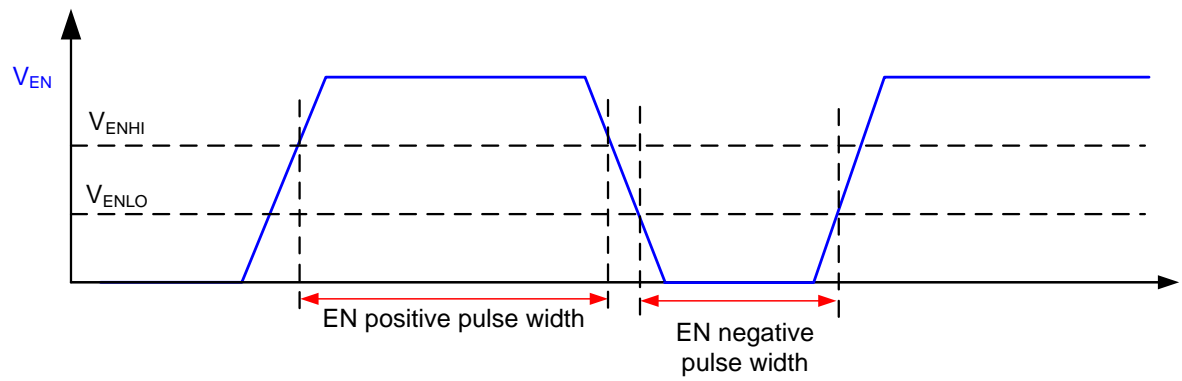
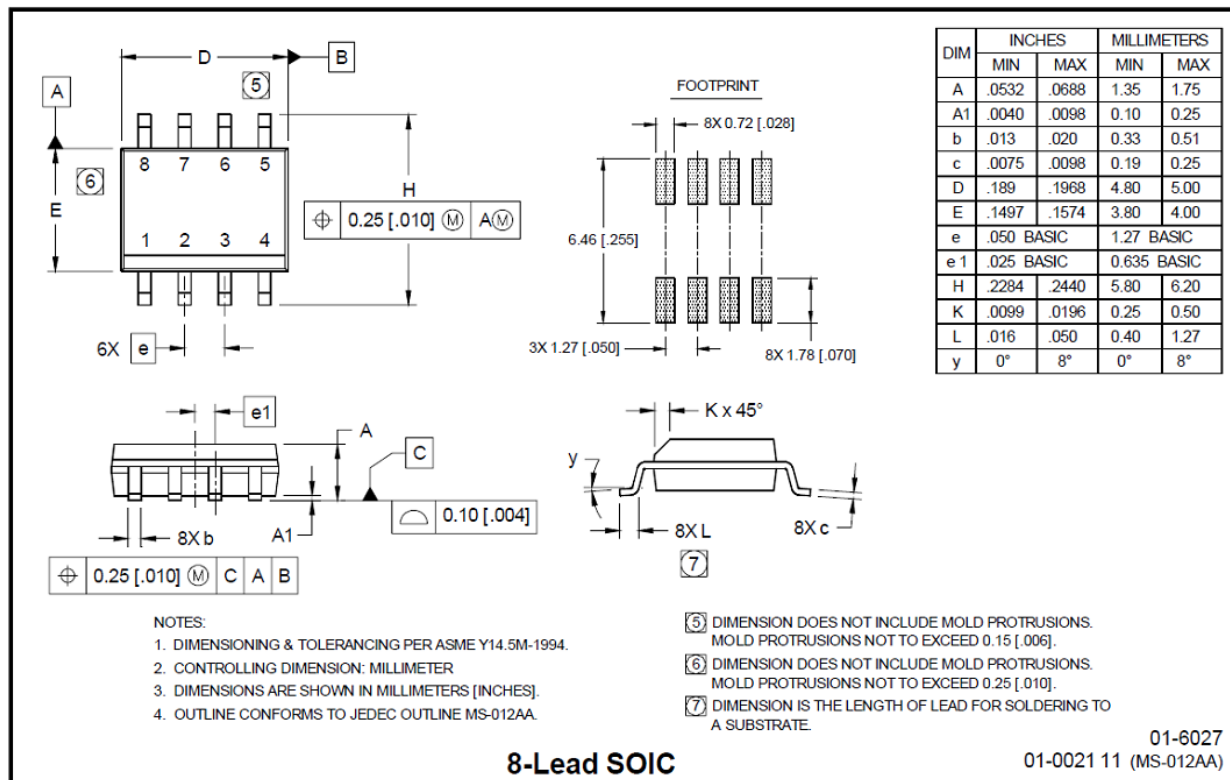
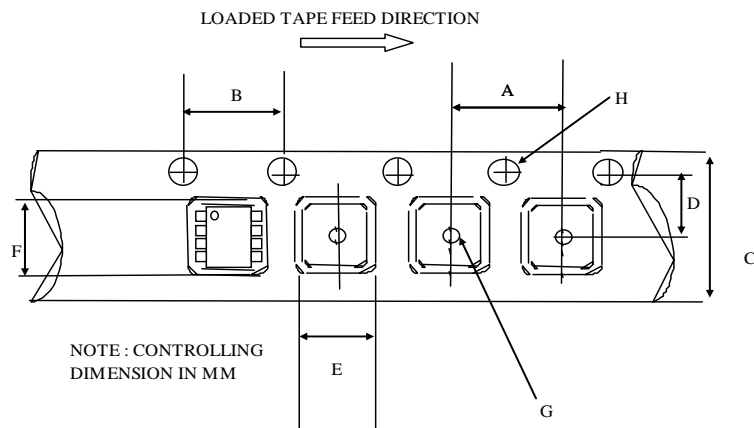


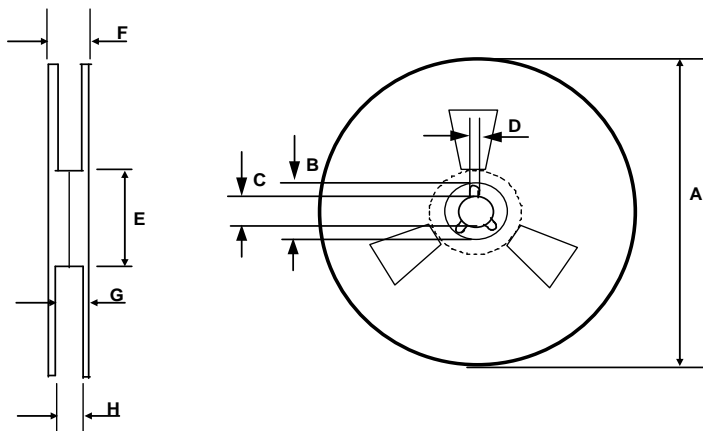
Figure 22B: Enable Timing Waveform

## Package Details: SOIC8N

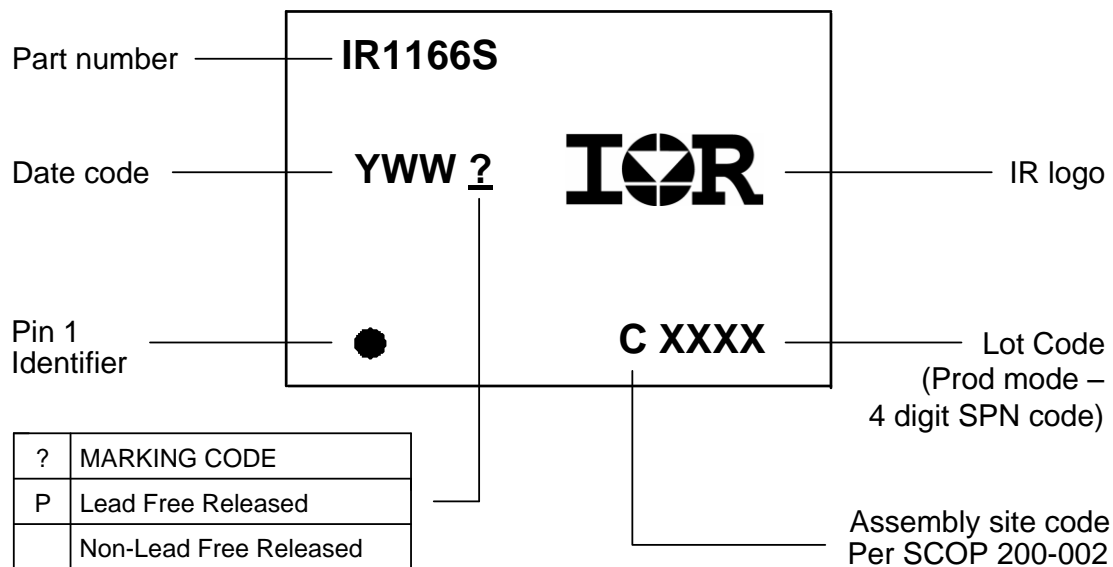


**Tape and Reel Details: SOIC8N**

**CARRIER TAPE DIMENSION FOR 8SOICN**

| Code | Metric |       | Imperial |       |
|------|--------|-------|----------|-------|
|      | Min    | Max   | Min      | Max   |
| A    | 7.90   | 8.10  | 0.311    | 0.318 |
| B    | 3.90   | 4.10  | 0.153    | 0.161 |
| C    | 11.70  | 12.30 | 0.46     | 0.484 |
| D    | 5.45   | 5.55  | 0.214    | 0.218 |
| E    | 6.30   | 6.50  | 0.248    | 0.255 |
| F    | 5.10   | 5.30  | 0.200    | 0.208 |
| G    | 1.50   | n/a   | 0.059    | n/a   |
| H    | 1.50   | 1.60  | 0.059    | 0.062 |


**REEL DIMENSIONS FOR 8SOICN**

| Code | Metric |        | Imperial |        |
|------|--------|--------|----------|--------|
|      | Min    | Max    | Min      | Max    |
| A    | 329.60 | 330.25 | 12.976   | 13.001 |
| B    | 20.95  | 21.45  | 0.824    | 0.844  |
| C    | 12.80  | 13.20  | 0.503    | 0.519  |
| D    | 1.95   | 2.45   | 0.767    | 0.096  |
| E    | 98.00  | 102.00 | 3.858    | 4.015  |
| F    | n/a    | 18.40  | n/a      | 0.724  |
| G    | 14.50  | 17.10  | 0.570    | 0.673  |
| H    | 12.40  | 14.40  | 0.488    | 0.566  |

**Part Marking Information**




**Qualification Information<sup>†</sup>**

|                            |   |
|----------------------------|---|
| Qualification Level        | Industrial <sup>††</sup>  |
|                            | Comments: This family of ICs has passed JEDEC's Industrial qualification. IR's Consumer qualification level is granted by extension of the higher Industrial level. |
| Moisture Sensitivity Level | MSL2 <sup>†††</sup> 260°C<br>(per IPC/JEDEC J-STD-020)  |
| RoHS Compliant             | Yes   |

† Qualification standards can be found at International Rectifier's web site <http://www.irf.com/>

†† Higher qualification ratings may be available should the user have such requirements. Please contact your International Rectifier sales representative for further information.

††† Higher MSL ratings may be available for the specific package types listed here. Please contact your International Rectifier sales representative for further information.

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