

# ICE1HS01G-1

## Half-Bridge Resonant Controller

Power Management & Supply



Never stop thinking.

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**ICE1HS01G-1****Revision History:                      04 July 2011**

Previous Version:

Page	Subjects (major changes since last revision)

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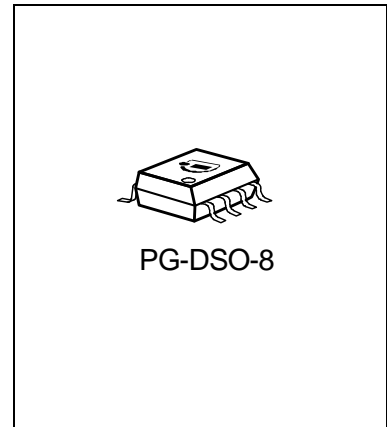
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## Half-Bridge Resonant Controller

### Product Highlights

- Minimum number of external components
- High accuracy oscillator
- Two-level over current protection
- Over load/open loop protection
- Mains undervoltage protection with adjustable hysteresis
- Adjustable blanking time for over load protection and restart



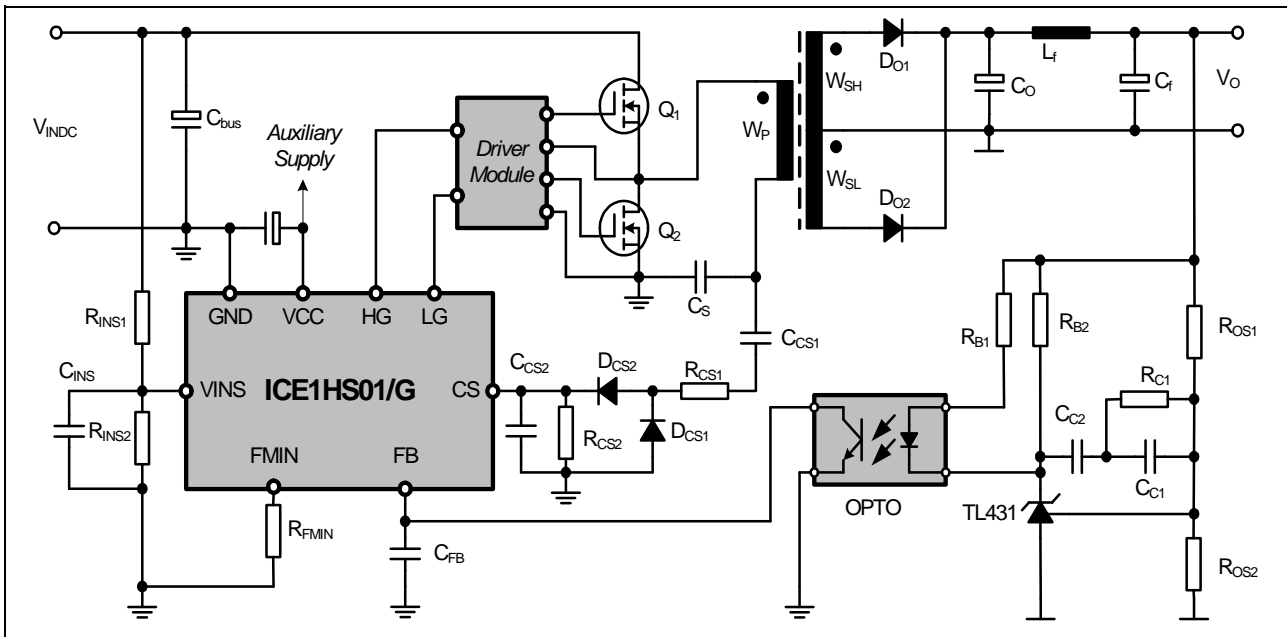
### Features

- DSO8 package
- Maximum 600kHz switching frequency
- Adjustable minimum switching frequency with high accuracy
- 50% duty cycle
- Mains input under voltage protection with adjustable hysteresis
- Two levels of overcurrent protection: frequency shift and latch off
- Open-loop/over load protection with extended blanking time
- Built-in digital and nonlinear softstart
- Adjustable restart time during fault protection period
- High-accuracy oscillator

### Applications

- LCD/PDP TV
- AC-DC adapter
- Audio SMPS

### Typical Application Circuit



Type	Marking	Package
ICE1HS01G-1	1H01-1	PG-DSO-8

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## 1 Pin Configuration and Functionality

### 1.1 Pin configuration with PG-DSO-8

Pin	Symbol	Function
1	FMIN	Minimum switching frequency
2	CS	Current sense
3	FB	Feedback voltage
4	VINS	Input voltage sense
5	GND	IC ground
6	LG	Low side gate drive
7	HG	High side gate drive
8	VCC	IC power supply

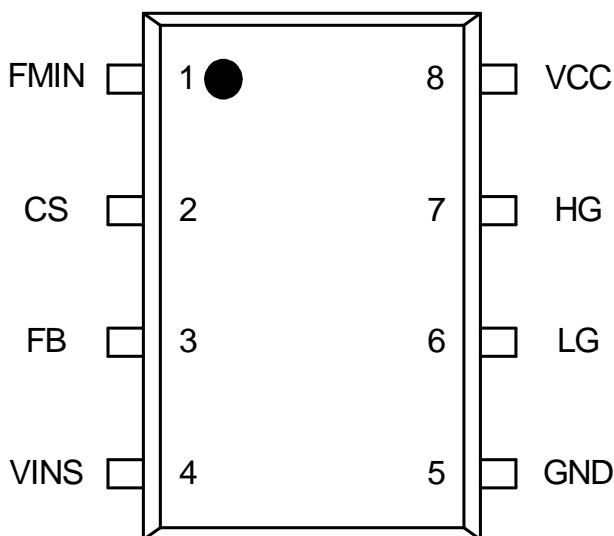


Figure 1 Pin configuration with PG-DSO-8

### 1.2 Pin Functionality

#### FMIN (minimum switching frequency)

An external resistor is connected between this pin and the ground. The voltage of this pin is constant during operation and thus the resistance determines the current flowing out of this pin. The minimum switching frequency is determined by this current. The maximum

#### Pin Configuration and Functionality

switching frequency and the switching frequency during soft start are also related to the current flowing out of FMIN pin.

#### CS (current sense)

The current sense signal is fed to this pin. Inside the IC, two comparators are provided. If the voltage on CS pin is higher than the first threshold, IC will increase the switching frequency to limit the maximum output power of the converter. If the voltage on this pin exceeds the second threshold, IC will be latched off immediately.

#### FB (feedback)

This pin is connected to the collector of the opto-coupler. Internally, during normal operation, this pin is connected to reference voltage source with a pull-up resistor ( $R_{FB}$ ). The IC uses the voltage on this pin to adjust the switching frequency within the range of maximum and minimum frequency set by FMIN pin. If FB voltage is higher than  $V_{FBH}$  for a certain fixed blanking time, an extended timer will be started. If over load/open loop protection exists longer than the extended blanking time, IC will enter auto-restart mode. An off timer starts from the instant IC stops switching till IC starts another soft start. This off time is determined by the resistors and capacitor connected to VINS pin.

#### VINS (mains input voltage sense)

The mains input voltage is fed to this pin via a resistive voltage divider. If the voltage on VINS pin is higher than the threshold  $V_{INSON}$ , IC will start to operate with softstart when VCC increases beyond turn on threshold. During operation, if the voltage on this pin falls below the threshold  $V_{INSON}$ , IC will stop switching until the voltage on this pin increases again.

When IC goes into over load protection mode, IC will stop switching and try to restart after a period of time. This period can be adjusted by connecting different capacitors between this pin and ground.

#### GND (ground)

IC common ground.

#### LG (low side gate drive)

Low side power MOSFET driver.

#### HG (high-side gate drive)

Up side power MOSFET driver.

#### VCC (IC power supply)

Supply voltage of the IC.

## 2 Representative Block Diagram

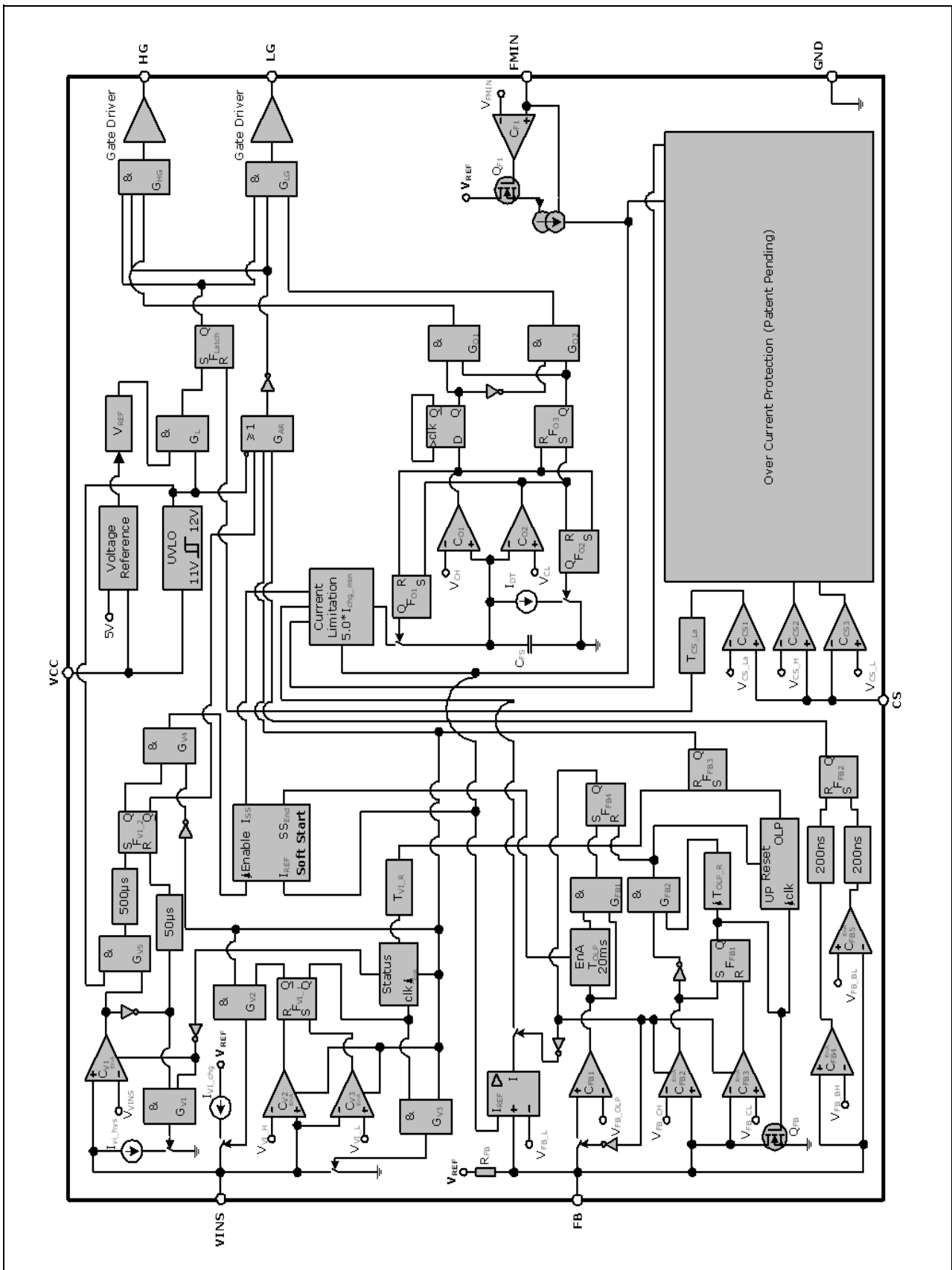


Figure 2 Representative Block Diagram

## Functional description

### 3 Functional description

The controller ICE1HS01G-1 with two gate outputs is specially designed for LLC resonant half-bridge converters. An oscillator with accurately-programmed frequency range is built inside the IC. The two gate signals are obtained by passing the signal out from the oscillator through a divide-by-two flip-flop. Therefore, two signals are of exactly 50% duty cycle and 180° out of phase. To guarantee the zero-voltage-switching and safe operation in half-bridge topologies, a fixed dead time of 380ns is inserted in each internal when one switch is turned off and the other is turned on.

For LLC resonant half-bridge converter, the output voltage is regulated by changing the switching frequency. ICE1HS01G-1 offers the designer to choose suitable operation frequency range by programming the oscillator with one single resistor.

In addition, ICE1HS01G-1 offers a programmed soft-start function to limit both the inrush current and the overshoot in output voltage.

To protect the system during operation, mains input under-voltage protection and over-current protection are integrated in ICE1HS01G-1 as well.

#### 3.1 Oscillator and Pulse Frequency Modulation

The oscillator is programmed with only one external resistor  $R_{FMIN}$  connected to FMIN pin. The trimmed capacitor  $C_{FS}$  is built inside the IC with high accuracy. The simplified oscillator circuit is shown in Figure 3.

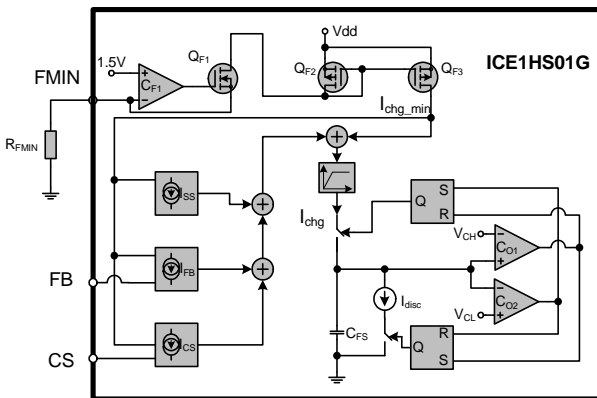


Figure 3 Simplified oscillator circuit

The charge current  $I_{chg}$  is sum of four currents which are  $I_{chg\_min}$ ,  $I_{FB}$ ,  $I_{CS}$  and  $I_{SS}$ .

$$I_{chg} = I_{chg\_min} + I_{FB} + I_{CS} + I_{SS} \quad [1]$$

Everytime the capacitor  $C_{FS}$  is charged by  $I_{chg}$  to  $V_{CH}$ , the upper switch is turned off and  $C_{FS}$  will be discharged through  $I_{disc}$ . The charge time determines the on time for gate signal. The discharge time determines the dead time during transition from one gate off to another gate on. The switching waveforms of the oscillator and gate signals are shown in Figure 4.

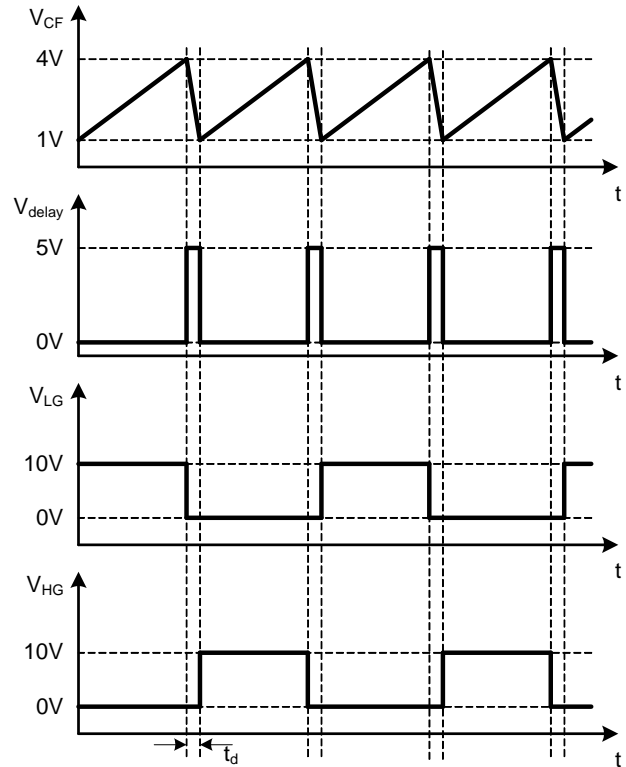


Figure 4 Oscillator waveforms

According to Figures 3 and 4, the on time of each gate can be obtained as

$$T_{on} = \frac{3C_{FS}}{I_{chg}} \quad [2]$$

The switching frequency can be obtained as

$$f_s = \frac{1}{2 \left( \frac{3C_{FS}}{I_{chg}} + T_d \right)} \quad [3]$$

where the dead time  $T_d$  is fixed as 380ns.

#### 3.1.1 Minimum charge current

The voltage on pin FMIN is a constant of 1.5V during normal operation. The resistor  $R_{FMIN}$  determines the current ( $I_{FMIN}$ ) flowing out from FMIN pin. Around one-tenth of  $I_{FMIN}$  is defined as the minimum charging current ( $I_{chg\_min}$ ), which in turn defines the minimum switching frequency as follows.

## Functional description

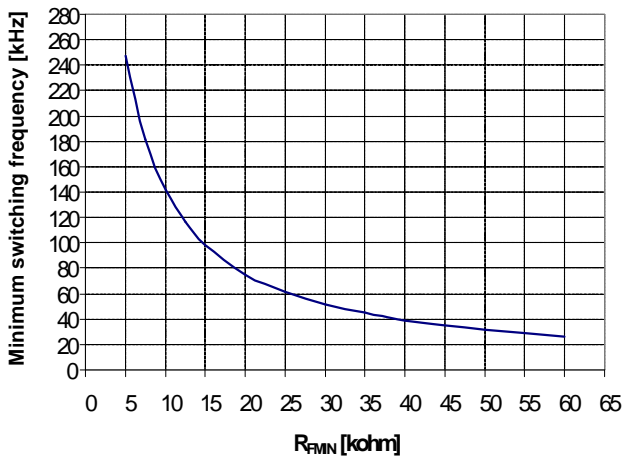


Figure 5  $F_{MIN}$  versus  $R_{FMIN}$

### 3.1.2 Feedback regulation

The output information is fed into the controller through feedback voltage. If the output power is higher, the feedback voltage will be higher, which will cause the switching frequency to decrease and vice versa.

The regulation of switching frequency is achieved by changing the charging current. An accurate operational transconductance amplifier (OTA) is used to translate the feedback voltage  $V_{FB}$  into current  $I_{FB}$ . The effective range of feedback voltage is from 0.9V to 3.9V.

Figure 6 graphs the relationship between the actual switching frequency and feedback voltage  $V_{FB}$  when  $R_{FMIN}=22\text{kohm}$ .

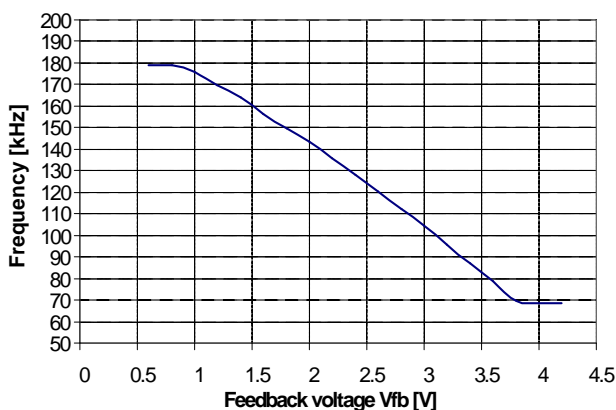


Figure 6 Switching frequency versus  $V_{FB}$

Burst mode operation is also provided by ICE1HS01G-1. During LLC operation, the feedback signal  $V_{FB}$  is continuously monitored. When  $V_{FB}$  drops below  $V_{FB\_off}$ , the switching signal will be disabled after a fixed blanking time  $T_{FB}$ .  $V_{FB}$  will then rise as  $V_{out}$  starts to decrease due to no switching signal. Once  $V_{FB}$  exceeds the threshold  $V_{FB\_on}$ , the IC resumes to normal operation.

### 3.1.3 Current sense current $I_{CS}$

In LLC resonant topologies, it is necessary to limit the resonant current in case of short circuit or other fault conditions. It is achieved by adding another current  $I_{CS}$  to the charging current  $I_{chg}$ .  $I_{CS}$  is limited to 3 times of the minimum charge current.

### 3.1.4 Soft start current $I_{SS}$

To limit the inrush current and output overshoot during start up, the switching frequency shall be necessary high at start up. The switching frequency will change gradually toward the minimum switching frequency until the feedback voltage comes into regulation. The switching frequency will then go to desired value according to load and input conditions. The soft start current  $I_{SS}$  also has a upper limit of around 3.4 times of minimum charge current. Details of soft start will be shown later.

### 3.1.5 Charge current $I_{chg}$

The charge current  $I_{chg}$  for IC oscillator capacitor  $C_{FS}$  is the sum of the four parts including  $I_{chg\_min}$ ,  $I_{FB}$ ,  $I_{SS}$  and  $I_{CS}$ . To limit the maximum switching frequency, maximum value of  $I_{chg}$  is 5 times of  $I_{chg\_min}$ .

In summary, the maximum charge current during normal operation is  $3I_{chg\_min}$  while the maximum charge current during fault condition or softstart is around  $4I_{chg\_min}$  and  $4.43 \cdot I_{chg\_min}$  respectively. Figure 7 shows the maximum switching frequency versus minimum switching frequency during normal operation.

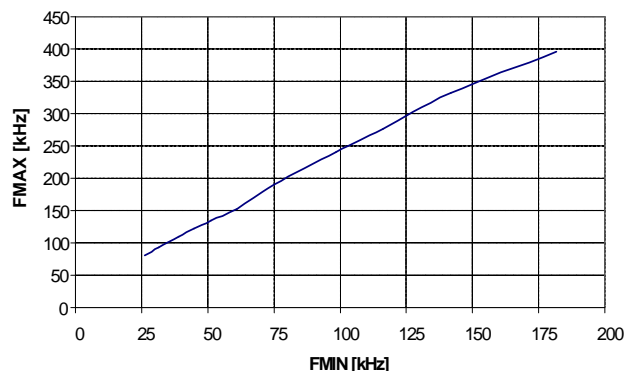


Figure 7  $F_{max}$  versus  $F_{min}$  during normal operation



## Functional description

Figure 8 shows the maximum switching frequency versus minimum switching frequency during softstart.

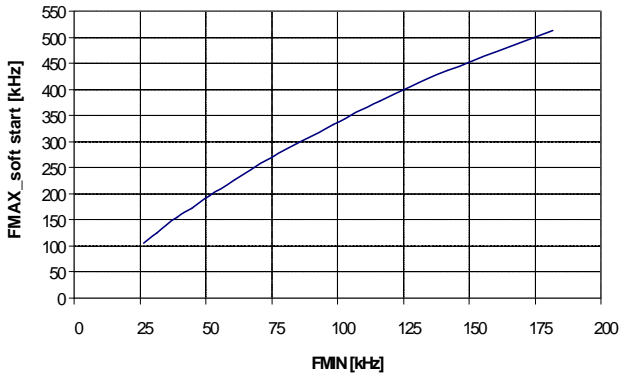


Figure 8  $F_{max\_ss}$  versus  $F_{min}$  during soft start

### 3.2 IC power supply

The controller ICE1HS01G-1 is targeting at applications with auxiliary power supply. In most cases, a front-end PFC pre-regulator with a PFC controller is used in the same system.

The controller ICE1HS01G-1 starts to operate when the supply voltage  $V_{VCC}$  reaches the on-threshold,  $V_{VCCon}$  of 12V. The minimum operating voltage after turn-on,  $V_{VCCoff}$ , is at 11V. The maximum recommended operating voltage  $V_{VCCmax}$  is 18V.

### 3.3 Soft start

At the beginning of the startup phase, the IC provides a soft start with duration of 32ms with 32 steps. During this period, the switching frequency is controlled internally by changing the current  $I_{SS}$ .

Figure 9 illustrates the actual switching frequency vs. startup time when  $R_{FMIN}=22k\Omega$ . During softstart, the frequency starts from 250kHz, and step by step drops to normal operation point.

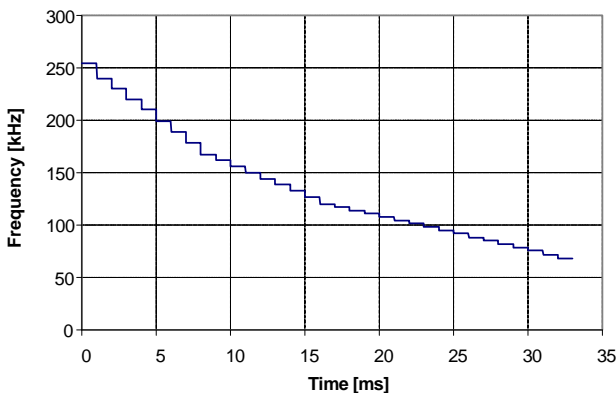


Figure 9 Switching frequency during softstart when  $R_{FMIN}=22k\Omega$

During soft start, the overload protection is disabled although FB voltage is high.

### 3.4 Current sense

Current sense in LLC half bridge converters is for protection purpose. The voltage of resonant capacitor  $C_S$  is the sum of the resonant voltage and the dc voltage which is equal to half of the input bus voltage. If resonant current is higher, then the voltage on  $C_S$  is higher. The current informations for both primary side and secondary side are almost the same and can be obtained by dividing and filtering the resonant voltage. The circuit is shown in Figure 10.

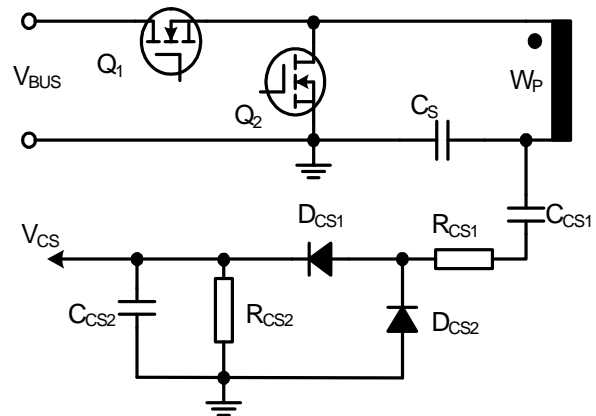


Figure 10 Current sense circuit

### 3.5 Over current protection

The controller ICE1HS01G-1 incorporates two-level over current protection. In case of over-load condition, the lower level OCP will be triggered, the switching frequency will be increased according to the duration and power of the over load. The higher level OCP is used to protect the converter if transformer winding is shorted, the IC will be latched immediately.

If  $V_{CS}$  is higher than 0.8V, IC will boost up the switching frequency. If  $V_{CS}$  is lower than 0.75V, IC will resume to normal operation gradually. If  $V_{CS}$  is always higher than 0.8V for 1.5ms, the frequency will rise to its maximum level. And vice versa.

To sum up, ICE1HS01G-1 will increase the switching frequency to limit the resonant current in case of temporary over-load and will also decrease the switching frequency to its normal value after over-load condition goes away.

### 3.6 Mains Input Voltage Sense

The working range of mains input voltage needs to be specified for LLC resonant converter. It is important for the controller to have input voltage sensing function and protection features, which lets the IC stop switching when the input voltage falls below the specified range and restarts when the input voltage increases back within the range. The mains input voltage sensing circuit is shown Figure 2. With the

## Functional description

current source  $I_{hys}$  connected between VINS and Ground, an adjustable hysteresis between the on and off input voltage can be created as

$$V_{HYS} = R_{INS1} \cdot I_{hys} \quad [4]$$

The mains input voltage is divided by  $R_{INS1}$  and  $R_{INS2}$  as shown in the typical application circuit. A current source  $I_{hys}$  is connected from VINS pin to ground in the IC. If the on and off threshold for mains voltage is  $V_{mainon}$  and  $V_{mainoff}$ , the resistors can be decided as

$$R_{INS1} = \frac{V_{mainon} - V_{mainoff}}{I_{hys}} \quad [5]$$

$$R_{INS2} = R_{INS1} \cdot \frac{V_{INSON}}{V_{mainoff} - V_{INSON}} \quad [6]$$

### 3.7 Over load protection

In case of open control loop or output over load fault, the FB voltage will increase to its maximum level. If FB voltage is higher than  $V_{FBH}$  and this condition last longer than a fixed blanking time of  $T_{OLP}$  (20ms), the IC will start the extended blanking timer. The extended blanking timer is realized by charging and discharging the filter capacitor  $C_{FB}$  via the pull up resistor  $R_{FB}$  and  $Q_{FB}$ . The circuit for extended blanking timer is shown in Figure 11.

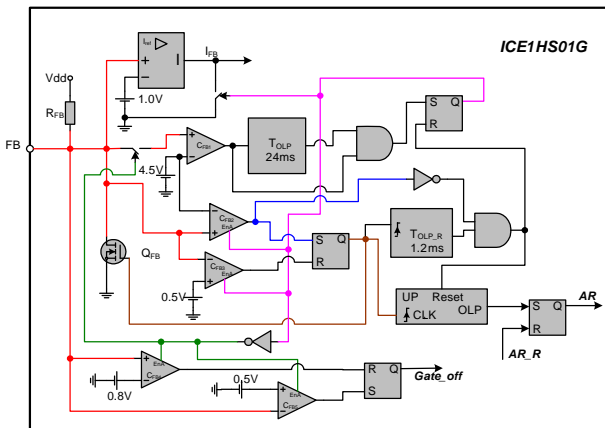


Figure 11 Circuit connected to FB pin

The FB voltage waveform during a OLP period is shown in Figure 12. After FB voltage has been higher than  $V_{FBH}$  for the fixed blanking time  $t_1$  shown in Figure 11, IC will use internal switch  $Q_{FB}$  to discharge  $V_{FB}$  to  $V_{FBL}$ . After the switch  $Q_{FB}$  is released,  $C_{FB}$  will be charged up by  $V_{dd}$  through  $R_{FB}$ . The time needed for  $C_{FB}$  being charged to  $V_{FBH}$  can be calculated as

$$t_{chg} = -\ln\left(\frac{V_{dd} - V_{FBH}}{V_{dd} - V_{FBL}}\right) \cdot R_{FB} \cdot C_{FB} \quad [7]$$

If  $C_{FB}$  is 10nF, the time is about 439us. After  $V_{FB}$  reaches  $V_{FBH}$ , an internal counter will increase by 1 and the capacitor is discharged to 0.5V by  $Q_{FB}$  again. The charging and discharging process of  $C_{FB}$  will be repeated for  $N_{OLP\_E}$  times if the fault condition still exist. After the last time of  $N_{OLP\_E}$  the FB voltage is pulled down to zero, IC will stop the switch when FB voltage rises to  $V_{FBH}$  again. This is called over load/open loop protection. During the charging and discharging period, the IC will operate with frequency determined by  $I_{chg\_min}$  and  $I_{CS}$ .

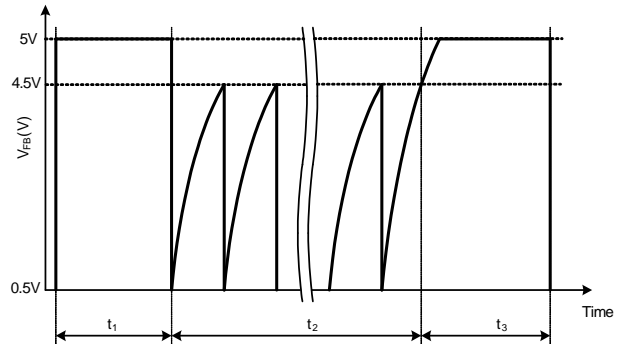


Figure 12 FB voltage waveform during over load protection

If the converter returns to normal operation during the extended blanking time period, FB voltage can not reach  $V_{FBH}$  again. Therefore, after FB voltage is discharged to zero voltage, if it can not reach  $V_{FBH}$  within  $T_{OLP\_R}$ , IC will reset all the fault timer to zero and return to normal operation.

After IC enters into OLP, both switches will be stopped. However, the IC remains active and will try to start with soft start after an adjustable period. This period is realized by charging and discharging the capacitor  $C_{INS}$  connected to VINS pin for  $N_{OLP\_R}$  times. The time is therefore determined by the capacitor  $C_{INS}$  and resistor  $R_{INS1}$  and  $R_{INS2}$ . The circuit implementation of the adjustable off time is shown in Figure 13 and Figure 14 shows the voltage waveform of VINS in this case.

As shown in Figure 14, the  $C_{INS}$  is discharged to  $V_{INS\_L}$  when IC enters into OLP at time  $t_1$ . After that, an internal constant current source  $I_{INST}$  is turned on to charge  $C_{INS}$ . Once the voltage on VINS is charged to  $V_{INS\_H}$ , the current source will be turned off and  $C_{INS}$  is discharged by another switch  $Q_3$  to  $V_{INS\_L}$  again. The charging and discharging of  $C_{INS}$  is thought as one cycle. The cycle time is also influenced by the bus

voltage. The charging time  $t_{cha}$  and discharging time  $t_{disc}$  can be respectively approximated as

$$t_{cha} = -\ln \left( \frac{\left( V_{BUS} \cdot \frac{R_{eq}}{R_{INS1}} \right) + (I_{INST} \cdot R_{eq}) - V_{INSH}}{\left( V_{BUS} \cdot \frac{R_{eq}}{R_{INS1}} \right) + (I_{INST} \cdot R_{eq}) - V_{INSL}} \right) \cdot R_{eq} \cdot C_{INS} \quad [8]$$

$$t_{disc} = -\ln \left( \frac{V_{BUS} \cdot \frac{R_{eq2}}{R_{INS1}} - V_{INSL}}{V_{BUS} \cdot \frac{R_{eq2}}{R_{INS1}} - V_{INSH}} \right) \cdot R_{eq2} \cdot C_{INS} \quad [9]$$

In [8],  $R_{eq}$  is the equivalent resistance for paralleling of  $R_{INS1}$  and  $R_{INS2}$ .

$$R_{eq} = \frac{1}{\frac{1}{R_{INS1}} + \frac{1}{R_{INS2}}} \quad [10]$$

In [9],  $R_{eq2}$  is the equivalent resistance for paralleling of  $R_{INS1}$ ,  $R_{INS2}$  and  $R_{Q3}$  (900ohm typically).

$$R_{eq2} = \frac{1}{\frac{1}{R_{INS1}} + \frac{1}{R_{INS2}} + \frac{1}{R_{Q3}}} \quad [11]$$

IC will repeat the charging and discharging process for  $N_{OLP\_R}$  times. After that, IC will turn off the switches for both charging and discharging. In addition, the current source for hysteresis will be turned on and another blanking time of  $T_{BL\_VINS}$ , the time between  $t_2$  and  $t_3$  as shown in Figure 14, will be added so that VINS pin fully recovers and represents the bus voltage information. IC will start the soft start after the additional blanking time in case  $V_{VINS}$  is higher than the  $V_{VINSon}$ .

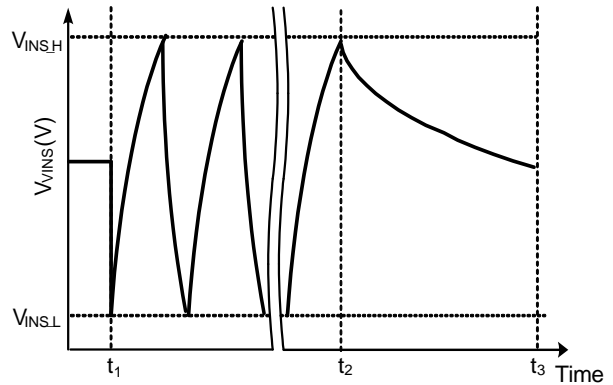


Figure 14 VINS voltage waveform during blanking time after OLP and before IC restarts

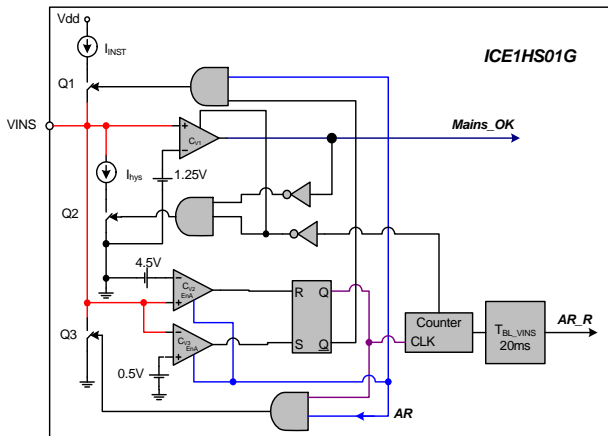


Figure 13 Circuit connected to VINS pin

## 4 Electrical Characteristics

*Note: All voltages are measured with respect to ground (Pin 5). The voltage levels are valid if other ratings are not violated.*

### 4.1 Absolute Maximum Ratings

*Note: Absolute maximum ratings are defined as ratings, which when being exceeded may lead to destruction of the integrated circuit. For the same reason make sure, that any capacitor that will be connected to pin 8 (VCC) is discharged before assembling the application circuit.*

Parameter	Symbol	Limit Values		Unit	Remarks
		min.	max.		
VCC Supply Voltage	$V_{VCC}$	-0.3	20.5 <sup>1)</sup>	V	
$V_{HG}$ Voltage	$V_{LG}$	-0.3	18	V	
$V_{LG}$ Voltage	$V_{LG}$	-0.3	18	V	
CS voltage	$V_{CS}$	-0.3	5	V	
FB voltage	$V_{FB}$	-0.3	5	V	
VINS voltage	$V_{VINS}$	-0.3	5	V	
FMIN voltage	$V_{FMIN}$	-0.3	5	V	
Maximum source current on FMIN	$I_{FMIN}$	-	2.5	mA	
Junction Temperature	$T_j$	-40	125	°C	
Storage Temperature	$T_s$	-55	150	°C	
Thermal Resistance Junction-Ambient for PG-DSO-8	$R_{thJA}(DSO)$	-	185	K/W	PG-DSO-8
ESD Capability	$V_{ESD}$	-	2	kV	Human body mode <sup>2)</sup>

1) Stress beyond this limit may destroy the device. Functional operation of the device at this or any condition beyond those indicated under 4.2 Operating Range is not implied. Exposure to absolute maximum rated conditions for extended periods of time may affect device reliability.

2) According to EIA/JESD22-A114-B (discharging a 100pF capacitor through a 1.5kΩ series resistor)

### 4.2 Operating Range

*Note: Within the operating range the IC operates as described in the functional description.*

Parameter	Symbol	Limit Values		Unit	Remarks
		min.	max.		
VCC Supply Voltage	$V_{VCC}$	10.2	18	V	
Junction Temperature	$T_{jCon}$	-25	125	°C	

## 4.3 Characteristics

### 4.3.1 Supply Section

Note: 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.

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	typ.	max.		
Start up Current	$I_{VCCstart}$	200	350	530	$\mu\text{A}$	$V_{VCCon}-0.1\text{V}$
Supply Current in operation with inactive gate	$I_{VCCop}$	-	-	3	$\text{mA}$	no switching;
Supply Current in normal operation with active gate	$I_{VCCactive}$	-	5.8	-	$\text{mA}$	Freq=50kHz $R_{FMIN}=30\text{k}\Omega$ $V_{FB}=4.2\text{V}$ , $V_{CS}=0\text{V}$ $C_L=2.2\text{nF}$ , $V_{VCC}=15\text{V}$
VCC Turn-On Threshold	$V_{VCCon}$	11.3	12	12.7	V	
VCC Hysteresis	$V_{VCChys}$	0.68	0.95	1.25	V	
VCC Turn-Off Threshold	$V_{VCCoff}$	-	$V_{VCCon}$ $V_{VCChys}$	-	V	
Trimmed Reference Voltage	$V_{REF}$	4.90	5.0	5.10	V	$I_{FB}=0$

### 4.3.2 Oscillator Section

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	typ.	max.		
Minimum switching frequency	$F_{MIN}$	47	50	53	$\text{kHz}$	$R_{FMIN}=30\text{k}\Omega$ ;
Maximum switching frequency during normal operation	$F_{MAX\_N}$	-	128	-	$\text{kHz}$	$R_{FMIN}=30\text{k}\Omega$ ; $V_{FB}=0.6\text{V}$ , $V_{CS}=0\text{V}$ , after softstart
Maximum switching frequency during protection	$F_{MAX\_P}$	-	203	-	$\text{kHz}$	$R_{FMIN}=30\text{k}\Omega$ ; $V_{FB}=0.6\text{V}$ , $V_{CS}=1\text{V}$
Absolute Maximum switching frequency	$F_{MAX\_abs}$	-	609	-	$\text{kHz}$	$R_{FMIN}=4.8\text{k}\Omega$ , $V_{FB}=0.9\text{V}$ , $V_{CS}=1\text{V}$ , soft start first cycle
Reference voltage on FMIN	$V_{OSCTref}$	1.44	1.5	1.56	V	
Dead time	$T_d$	340	380	420	$\text{ns}$	$R_{FMIN}=30\text{k}\Omega$ ; $V_{FB}=0.6\text{V}$ , $V_{CS}=0\text{V}$
Oscillation duty cycle	D	48	50	52	%	based on calculation

Electrical Characteristics

4.3.3 Input voltage sense

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	typ.	max.		
Input voltage on threshold	$V_{VINSon}$	1.2	1.25	1.3	V	
Bias current on VINS pin	$I_{hys}$	9	12	15	$\mu A$	
Blanking time for leaving mains undervoltage protection	$T_{VINS\_out}$	-	500	-	$\mu s$	
Blanking time for entering mains under voltage protection	$T_{VINS\_in}$	-	50	-	$\mu s$	

4.3.4 Current sense

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	typ.	max.		
Overcurrent protection low	$V_{CSL}$	0.75	0.8	0.85	V	
Hysteresis voltage for overcurrent protection low		-	50	-	mV	
Overcurrent protection high	$V_{CSH}$	1.57	1.63	1.7	V	
Blanking time for OCP latch	$T_{OCP\_L}$	-	300	-	ns	
Maximum switching frequency during over current protection	$F_{MAX\_C}$	-	163	-	kHz	$R_{FMIN}=30k\Omega; V_{FB}=4.2V, V_{CS}=1V$ , after soft start and 2ms after $V_{CS}$ higher than 0.8V
Counter input voltage high	$V_{CS\_CH}$	-	4.5	-	V	Not subject to test
Counter input voltage low level	$V_{CS\_CL}$	-	0.5	-	V	Not subject to test
Blanking time after each gate is turned on	$T_{LEB}$	-	250	-	ns	

**Electrical Characteristics**

**4.3.5 Soft start**

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	typ.	max.		
Soft start timer	$T_{SS}$	-	1	-	ms	Test as a 32ms softstart time
Soft start steps	$N_{SS}$	-	32	-		
Ratio of $I_{SS}$ over $I_{chgmin}$		-	3.43	-		Not subject to test
Soft start frequency	$F_{ss\_step}$	-	184	-	kHz	$R_{FMIN}=30k\Omega$ ; $T_d=380ns$ ; first cycle softstart

**4.3.6 Feedback**

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	typ.	max.		
Feedback voltage below which there is no regulation	$V_{FB\_min}$	-	0.9	-	V	
Feedback voltage above which there is no regulation	$V_{FB\_max}$	-	3.9	-	V	
Pull up resistance	$R_{FB}$	15	20	25	$k\Omega$	
Feedback voltage below which there is no switch	$V_{FB\_off}$	-	0.2	-	V	
Feedback voltage above which IC resumes switch	$V_{FB\_on}$	-	0.3	-	V	
Blanking time for switch on and off	$T_{FB}$	-	200	-	ns	

Note: The trend of all the voltage levels in the Control Unit is the same regarding the deviation except  $V_{VCCOVP}$

### Electrical Characteristics

#### 4.3.7 Over load/Open loop protection

Feedback voltage for open loop/over load protection	$V_{FBH}$	-	4.5	-	V	
Feedback voltage high level for extended timer	$V_{FB\_CH}$	-	4.5	-	V	
Feedback voltage low level for extended timer	$V_{FB\_CL}$	-	0.5	-	V	
On resistance of pulling down switch $Q_{FB}$	$R_{QFB}$	-	900	-	ohm	
Fixed Blanking time for open loop/over load protection	$T_{OLP\_F}$	-	20	-	ms	
Maximum time for FB voltage to go up to $V_{FBH}$ during extended blanking timer	$T_{OLP\_R}$	-	1.28	-	ms	
Extended counter	$N_{OLP\_E}$	-	512	-		
Charging current on VINS pin for restart time	$I_{INST}$	-	750	-	$\mu A$	
Maximum voltage on VINS pin charged by $I_{INST}$	$V_{INS\_H}$	-	4.5	-	V	
Minimum voltage on VINS pin pulled down by $Q_3$	$V_{INS\_L}$	-	0.5	-	V	
On resistance of pulling down switch $Q_3$	$R_{Q3}$	-	900	-	ohm	
Restart counter number	$N_{OLP\_R}$	-	2048	-		
Blanking time before IC restarts after restart counter reaches 2048	$T_{BL\_VINS}$	-	20	-	ms	

#### 4.3.8 Gate driver

Parameter	Symbol	Limit Values			Unit	Test Condition
		min.	typ.	max.		
Output voltage at logic low	$V_{GATElow}$	-	-	1.5	V	$V_{VCC}=5V, I_{OUT} = 20mA$
Output voltage at logic high	$V_{GATEhigh}$	-	9	-	V	$V_{VCC}=V_{VCCoff}+0.2V$ $C_L=2.2nF$
Output voltage active shut down	$V_{GATEasd}$	-	1.0	-	V	$V_{VCC} = 5V, I_{OUT} = 20mA$
Rise Time	$t_{rise}$	-	100	-	ns	$C_L = 2.2nF$
Fall Time	$t_{fall}$	-	25	-	ns	$C_L = 2.2nF$
GATE current, Peak Rising Edge	$I_{GATE\_R}$	1	-	-	A	$C_L = 2.2nF^1)$
GATE current, Peak Falling Edge	$I_{GATE\_F}$	-	-	1.5	A	$C_L = 2.2nF^1)$

1) Design characteristics (not meant for production testing)



## 5 Outline Dimension

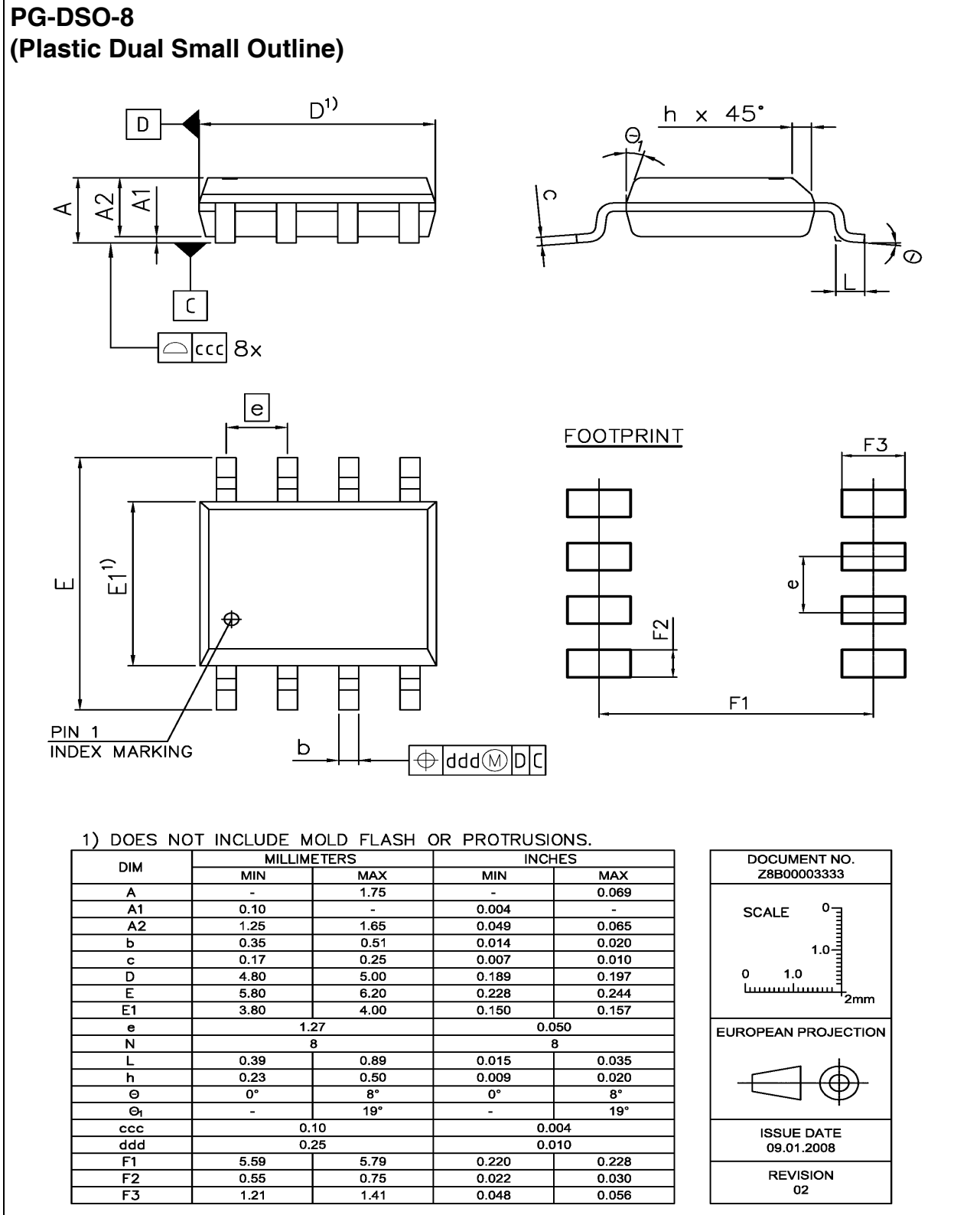


Figure 15 PG-DSO-8

## 6 Marking

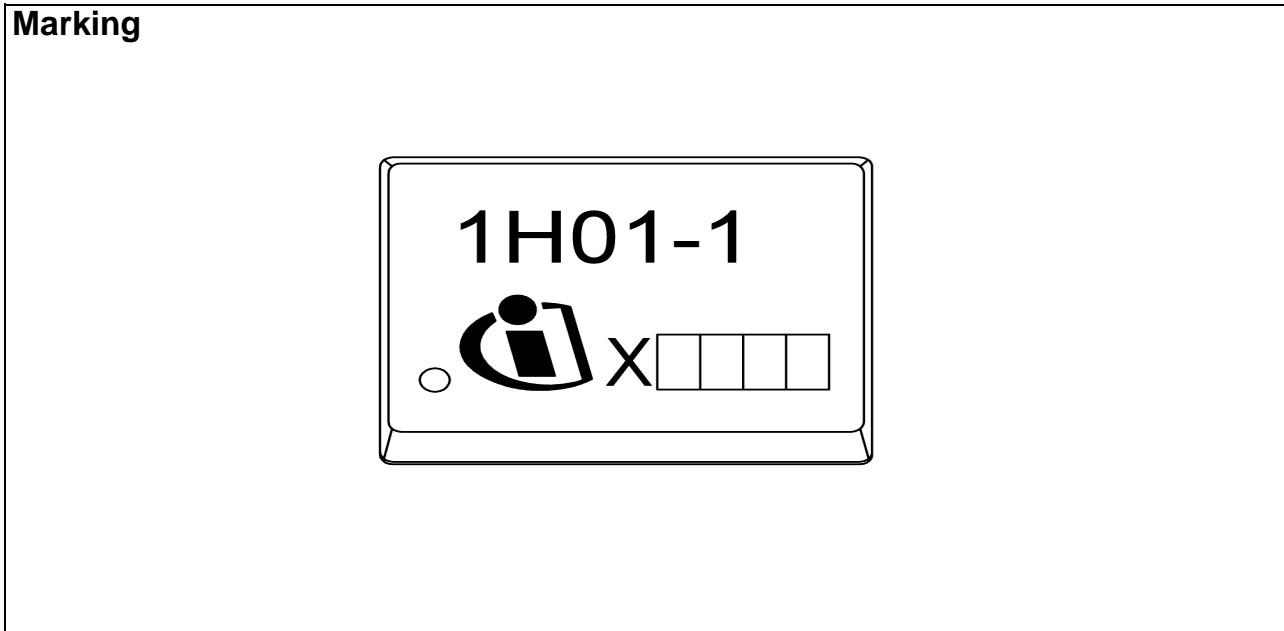


Figure 16 Marking for ICE1HS01G-1

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