

POWER MANAGEMENT UNIT FOR MICROCONTROLLED BALLAST

1 FEATURES

- INTEGRATED HIGH-VOLTAGE START-UP
- 4 DRIVERS FOR PFC, HALF-BRIDGE & PRE-HEATING MOSFETS
- 3.3V MICROCONTROLLER COMPATIBLE
- FULLY INTEGRATE POWER MANAGEMENT FOR ALL OPERATING MODES
- INTERNAL TWO POINT V_{CC} REGULATOR
- OVER-CURRENT PROTECTION WITH DIGITAL OUTPUT SIGNAL
- CROSS-CONDUCTION PROTECTION (INTERLOCKING)
- UNDER VOLTAGE LOCK OUT
- INTEGRATED BOOTSTRAP DIODE

2 APPLICATIONS

- DIMMABLE/NON-DIMMABLE BALLAST

3 DESCRIPTION

Designed in High-voltage BCD Off-line technology, the L6382D is provided with 4 input pins and a

Figure 1. Package



Table 1. Order Codes

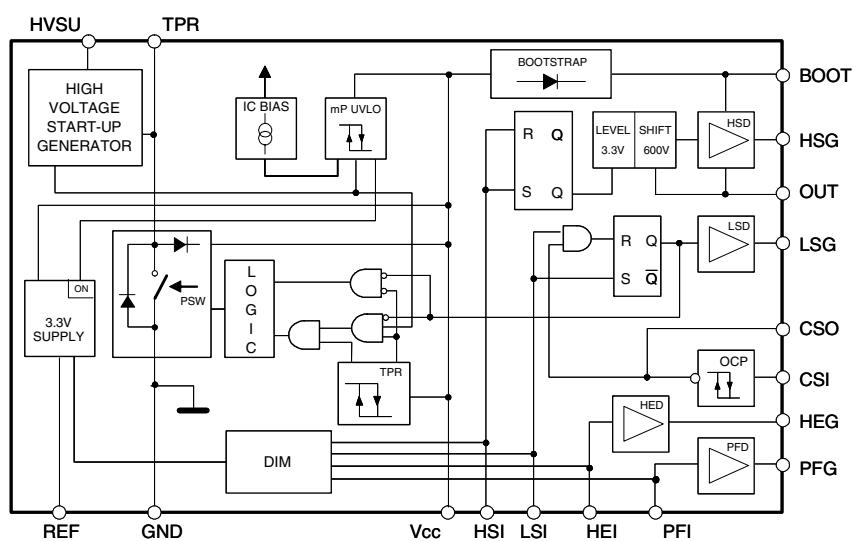
Part Number	Package
L6382D	SO20 tube
L6382DTR	SO20 in Tape & Reel

high voltage start-up generator conceived for applications managed by a microcontroller.

It allows the designer to use the same ballast circuit for different lamp wattage/type by simply changing the µC software.

The digital input pins - able to receive signals up to 400KHz - are connected to level shifters that provide the control signals to their relevant drivers;

Figure 2. Block Diagram



in particular the L6382D embeds one driver for the PFC pre-regulator stage, two drivers for the ballast half-bridge stage (High Voltage, including also the bootstrap function) and the last one to provide supplementary features like preheating of filaments supplied through isolated filaments in dimmable applications.

A precise reference voltage ($+3.3V \pm 1\%$) able to provide up to 30mA is available to supply the μC in operating mode. Instead, during start-up and save mode the current available at V_{REF} is up to 10mA and it is provided by the internal high voltage start-up generator.

The chip has been conceived with advanced power management logic to minimize power losses and increase the application reliability.

In the half-bridge section, a patented integrated bootstrap section replaces the external bootstrap diode.

The L6382D integrates also a function that regulates the IC supply voltage (without the need of any external charge pump) and optimizes the current consumption.

Figure 3. Pin Connection (Top View)

PFI	1	20	VREF
LSI	2	19	CSI
HSI	3	18	CSO
HEI	4	17	HEG
PFG	5	16	N.C.
N.C.	6	15	HVSU
TPR	7	14	N.C.
GND	8	13	OUT
LSG	9	12	HSG
VCC	10	11	BOOT

Figure 4. Typical System Block Diagram

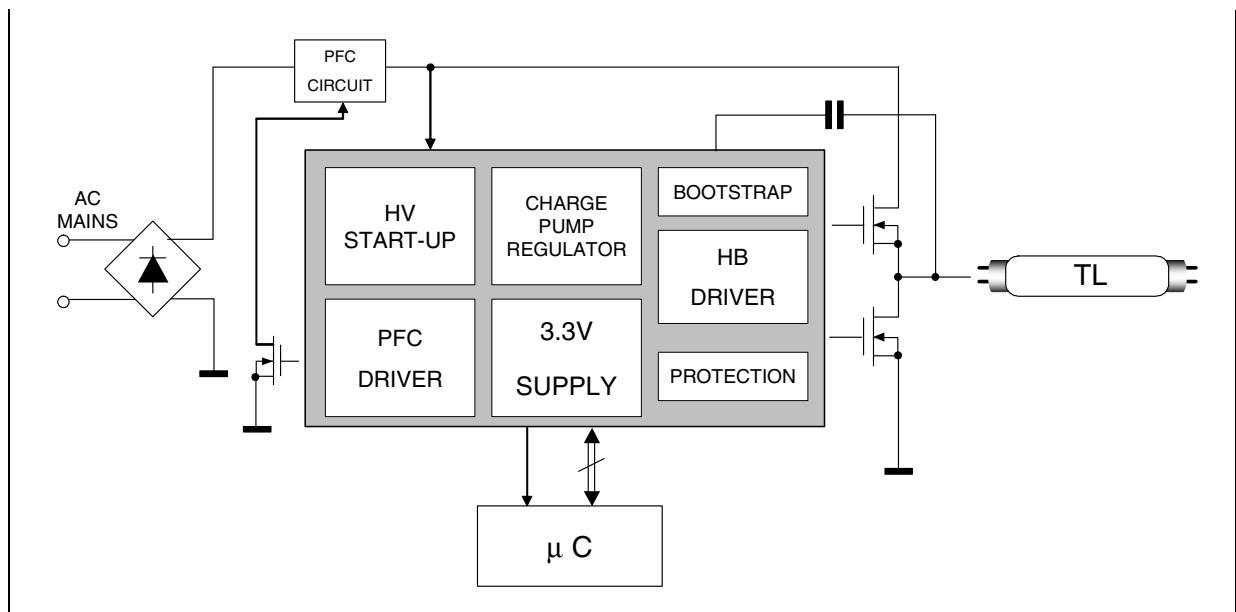


Table 2. Pin Functions

N.	Pin	Function
1	PFI	Digital input signal to control the PFC gate driver. This pin has to be connected to a TTL compatible signal.
2	LSI	Digital input signal to control the half-bridge low side driver. This pin has to be connected to a TTL compatible signal.
3	HSI	Digital input signal to control the half-bridge high side driver. This pin has to be connected to a TTL compatible signal.
4	HEI	Digital input signal to control the HEG output. This pin has to be connected to a TTL compatible signal.
5	PFG	PFC Driver Output. This pin must be connected to the PFC power MOSFET gate. A resistor connected between this pin and the power MOS gate can be used to reduce the peak current. An internal 10KΩ resistor toward ground avoids spurious and undesired MOSFET turn-on. The totem pole output stage is able to drive the power MOS with a peak current of 120mA source and 250mA sink.
6	N.C.	Not connected
7	TPR	Input for two point regulator; by coupling the pin with a capacitor to a switching circuit, it is possible to implement a charge circuit for the Vcc.
8	GND	Chip ground. Current return for both the low-side gate-drive currents and the bias current of the IC. All of the ground connections of the bias components should be tied to a track going to this pin and kept separate from any pulsed current return.
9	LSG	Low Side Driver Output. This pin must be connected to the gate of the half-bridge low side power MOSFET. A resistor connected between this pin and the power MOS gate can be used to reduce the peak current. An internal 20KΩ resistor toward ground avoids spurious and undesired MOSFET turn-on. The totem pole output stage is able to drive power with a peak current of 120mA source and 120mA sink.
10	Vcc	Supply Voltage for the signal part of the IC and for the drivers.
11	BOOT	High-side gate-drive floating supply Voltage. The bootstrap capacitor connected between this pin and pin 13 (OUT) is fed by an internal synchronous bootstrap diode driven in phase with the low-side gate-drive. This patented structure normally replaces the external diode.
12	HSG	High Side Driver Output. This pin must be connected to the gate of the half bridge high side power MOSFET . A resistor connected between this pin and the power MOS gate can be used to reduce the peak current. An internal 20KΩ resistor toward OUT pin avoids spurious and undesired MOSFET turn-on. The totem pole output stage is able to drive the power MOS with a peak current of 120mA source and 120mA sink.
13	OUT	High-side gate-drive floating ground. Current return for the high-side gate-drive current. Layout carefully the connection of this pin to avoid too large spikes below ground.
14	N.C.	Not connected
15	HVSU	High-voltage start-up. The current flowing into this pin charges the capacitor connected between pin Vcc and GND to start up the IC. Whilst the chip is in <u>save</u> mode, the generator is cycled on-off between turn-on and <u>save</u> mode voltages. When the chip works in <u>operating</u> mode the generator is shut down and it is re-enabled when the Vcc voltage falls below the UVLO threshold. According to the required VREF pin current, this pin can be connected to the rectified mains voltage either directly or through a resistor.
16	N.C.	High-voltage spacer. The pin is not connected internally to isolate the high-voltage pin and comply with safety regulations (creepage distance) on the PCB.
17	HEG	Output for the HEI block; this driver can be used to drive the MOS employed in isolated filaments preheating. An internal 20KΩ resistor toward ground avoids spurious and undesired MOSFET turn-on.

Table 2. Pin Functions (continued)

N.	Pin	Function
18	CSO	Output of current sense comparator, compatible with TTL logic signal; during <i>operating mode</i> , the pin is forced low whereas whenever the OC comparator is triggered ($CSI > 0.55$ typ.) the pin latches high.
19	CSI	Input of current sense comparator, it is enabled only during <i>operating mode</i> ; when the pin voltage exceeds the internal threshold, the CSO pin is forced high and the half bridge drivers are disabled. It exits from this condition by either cycling the Vcc below the UVLO or with LGI=HGI=low simultaneously.
20	VREF	Voltage reference. During <i>operating mode</i> an internal generator provides an accurate voltage reference that can be used to supply up to 30mA (during <i>operating mode</i>) to an external circuit. A small film capacitor (0.22 μ F min.), connected between this pin and GND is recommended to ensure the stability of the generator and to prevent noise from affecting the reference.

Table 3. Absolute Maximum Ratings

Symbol	Pin	Parameter	Value	Unit
V _{CC}	10	IC supply voltage ($I_{CC} = 20$ mA)	Self-limited	
V _{HVSU}	15	High voltage start-up generator voltage range	-0.3 to 600	V
V _{BOOT}	11	Floating supply voltage	-1 to $V_{HVSU}+V_{CC}$	V
V _{OUT}	13	Floating ground voltage	-1 to 600	V
I _{TPR(RMS)}	6	Maximum TPR RMS current	± 200	mA
I _{TPR(PK)}	6	Maximum TPR peak current	± 600	mA
V _{TPR}	6	Maximum TPR voltage (*)	14	V
	19	CSI input voltage	-0.3 to 7	V
	1, 2, 3, 4	Logic input voltage	-0.3 to 7	V
	9, 12, 17	Operating frequency	15 to 400	KHz
	5	Operating frequency	15 to 600	KHz
T _{stg}		Storage Temperature	-40 to +150	°C
T _j		Ambient Temperature operating range	-40 to +125	°C

(*) excluding *operating mode***Table 4. Thermal Data**

Symbol	Parameter	Value	Unit
R _{th j-amb}	Max. Thermal Resistance, Junction-to-ambient	120	°C/W

Table 5. Electrical Characteristics ($T_j = 25^\circ\text{C}$, $V_{CC}=12\text{V}$ unless otherwise specified)

Symbol	Pin	Parameter	Test condition	min.	typ	max	UNIT
SUPPLY VOLTAGE							
V_{ccON}	10	Turn-on voltage		13	14	15	V
V_{ccOFF}	10	Turn-off voltage		7.5	8.25	9.2	V
V_{ccSM}	10	Save mode voltage		12.75	13.8	14.85	V
VSMhys	10	Save mode hysteresys		0.15	0.2	0.25	V
$V_{REF(OFF)}$	10	Reference turn-off		5.7	6	6.33	V
I_{vccON}	10	Start-up current				150	μA
I_{vccSM}	10	Save Mode current consumption				190	μA
			(1)			150	μA
I_{vcc}	10	Quiescent current in operating mode	$V_{CC}=13\text{V}; LGI=HGI=\text{high}; \text{no load on } V_{REF}$			2	mA
V_z	10	Internal Zener		TBD			V
HIGH VOLTAGE START-UP							
IMSS	15	Maximum current	$V_{HVSU} > 50\text{V}$	20			mA
	15	Turn-on Voltage	$I_{HVSU}=5\text{mA}$		TBD		V
ILSS	15	Leakage current off state	$V_{HVSU} = 600\text{V}$			40	μA
TWO POINT REGULATOR (TPR) PROTECTION							
TPR_{st}	10	Vcc Protection level	<i>Operating mode</i>	14.0		15.0	V
$TPR_{(ON)}$	10	Vcc Turn-on level	<i>Operating mode; after the first falling edge on LSG</i>	12.5		13.5	V
$TPR_{(OFF)}$	10	Vcc Turn-off level	<i>Operating mode; after the first falling edge on LSG</i>	12.45		13.48	V
	7	Output voltage on state	$I_{TPR} = 200\text{mA}$			2	V
	7	Forward voltage drop Diode	@ 600mA forward current.			2	V
	7	Leakage current off state	$V_{TPR} = 13\text{V}$			5	μA
LSG, HEG & PFG DRIVERS							
$V_{OH(LS)}$	5, 9, 17	HIGH Output Voltage	$I_{LSG} = 10\text{mA}$		$V_{CC} - 0.5$		V
$V_{OL(LS)}$	5, 9, 17	LOW Output Voltage	$I_{LSG} = 10\text{mA}$		0.5		V
		Sink Current Capability	LSG and PFG	120			mA
			HEG	50			mA

Table 5. Electrical Characteristics (continued)

Symbol	Pin	Parameter	Test condition	min.	typ	max	UNIT
		Source Current Capability	LSG	120			mA
			HEG	70			
			PFG	250			
T _{RISE}	5, 9, 17	Rise time	Cload = 1nF		TBD		ns
T _{FALL}	5, 9, 17	Fall time	Cload = 1nF		TBD		ns
T _{DELAY}		Propagation delay (input to output)	LSG; high to low and low to high			300	ns
			HEG; high to low and low to high			200	ns
			PFG; high to low			250	ns
			PFG; low to high			200	ns
R _B		Pull down Resistor	LSG		20		KΩ
			HEG		50		KΩ
			PFG		10		KΩ
HSG DRIVER (VOLTAGES REFERRED TO OUT)							
V _{OH(HS)}	12	HIGH Output Voltage	I _{HSG} = 10 mA		V _{OUT} - 0.5		V
V _{OL(HS)}	12	LOW Output Voltage	I _{HSG} = 10 mA		0.5		V
	12	Sink Current Capability		120			mA
	12	Source Current Capability		120			mA
T _{RISE}	12	Rise time	Cload = 1nF		TBD		ns
T _{FALL}	12	Fall time	Cload = 1nF		TBD		ns
T _{DELAY}	12	Propagation delay (LGI to LSG)	high to low and low to high			300	ns
R _B	12	Pull down Resistor	to OUT		20		KΩ
HIGH-SIDE FLOATING GATE-DRIVER SUPPLY							
I _{LKBOOT}	11	V _{BOOT} pin leakage current	V _{BOOT} = 580V			5	µA
I _{LKOUT}	13	OUT pin leakage current	V _{OUT} = 562V			5	µA
R _{D(on)}		Synchronous bootstrap diode on-resistance	V _{LVG} = HIGH		100		Ω
		Forward Voltage Drop	at 10 mA forward current		1.9	2.4	V
		Forward Current	at 5V forward voltage drop	25			mA

Table 5. Electrical Characteristics (continued)

Symbol	Pin	Parameter	Test condition	min.	typ	max	UNIT
VREF							
V _{REF}	20	Reference voltage	15mA load.	3.267	3.3	3.333	V
			15mA load, (1)	3.234	3.3	3.366	V
	20	Load regulation	I _{Ref} = -3 to +30 mA	-20		2	mV
	20	Voltage change	15mA load; V _{cc} = 9V to 15V			15	mV
	20	V _{REF} latched protection			2		V
	20	V _{REF} Clamp @3mA	V _{cc} from 0 to V _{CCON} during start-up; V _{cc} from V _{REF(OFF)} to 0 during shut-down.			1.2	V
I _{REF}	20	Current Drive Capability		-3		+30	mA
			Save mode	-3		+10	mA
OVERTCURRENT BUFFER STAGE							
V _{CSI}	19	Comparator Level	Bandgap	0.49	0.5	5.01	V
I _{CSI}	19	Input Bias Current				500	nA
		Propagation delay	CSO turn off to LSG low			200	ns
	18	High output voltage	I _{CSO} = 200µA	V _{REF-0.5V}			
	18	Low output voltage	I _{CSO} = -150µA			0.5	V
DIM							
		Normal Mode Time Out		65	100	135	µs
		Vref enabling drivers			3.0		V
T _{ED}		Time enabling drivers			10		µs
LOGIC INPUT							
	1 to 4	Low Level Logic Input Voltage				0.8	V
	1 to 4	High Level Logic Input Voltage		2.2			V
	LGI	Pull down resistor			100		KΩ

Notes: 1. Specification over the -40°C to +125°C junction temperature range are ensured by design, characterization and statistical correlation.

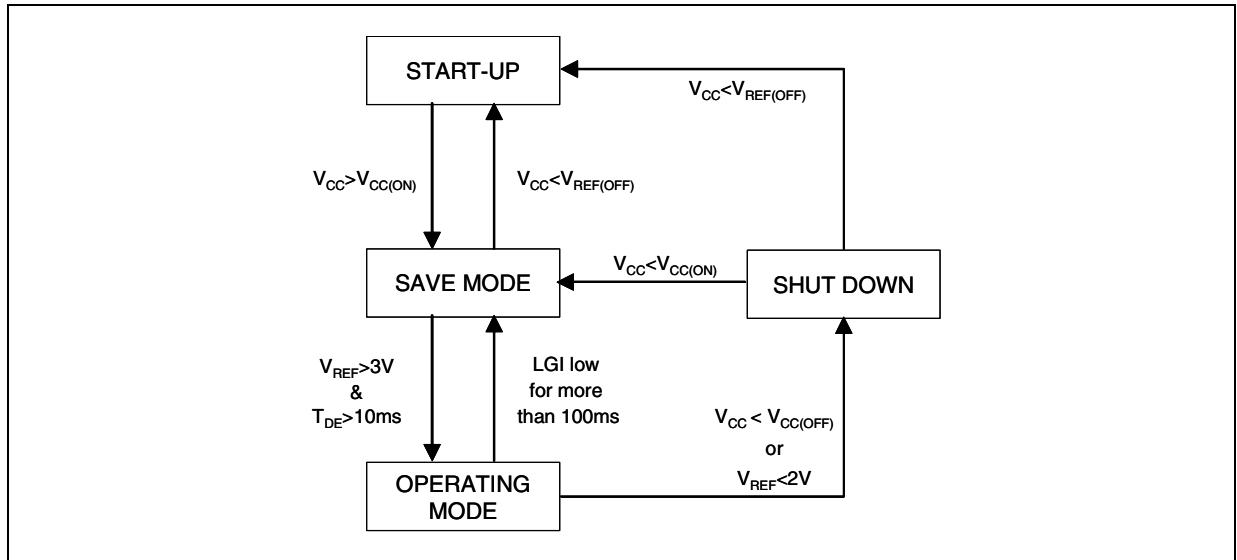
4 APPLICATION INFORMATION

4.1 POWER MANAGEMENT

The L6382D has two stable states (*save* mode and *operating* mode) and two additional states that manage the Start-up and fault conditions (fig. 5): the Over Current Protection is a parallel asynchronous process enabled when in *operating* mode.

Following paragraphs will describe each mode and the condition necessary to shift between them.

Figure 5.



4.1.1 START-UP mode

With reference to the timing diagram of figure 6, when power is first applied to the converter, the voltage on the bulk capacitor builds up and the HV generator is enabled to operate drawing about 10mA. This current, diminished by the IC consumption (less than 150µA), charges the bypass capacitor connected between pin Vcc and ground and makes its voltage rise almost linear.

During this phase, all IC's functions are disabled except for:

- the current sinking circuit on VREF pin that maintains low the voltage by keeping disabled the microcontroller connected to this pin;
- the High-Voltage Start-Up (HVSU) that is ON (conductive) to charge the external capacitor on pin Vcc. As the Vcc voltage reaches the start-up threshold (14V typ.) the chip starts operating and the HV generator is switched off.

Summarizing:

- the high-voltage start-up generator is active;
- VREF is disabled with additional sinking circuit on pin VREF is enabled;
- TPR is disabled;
- OCP is disabled;
- the drivers are disabled.

4.1.2 SAVE Mode

This mode is entered after the Vcc voltage reaches the turn-on threshold; the VREF is enabled in low current source mode to supply the µC connected to it, whose wake-up required current must be less than 10mA: if no switching activity is detected at LGI input, the high voltage start-up generator cycles ON-OFF keeping the Vcc voltage between VccON and VccSM.

Summarizing:

- the high-voltage start-up generator is cycling;
- V_{REF} is enabled in low source current capability ($I_{REF} \leq 10\text{mA}$);
- TPR circuit is disabled;
- OCP is disabled;
- the drivers are disabled.

If the V_{CC} voltage falls below the $V_{REF(OFF)}$ threshold, the device enters the start-up mode.

4.1.3 OPERATING Mode

After $10\mu\text{s}$ in save mode and only if the voltage at V_{REF} is higher than 3.0V , on the falling edge on the HGI input, the drivers are enabled as well as all the IC's functions; this is the mode correspondent to the proper lamp behavior.

Summarizing:

- HVSU is OFF
- V_{REF} is enabled in high source current mode ($I_{REF} < 30\text{mA}$)
- TPR circuit is enabled
- OCP is enabled
- the drivers are enabled

If there is no switching activity on LGI for more than $100\mu\text{s}$, the IC returns in save mode.

4.1.4 Shut Down

This state permits to manage the fault conditions in operating mode and it is entered by the occurrence on one of the following conditions:

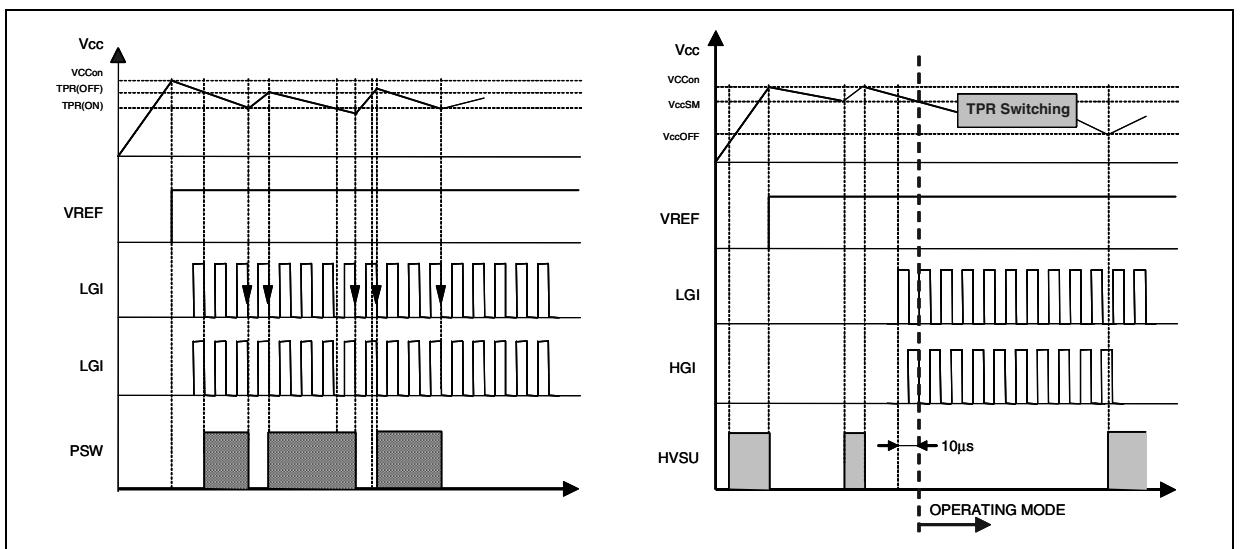
- 1. $V_{CC} < V_{CC OFF}$ (Under Voltage fault on Supply),
- 2. $V_{REF} < 2.0\text{V}$ (Under Voltage fault on V_{REF})

In this state the functions are:

- The HVSU generator is ON
- V_{REF} is enabled in low source current mode ($I_{REF} < 10\text{mA}$)
- TPR is disabled
- OCP is disabled
- the drivers are disabled

In this state if V_{CC} reaches $V_{CC On}$, the device enters the save mode otherwise, if $V_{CC} < V_{REF(OFF)}$, also the μC is turned off and the device will be ready to execute the Start-up sequence.

Figure 6. Timing Sequences: TPR behavior (left) Start-up, save mode and operating mode (right).



5 BLOCK DESCRIPTION

5.1 SUPPLY SECTION

- **PUVLO (Power Under Voltage Lock Out):** This block controls the power management of the L6382D ensuring the right current consumption in each operating state, the correct V_{REF} current capability, the driver enabling and the high-voltage start-up generator switching.

During Start-up the device sinks the current necessary to charge the external capacitor on pin V_{CC} from the high voltage bus; in this state the other IC's functions are disabled and the current consumption of the whole IC is less than 150 μ A.

When the voltage on V_{CC} pin reaches V_{ccON}, the IC enters the save mode where the μ PUVLO block controls V_{cc} between V_{ccON} and V_{ccSM} by switching ON/OFF the high voltage start-up generator.

- **HVSU (High-Voltage Start-Up generator):** a 600V internal MOS transistor structure controls the V_{cc} supply voltage during start-up and save mode conditions and it reduces the power losses during operating Mode by switching OFF the MOS transistor. The transistor has a source current capability of up to 30mA.

- **TPR (Two Point Regulator) & PWS:** during operating mode, the TPR block controls the PSW switch in order to regulate the IC supply voltage (V_{CC}) to a value in the range between TPR(ON) and TPR(OFF) by switching ON and OFF the PSW transistor.

- V_{cc} > TPRst: the PSW is switched ON immediately;
- TPR(ON) < V_{cc} < TPRst: the PSW is switched ON at the following falling edge of LGI;
- V_{cc} < TPR(OFF): the PSW is switched OFF at the following falling edge on LGI.

When the PSW switch is OFF, the diodes build a charge pump structure so that, connecting the TPR pin to a switching voltage (through a capacitor) it is possible to supply the low voltage section of the chip without adding any further external component. The diodes and the switch are designed to withstand a peak current of at least 200mA_{RMS}.

5.2 3.3V REFERENCE VOLTAGE

This block is used to supply the microcontroller; this source is able to supply 10mA in save mode and 30mA in operating mode; moreover, during start-up when V_{REF} is not yet available, an additional circuit ensures that, even sinking 3mA, the pin voltage doesn't exceed 1.2V.

The reference is available until V_{cc} is above V_{REF(OFF)}; below that it turns off and the additional sinking circuit is enabled again.

5.3 DRIVERS

- **LSD (Low Side Driver):** it consists of a level shifter from 3.3V logic signal (LGI) to V_{cc} MOS driving level; conceived for the half-bridge low-side power MOS, it is able to source and sink 120mA (min).
- **HSD (Level Shifter and High Side Driver):** it consists of a level shifter from 3.3V logic signal (HGI) to the high side gate driver input up to 600V. Conceived for the half-bridge high-side power MOS, the HSD is able to source 120mA from HSB to HSG (turn-on) and to sink 120mA to HSS (turn-off).
- **PFD (Power Factor Driver):** it consists of a level shifter from 3.3V logic signal (PFI) to V_{cc} MOS driving level: the driver is able to source 120mA from V_{cc} to PFG (turn-on) and to sink 250mA to GND (turn-off); it is suitable to drive the MOS of the PFC pre-regulator stage.
- **HED (Heat Driver):** it consists of a level shifter from 3.3V logic signal (HEI) to V_{cc} MOS driving level; the driver is able to source 30mA from V_{cc} to HEG and to sink 75mA to GND and it is suitable for the

filament heating when they are supplied by independent winding.

- *Bootstrap Circuit*: it generates the supply voltage for the high side Driver (HSD). This circuit sources current from Vcc to PIN HSB when LSG in ON. A patented integrated bootstrap section replaces an external bootstrap diode. This section together with a bootstrap capacitor provides the bootstrap voltage to drive the high side power MOSFET. This function is achieved using a high voltage DMOS driver which is driven synchronously with the low side external power MOSFET. For a safe operation, current flow between BOOT pin and Vcc is always inhibited, even though ZVS operation may not be ensured.

5.4 INTERNAL LOGIC, OVER CURRENT PROTECTION (OCP) AND INTERLOCKING FUNCTION.

The DIM (*Digital Input Monitor*) block manages the input signals delivered to the drivers ensuring that they are low during the described start-up procedure; the DIM block controls the L6382D behaviour during both save and operating modes.

When the voltage on pin CSI overcomes the internal reference of 0.5V (typ.) the block latches the fault condition: in this state the OCP block forces low both HSD and LSD signals while CSO will be forced high. This condition remains latched until LSI and HSI are simultaneously low and CSI is below 0.5V. This function is suitable to implement an over current protection or hard-switching detection by using an external sense resistor.

As the voltage on pin CSI can go negative, the current must be limited below 2mA by external components.

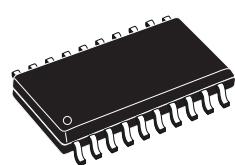
Another feature of the DIM block is the **internal interlocking** that avoids cross-conduction in the half-bridge FET's: if by chance both HGI and LGI input's are brought high at the same time, then LSG and HSG are forced low as long as this critical condition persists.

Figure 7. SO20 Mechanical Data & Package Dimensions

DIM.	mm			inch		
	MIN.	TYP.	MAX.	MIN.	TYP.	MAX.
A	2.35		2.65	0.093		0.104
A1	0.10		0.30	0.004		0.012
B	0.33		0.51	0.013		0.200
C	0.23		0.32	0.009		0.013
D ⁽¹⁾	12.60		13.00	0.496		0.512
E	7.40		7.60	0.291		0.299
e		1.27			0.050	
H	10.0		10.65	0.394		0.419
h	0.25		0.75	0.010		0.030
L	0.40		1.27	0.016		0.050
k	0° (min.), 8° (max.)					
ddd			0.10			0.004

(1) "D" dimension does not include mold flash, protusions or gate burrs. Mold flash, protusions or gate burrs shall not exceed 0.15mm per side.

OUTLINE AND MECHANICAL DATA



SO20

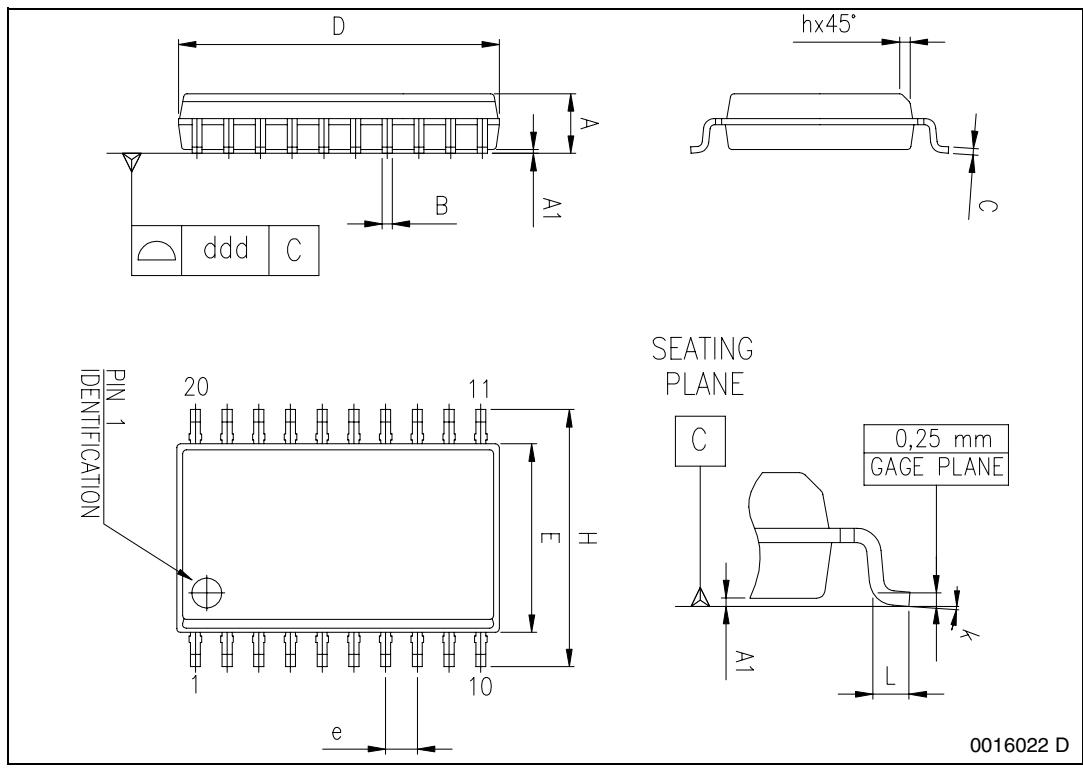


Table 6. Revision History

Date	Revision	Description of Changes
November 2004	1	First Issue
January 2005	2	Changed from "Preliminary Data" to "Final Datasheet".

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