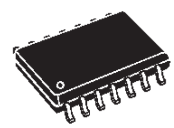
# L6567

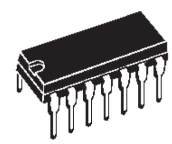
## HIGH VOLTAGE DRIVER FOR CFL

- BCD-OFF LINE TECHNOLOGY
- FLOATING SUPPLY VOLTAGE UP TO 570V
- GND REFERRED SUPPLY VOLTAGE UP TO 18V
- UNDER VOLTAGE LOCK OUT
- CLAMPING ON Vs
- DRIVER CURRENT CAPABILITY:
  30mA SOURCE
  70mA SINK
- PREHEAT AND FREQUENCY SHIFT TIMING

**MULTIPOWER BCD TECHNOLOGY**



**SO14**



**DIP14**

**ORDERING NUMBERS:**
L6567D L6567

### DESCRIPTION

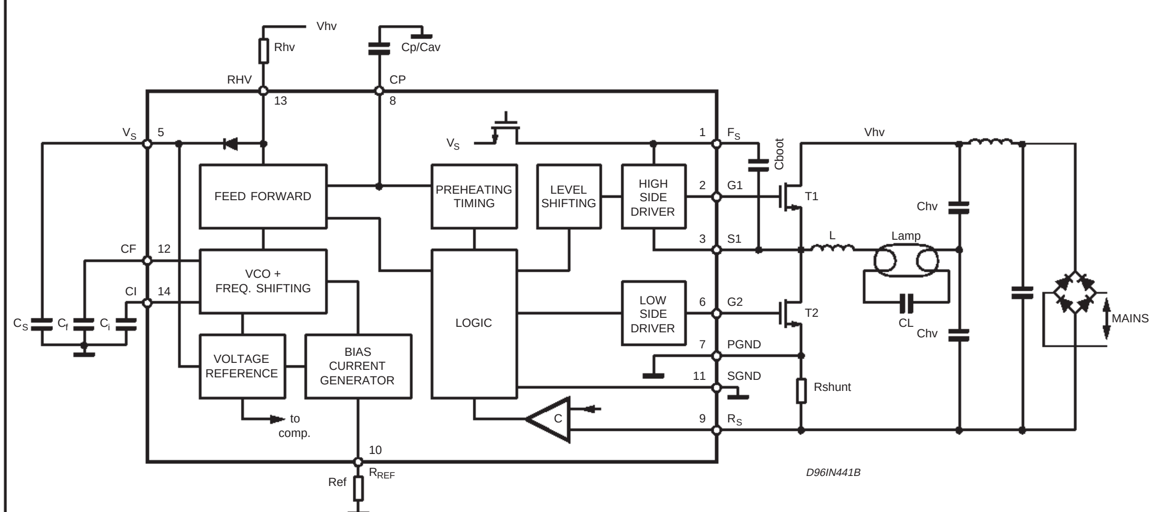
The device is a monolithic high voltage integrated circuit designed to drive CFL and small TL lamps with a minimum part count.

It provides all the necessary functions for proper preheat, ignition and steady state operation of the lamp:

- ♦ variable frequency oscillator;
- ♦ settable preheating and ignition time;
- ♦ capacitive mode protection;
- ♦ lamp power independent from mains voltage variation.

Besides the control functions, the IC provides the level shift and drive function for two external power MOS FETs in a half-bridge topology.

### BLOCK DIAGRAM



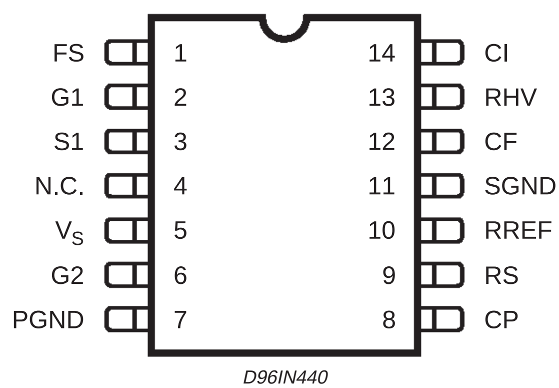



This is preliminary information on a new product now in development. Details are subject to change without notice.

## PIN FUNCTION

| N° | Pin | Description |
|---|---|---|
| 1 | $F_S$ | Floating Supply of high side driver |
| 2 | G1 | Gate of high side switch |
| 3 | S1 | Source of high side switch |
| 4 | NC | High Voltage Spacer. (Should be not connected) |
| 5 | $V_S$ | Supply Voltage for GND level control and drive |
| 6 | G2 | Gate of low side switch |
| 7 | PGND | Power Ground |
| 8 | CP | First timing (TPRE TIGN), then averaging the ripple in the representation of the HVB (derived through RHV). |
| 9 | $R_S$ | $R_{SHUNT}$: current monitoring input |
| 10 | $R_{REF}$ | Reference resistor for current setting |
| 11 | SGND | Signal Ground. Internally Connected to PGND |
| 12 | CF | Frequency setting capacitor |
| 13 | RHV | Start-up supply resistor, then supply voltage sensing. |
| 14 | CI | Timing capacitor for frequency shift |

## PIN CONNECTION (Top view)



## ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | Value | Unit |
|---|---|---|---|
| $V_S$ | Low Voltage Supply | 18 (1) | V |
| $V_{RHV}$ | Mains Voltage Sensing | VS +2VBE (2) | |
| $V_{CP}$ | Preheat/Averaging | 5 | V |
| $V_{CF}$ | Oscillator Capacitor Voltage | 5 | V |
| $V_{CI}$ | Frequency Shift Capacitor Voltage | 5 | V |
| $V_{RREF}$ | Reference Resistor Voltage | 5 | V |
| $V_{RS}$ | Current Sense Input Voltage | -5 to 5 | V |
| | transient 50ns | -15 | V |
| $V_{G2}$ | Low Side Switch Gate Output | 18 | V |
| $V_{S1}$ | High Side Switch Source Output: normal operation | -1 to 373 | V |
| | 0.5sec mains transient | -1 to 550 | V |
| VG1 | High Side Switch Gate Output: normal operation | -1 to 391 | V |
| | 0.5sec mains transient | -1 to 568 | V |
| | with respect to pin S1 | $V_{be}$ to $V_S$ | V |
| $V_{FS}$ | Floating Supply Voltage: normal operation | 391 | V |
| | 0.5sec mains transient | 568 | V |
| $V_{FS/S1}$ | Floating Supply vs S1 Voltage | 18 | V |
| $\Delta V_{FS}/\Delta T$ | VFS Slew Rate (Repetitive) | -4 to 4 | V/ns |
| $\Delta V_{S1}/\Delta T$ | VS1 Slew Rate (Repetitive) | -4 to 4 | V/ns |
| $I_{RHV}$ | Current Into $R_{HV}$ | 3 (3) | mA |
| $I_{VS}$ | Clamped Current into $V_S$ | 200 (4) | mA |
| $T_{stg}$ | Storage Temperature | -40 to 150 | °C |
| $T_j$ | Junction Temperature | -40 to 150 | °C |

NOTES: (1) Do not exceed package thermal dissipation limits
(2) For VS ≤ VS high 1
(3) For VS > VS high 1
(4) Internally Limited

Note: ESD immunity for pins 1, 2 and 3 is guaranteed up to 900 V (Human Body Model)

## ELECTRICAL CHARACTERISTCS

($V_S$ = 12V; $R_{REF}$ = 30KΩ; $C_F$ = 100pF; $T_j$ = 25°C; unless otherwise specified.)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| **$V_S$ - SUPPLY VOLTAGE SECTION** | | | | | | |
| $V_{S\ high\ 1}$ | $V_S$ Turn On Threshold | | 10.7 | 11.7 | 12.7 | V |
| $V_{S\ high2}$ | $V_S$ Clamping Voltage | VS = 20mA | 12 | 13 | 14 | V |
| $V_{S\ low\ 2}$ | $V_S$ Turn Off Threshold | | 9 | 10 | 11 | V |
| $V_{S\ HYST}$ | Supply Voltage Hysteresis | | 1.5 | 1.65 | 1.8 | V |
| $V_{S\ low\ 1}$ | $V_S$ Voltage to Guarantee $V_{G1}$ =”0”and $V_{G2}$ = ”1 | | 1 | | 6 | V |
| $I_{SSP}$ | $V_S$ Supply Current at Start Up | $V_S$ = 10.6V Before turn on | 50 | | 250 | mA |
| $I_{SOP}$ | $V_S$ Supply Operative Current | $V_S$ = VShigh 1 | | | 1.2 | mA |
| **OSCILLATOR SECTION** | | | | | | |
| $f_{osc\ min}$ | Minimum Oscillator frequency | $I_{RHV}$ = 0mA; CI = 5V | 41.7 | 43 | 44.29 | kHz |
| $f_{osc\ 600m}$ | Feed Forward Frequency | $I_{RHV}$ = 600mA | 47.88 | 50.4 | 52.92 | kHz |
| $f_{osc\ 1mA}$ | Feed Forward Frequency | $I_{RHV}$ = 1mA | 79.8 | 84 | 88.2 | kHz |
| fosc max | Maximum Oscillator Frequency | CI = 0V | 96.75 | 107.5 | 118.25 | KHz |
| $\Delta I_{CF}/\Delta V_{CI}$ | Oscillator Transconductance | | 9 | | 17.5 | µA/V |
| PREHEAT/IGNITION SECTION | | | | | | |
| P.H.T. | Preheat Time | Cp = 150nF | 0.88 | 1 | 1.12 | sec |
| P.H.clocks | Number of Preheat Clocks | | | 16 | | |
| IGN.clocks | Number of Ignition Clocks | | | 15 | | |
| **RATE OF FREQUENCY CHANGE SECTION** | | | | | | |
| ICIP charge | CI Charging Current During Preheat | | 106 | 118 | 130 | mA |
| ICII charge | CI Charging Current During Ignition | | 1 | 1.2 | 1.4 | mA |
| ICI disch | CI Discharge Current | | -52 | -47 | -42 | mA |
| $V_{TH\ CI}$ | CI Low Voltage Threshold | | 10 | | 100 | mV |
| **RS - THRESHOLD SECTION** | | | | | | |
| $V_{CMTH}$ | Capacitive Mode Voltage Threshold | | 0 | 20 | 40 | mV |
| $V_{PH}$ | Preheat Voltage Threshold | | -0.64 | -0.6 | -0.56 | V |
| **G1 - G2 DELAY TIMES SECTION** | | | | | | |
| $G1_{DON}$ | On Delay of G1 Output | | 1.05 | 1.4 | 1.75 | µs |

**ELECTRICAL CHARACTERISTCS** (Continued)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit |
|---|---|---|---|---|---|---|
| $G2_{DON}$ | On Delay of G2 Output | | 1.05 | 1.4 | 1.75 | µs |
| $\frac{G1_{DON} + G1_{ON}}{G2_{DON} + G2_{ON}}$ | Ratio between Delay Time + Conduction Time of G1 and G2 | $I_{RHV}$ = 1mA; Cl = 5V<br>Cl = 0V | 0.87<br>0.77 | | 1.15<br>1.30 | |
| **LOW SIDE DRIVER SECTION** | | | | | | |
| Ron G2 so | G2 Source Output Resistance | $V_S$ = 12V, V = 3V | 80 | | 190 | Ω |
| Ron G2 si | G2 Sink Output Resistance | $V_S$ = 12V, V = 3V | 65 | | 125 | Ω |
| Ron G1 so | G1 Source Output Resistance | $V_S$ = 10V, V = 3V | 80 | | 190 | Ω |
| Ron G1 si | G1 Sink Output Resistance | $V_S$ = 10V, V = 3V | 65 | | 125 | Ω |
| **HIGH SIDE DRIVER SECTION** | | | | | | |
| $I_{FSLK}$ | Leakage Current of FS PIN to GND | $V_{FS}$ = 568V; G1 = L<br>$V_{FS}$ = 568V; G1 = H | | | 5<br>5 | µA<br>µA |
| $I_{S1\ LK}$ | Leakage Current of S1 PIN to GND | $V_{S1}$ = 568V; G1 = L<br>$V_{S1}$ = 568V; G1 = H | | | 5<br>5 | µA<br>µA |
| **BOOTSTRAP SECTION** | | | | | | |
| Boot Th | BOOTSTRAP Threshold | $V_S$ = 10.6V before turn on | 5 (*) | | | V |
| **AVERAGE RESISTOR** | | | | | | |
| $R_{AVERAGE}$ | Average Resistor | | 27 | 38.5 | 50 | kΩ |

(*) Before starting the first commutation; when switching 6V is guaranteed.

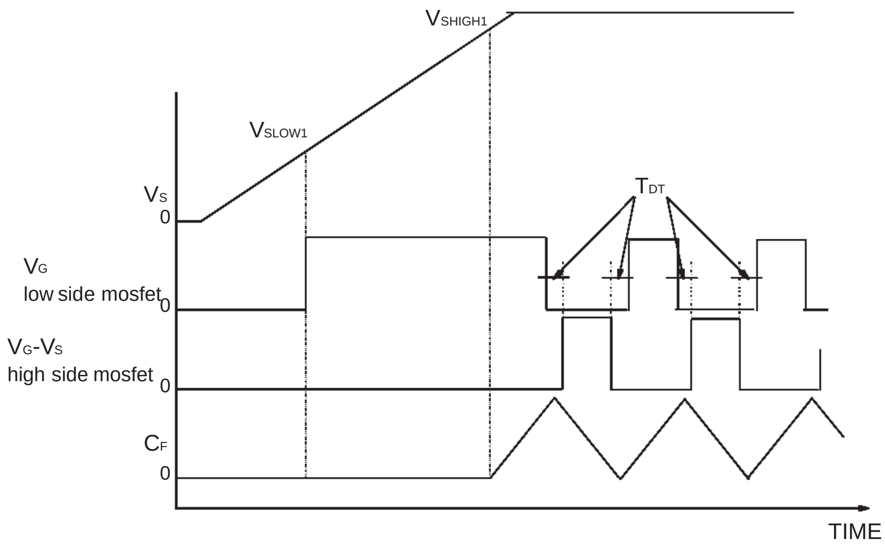
### General operation

The L6567 uses a small amount of current from a supply resistor(s) to start the operation of the IC. Once start up condition is achieved, the IC turns on the lower MOS transistor of the half bridge which allows the bootstrap capacitor to charge. Once this is achieved, the oscillator begins to turn on the upper and lower MOS transistors at high frequency, and immediately ramps down to a preheat frequency. During this stage, the IC preheats the lamp and after a predetermined time ramps down again until it reaches the final operating frequency. The IC monitors the current to determine if the circuit is operating in capacitive mode. If capacitive switching is detected, the IC increases the output frequency until zero-voltage switching is resumed.

### Startup and supply in normal operation

At start up the L6567 is powered via a resistor connected to the $R_{HV}$ pin (pin 13) from the rectified mains. The current charges the $C_S$ capacitor connected to the $V_S$ pin (pin 5). When the $V_S$ voltage reaches the threshold $V_{S\ LOW1}$ (max 6V), the low side MOS transistor is turned on while the high side one is kept off. This condition assures that the bootstrap capacitor is charged. When $V_{S\ HIGH1}$ threshold is reached the oscillator starts, and the $R_{HV}$ pin does not provide anymore the supply current for the IC (see fig.1).

**Figure 1. Start up**




### Oscillator

The circuit starts oscillating when the voltage supply $V_S$ has reached the $V_{S\ HIGH1}$ threshold. In steady state condition the oscillator capacitor $C_F$ (at pin 12) is charged and discharged symmetrically with a current set mainly by the external resistor $R_{REF}$ connected to pin 10. The value of the frequency is determined by capacitor $C_F$ and resistor $R_{REF}$. This fixed value is called $F_{MIN}$. A dead time $T_{DT}$ between the ON phases of the transistors is provided for avoiding cross conduction, so the duty cycle for each is less than 50%. The dead time depends on $R_{REF}$ value (fig. 7).

The IC oscillating frequency is between $F_{MIN}$ and $F_{MAX} = 2.5 \cdot F_{MIN}$ in all conditions.

### Preheating mode

The oscillator starts switching at the maximum frequency $F_{MAX}$. Then the frequency decreases at once to reach the programmed preheating frequency (fig.2). The rate of decreasing (df/dt) is determined by the external capacitor $C_I$ (pin 14). The preheat time $T_{PRE}$ is adjustable with external components ($R_{REF}$ and $C_P$). The preheat current is adjusted by sense resistance $R_{SHUNT}$. During the preheating time the load current is sensed with the sense resistor $R_{SHUNT}$ (connected between pin 9-$R_S$- and pin 7-PGND-). At pin 9 the voltage drop on $R_{SHUNT}$ is sensed at the moment the low side MOS FET is turned off. There is an internal comparator with a fixed threshold $V_{PH}$: if $V_{RS} > V_{PH}$ the frequency is decreased and if $V_{RS} < V_{PH}$ the frequency is increased. If the $V_{PH}$ threshold is reached, the frequency is held constant for the programmed preheating time $T_{PRE}$.

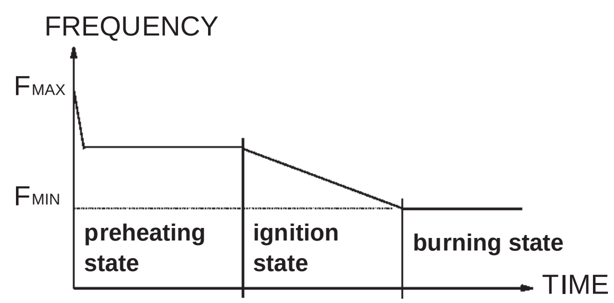
$T_{PRE}$ is determined by the external capacitor $C_P$ (pin8) and by the resistor $R_{REF}$: $C_P$ is charged 16 times with a current that depends on $R_{REF}$, and these 16 cycles determine the $T_{PRE}$.

So the preheat mode is programmable with external components as far as $T_{PRE}$ is concerned ($R_{REF}$ &$C_P$) and as far as the preheating current is concerned (choosing properly $R_{SHUNT}$ and the resonant load components: L and $C_L$).

The circuit is held in the preheating mode when pin 8 ($C_P$) is grounded.

In case $F_{MIN}$ is reached during preheat, the IC assumes an open load. Consequently the oscillation stops with the low side MOS transistor gate on and the high side gate off. This condition is kept until $V_S$ undershoots $V_{S\ LOW1}$.

**Figure 2. Preheating and ignition state.**




### Ignition mode

At the end of the preheat phase the frequency decreses to the minimum frequency ($F_{MIN}$), causing an increased coil current and a high voltage appearing across the lamp. That is because the circuit works near resonance. This high voltage normally ignites the lamp. There is no protection to avoid high ignition currents through the MOS transistors when the lamp doesn't ignite. This only occurs in an end of lamp life situation in which the circuit may break. Now the lowest frequency is the resonance frequency of L and $C_L$ (the capacitor across the lamp).

The ignition phase finishes when the frequency reaches $F_{MIN}$ or (at maximum) when the ignition time has elapsed. The ignition time is related to $T_{PRE}$: $T_{IGN} = (15/16) \cdot T_{PRE}$. The $C_P$ capacitor is charged 15 times with the same current used to charge it during $T_{PRE}$.

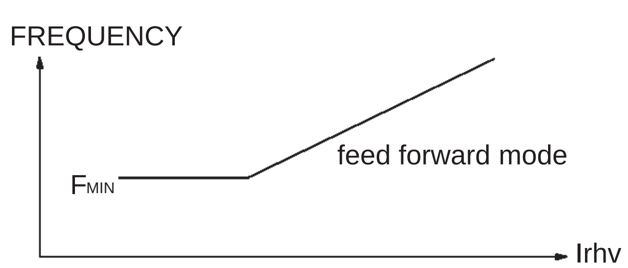
The frequency shifting slope is determined by $C_I$.

During the ignition time the $V_{RS}$ monitoring function changes in the capacitive mode protection.

### Steady state operation: feed forward frequency

The lamp starts operating at $F_{MIN}$, determined by $R_{REF}$ and $C_F$ directly after the ignition phase. To prevent too high lamp power at high mains voltages, a feed forward correction is implemented. At the end of the preheat phase the $R_{HV}$ pin is connected to an internal resistor to sense the High Voltage Bus. If the current in this resistor increases and overcomes a value set by $R_{REF}$ , the current that charges the oscillator capacitor $C_F$ increases too. The effect is an increase in frequency limiting the power in the lamp. In order to prevent feed forward of the ripple of the $V_{HV}$ voltage, the ripple is filtered with capacitor $C_P$ on pin 8 and an integrated resistor $R_{AVERAGE}$.

**Figure 3. Burn state**



### Capacitive mode protection

During ignition and steady state the operating frequency is higher than the resonance frequency of the load ($L, C_L, R_{LAMP}$ and $R_{FILAMENT}$), so the transistors are turned on during the conduction time of the body diode in order to maintain Zero Voltage Switching.

If the operating frequency undershoots the resonance frequency ZVS doesn't occur and causes hard switching of the MOS transistors. The L6567 detects this situation by measuring $V_{RS}$ when the low side MOS FET is turned on. At pin 9 there is an internal comparator with threshold $V_{CM\ TH}$ (typ~20mV): if $V_{RS} < V_{CM\ TH}$ capacitive mode is assumed and the frequency is increased as long as this situation is present. The shift is determined by CI.

### Steady state frequency

At any time during steady state the frequency is determined by the maximum on the following three frequencies:

$$f_{STEADY\ STATE} = MAX\{F_{MIN}, f_{FEED\ FORWARD}, f_{CAPACITIVE\ MODE\ PROTECTION}\}.$$

### IC supply

At start up the IC is supplied with a current that flows through $R_{HV}$ and an internal diode to the $V_S$ pin which-charges the external capacitor $C_S$. In steady state condition $R_{HV}$ is used as a mains voltage sensor, so it doesn't provide anymore the supply current. The easiest way to charge the $C_S$ capacitor (and to supply the IC) is to use a charge pump from the middle point of the half bridge.

To guarantee a minimum gate power MOS drive, the IC stops oscillating when $V_S$ is lower than $V_{S\ HIGH2}$. It will restart once the $V_S$ will become higher than $V_{S\ HIGH1}$. A minimum voltage hysteresis is guaranteed. The IC restarts operating at $f = F_{MAX}$ ,then the frequency shifts towards $F_{MIN}$. The timing of this frequency shifting is $T_{IGN}$ (that is: $C_P$ capacitor is charged and discharged 15 times).Now the oscillator frequency is controlled as in standard burning condition (feed forward and capacitive mode control). Excess charge on $C_S$ is drained by an internal clamp that turns on at voltage $V_{S\ CL}$ .

### Ground pins

Pin 7(PGND) is the ground reference of the IC with respect to the application. Pin 11( SGND) provides a local signal ground reference for the components connected to the pins $C_P$, $C_I$, $R_{REF}$ and $C_F$.

### Relationship between external components and sistem working condition

L6567 is designed to drive CFL and TL lamps with a minimum part count topology. This feature implies that each external component is related to one or more circuit operating state.

This table is a short summary of these relationships:

$F_{MIN}$ ---> $R_{REF}$ & $C_F$

$F_{FEED\ FORWARD}$ ---> $C_F$ & $I_{RHV}$

$T_{PRE}$ & $T_{IGN}$ ---> $C_P$ & $R_{REF}$

$F_{PRE}$ ---> $R_{SHUNT}$, L, $C_L$, LAMP

$T_{DT}$ ---> $R_{REF}$

df/dt ---> $C_I$

Some useful formulas can well approximate the values:

$$F_{MIN} \cong \frac{1}{8 \cdot R_{REF} \cdot C_F}$$

If $I_{RHV}$ is greater than: $I_{RHV} \geq \frac{15}{R_{REF}}$ , the feed forward frequency is settled and the frequency value is fitted by the following expression:

$$F_{FEEDFORWARD} \cong \frac{I_{RHV}}{121 \cdot C_F}$$

Other easy formulas fit rather well:

$T_{DT} \cong 46.75 \cdot 10^{\wedge-12} \cdot R_{REF}$

$T_{PRE} \cong 224 \cdot C_P \cdot R_{REF}$

As far as df/dt is concerned, there are no easy formulas that fit the relation between $C_F$, $R_F$, and $C_I$. $C_I$ is charged and discharged by three different currents that are derived from different mirroring ratios by the current flowing on $R_{REF}$. The voltage variations on $C_I$ are proportional to the current that charges $C_F$, that is to say they are proportional to df/dt.

The values obtained in the testing conditions ($C_I$ = 100nF) are:

during preheating and working conditions the typical frequency increase is ~ 20KHz/ms, the typical decrease is ~-10Khz/ms;

During ignition the frequency variation is ~ -200Hz/ms.

If slower variations are needed, CI has to be increased.

Due to these tight relationships, it is recommended to follow a precise procedure: first $R_{HV}$ has to be chosen looking at startup current needs and dissipation problems. Then the feed forward frequency range has to be determined, and so $C_F$ is set.

Given a certain $C_F$, $R_{REF}$ is set in order to fix $F_{MIN}$. Now $C_P$ can be chosed to set the desired $T_{PRE}$ and $T_{IGN}$.

The other external parameters ($R_{SHUNT}$ and $C_I$) can be chosen at the end because they are just related to a single circuit parameters.

**Figure 4. IC Operation**

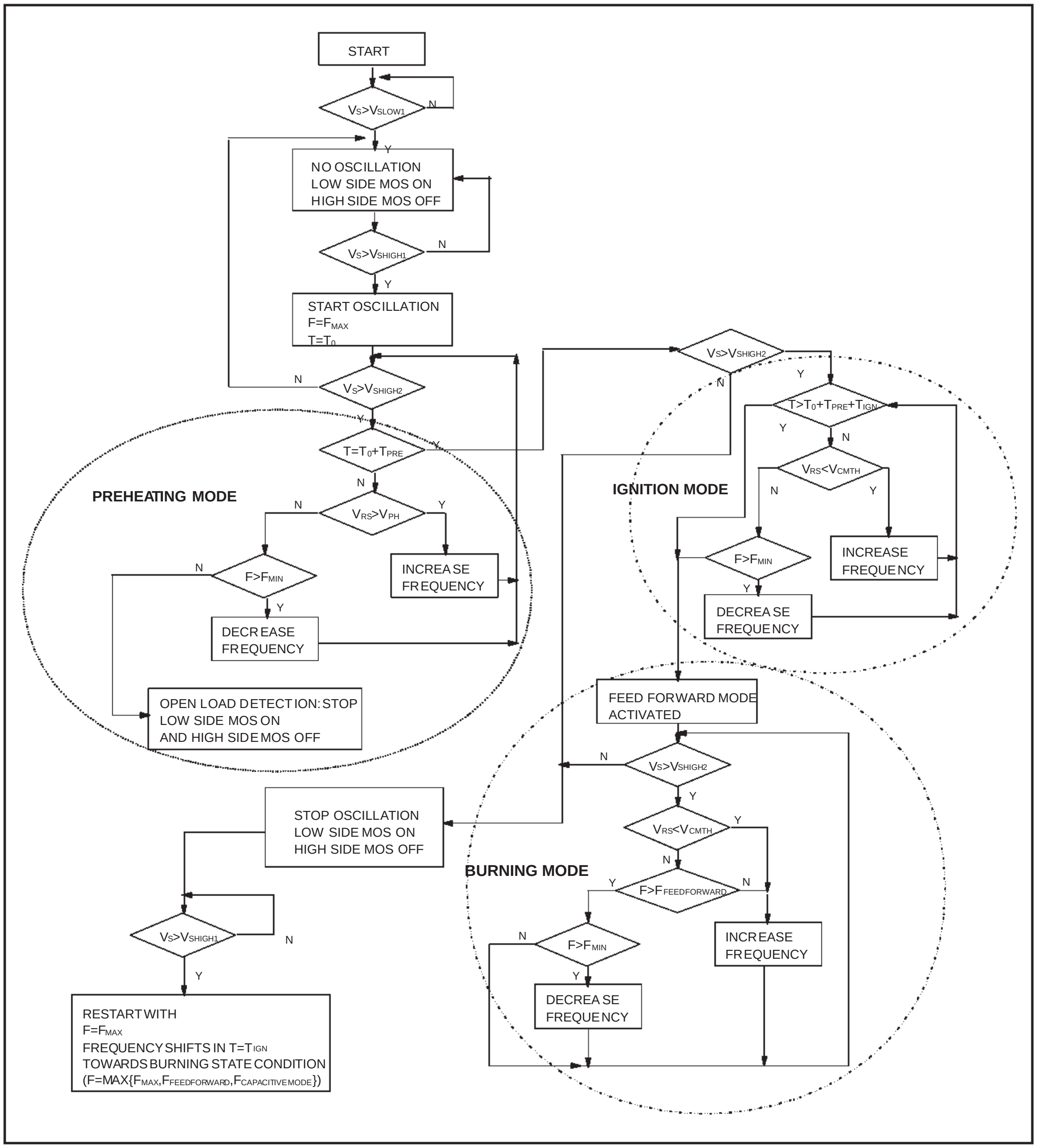


**Figure 5. Working frequency vs $I_{RHV}$ @ $R_{REF}$ = 30Kohm**

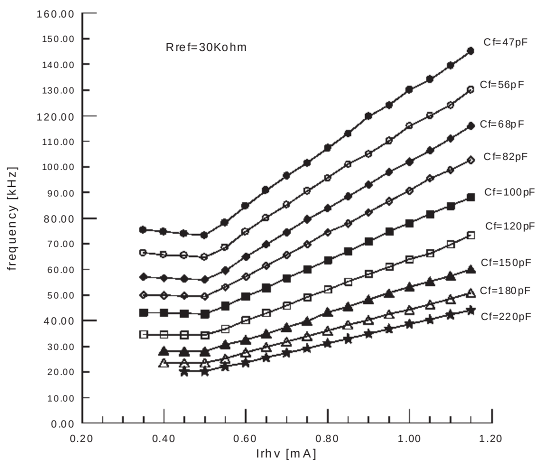



**Figure 6. Frequency vs $C_F$ @ $R_{REF}$=30Kohm**

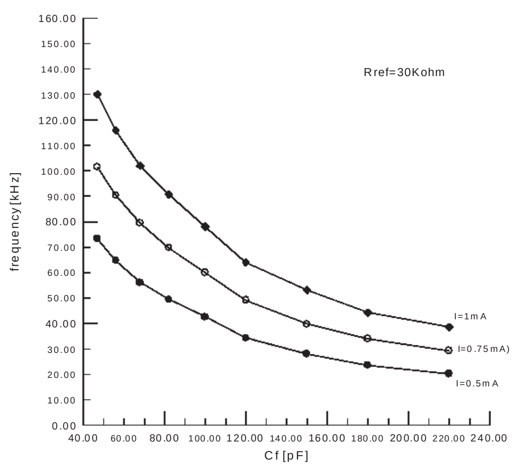



**Figure 7. $T_{DT}$ vs $R_{REF}$ @ $C_F$ = 100pF**

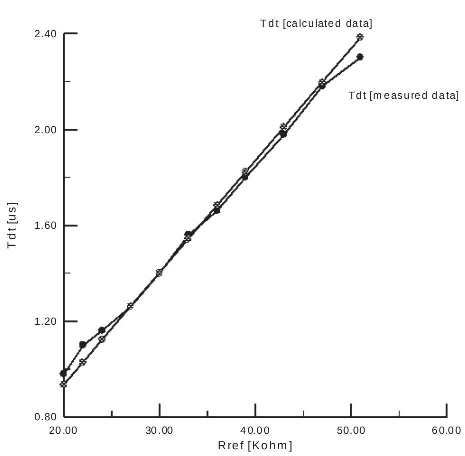



**Figure 8. Frequency vs $I_{RHV}$ @ $C_F$ = 82pF**

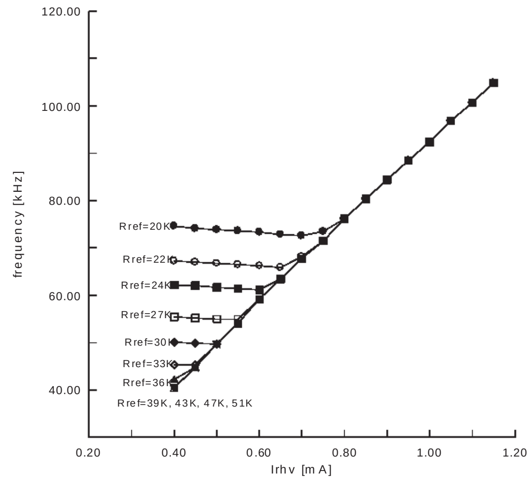



**Figure 9. Frequency vs $I_{RHV}$ @ $C_F$=100pF**

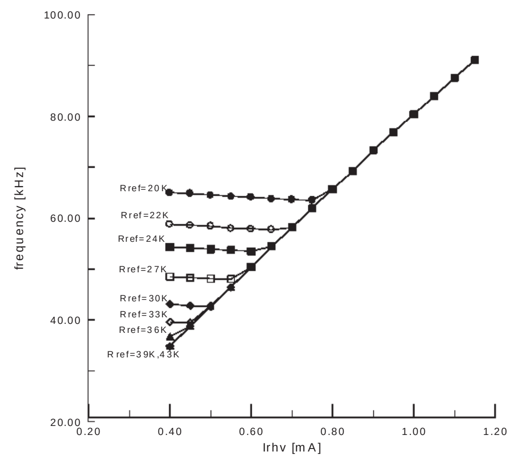



**Figure 10. Frequency vs $I_{RHV}$ @ $C_F$=120pF**

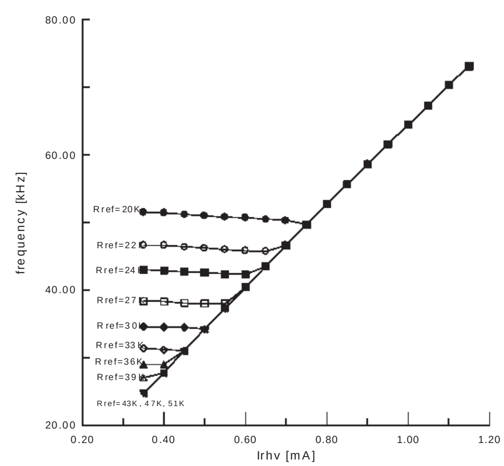


**Figure 11. Frequency vs $I_{RHV}$ @ $C_F$= 150pF**

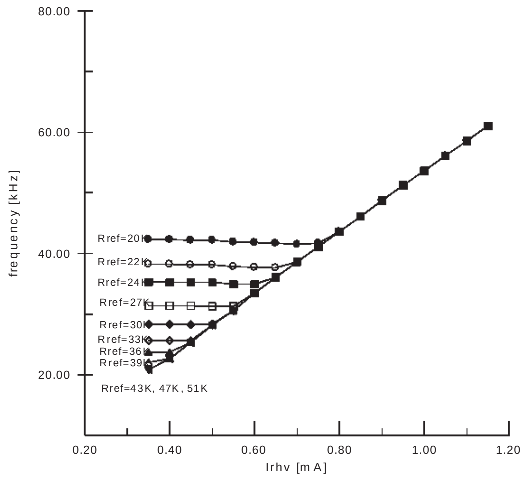



**Figure 13. $F_{FEED\ FORWARD}$: measurements and calculations**

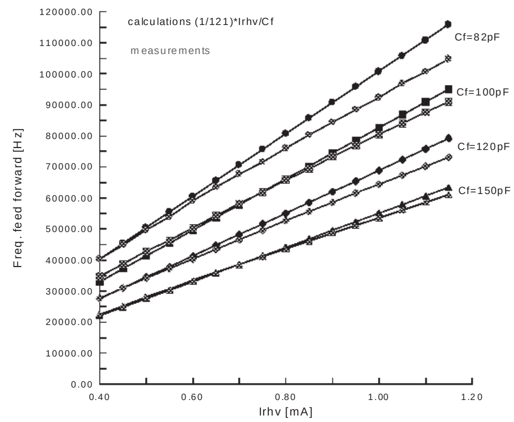
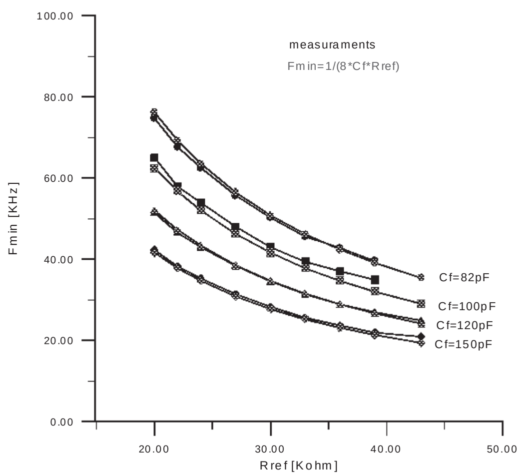
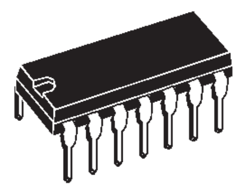



**Figure 12. $F_{MIN}$: measurements and calculations**



| DIM. | mm | | | inch | | |
|---|---|---|---|---|---|---|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| a1 | 0.51 | | | 0.020 | | |
| B | 1.39 | | 1.65 | 0.055 | | 0.065 |
| b | | 0.5 | | | 0.020 | |
| b1 | | 0.25 | | | 0.010 | |
| D | | | 20 | | | 0.787 |
| E | | 8.5 | | | 0.335 | |
| e | | 2.54 | | | 0.100 | |
| e3 | | 15.24 | | | 0.600 | |
| F | | | 7.1 | | | 0.280 |
| I | | | 5.1 | | | 0.201 |
| L | | 3.3 | | | 0.130 | |
| Z | 1.27 | | 2.54 | 0.050 | | 0.100 |

## OUTLINE AND MECHANICAL DATA



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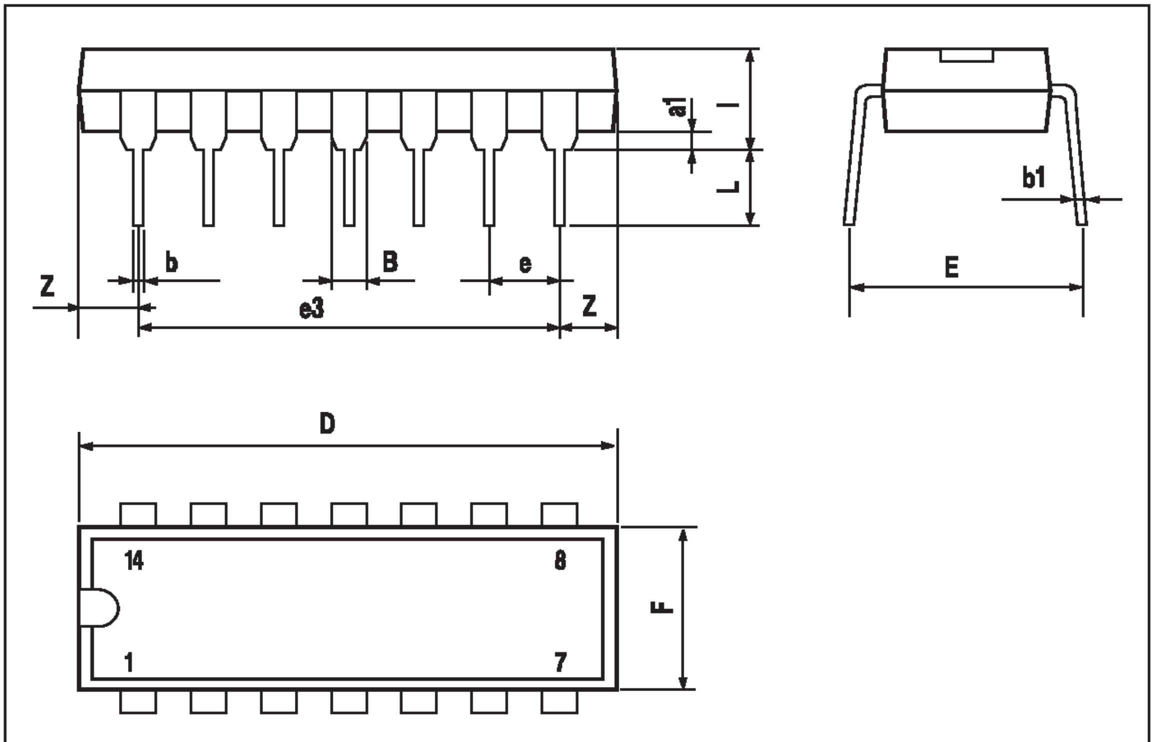
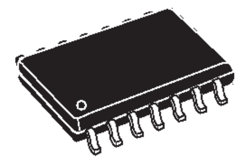


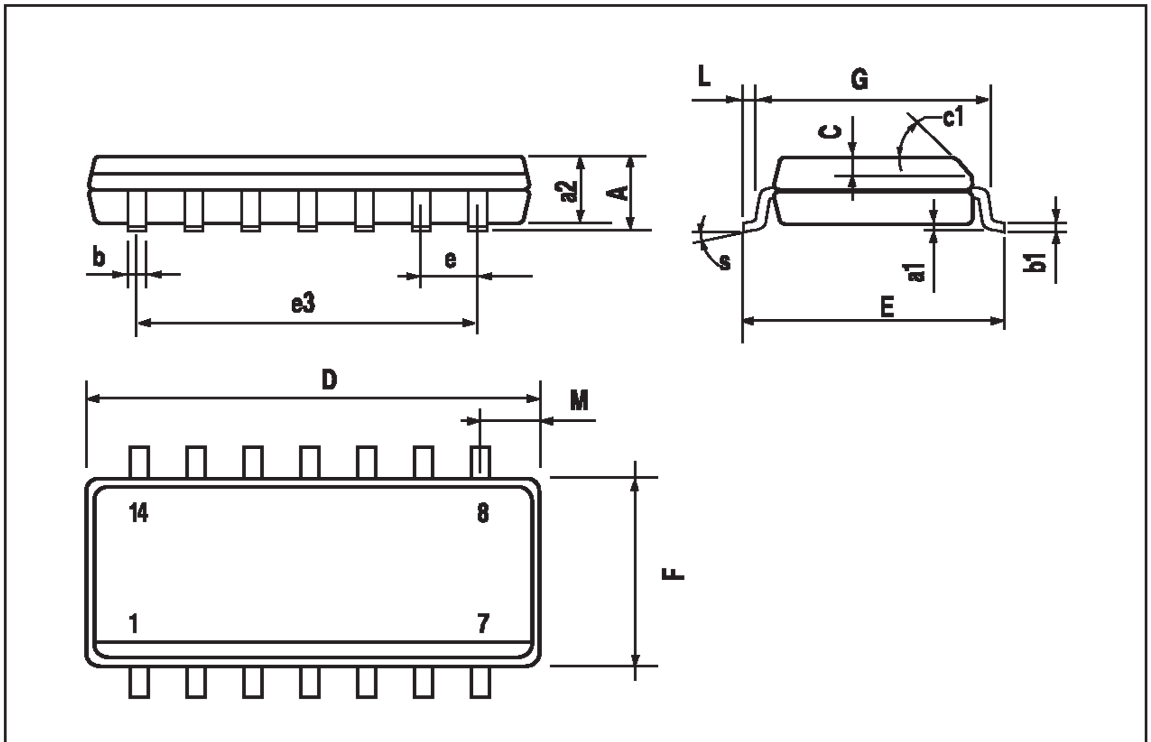
| DIM. | mm | | | inch | | |
|---|---|---|---|---|---|---|
| | MIN.. | TYP. | MAX.. | MIN.. | TYP.. | MAX.. |
| A | | | 1.75 | | | 0.069 |
| a1 | 0.1 | | 0.25 | 0.004 | | 0.009 |
| a2 | | | 1.6 | | | 0.063 |
| b | 0.35 | | 0.46 | 0.014 | | 0.018 |
| b1 | 0.19 | | 0.25 | 0.007 | | 0.010 |
| C | | 0.5 | | | 0.020 | |
| c1 | 45° (typ.) | | | | | |
| D (1) | 8.55 | | 8.75 | 0.336 | | 0.344 |
| E | 5.8 | | 6.2 | 0.228 | | 0.244 |
| e | | 1.27 | | | 0.050 | |
| e3 | | 7.62 | | | 0.300 | |
| F (1) | 3.8 | | 4 | 0.150 | | 0.157 |
| G | 4.6 | | 5.3 | 0.181 | | 0.209 |
| L | 0.4 | | 1.27 | 0.016 | | 0.050 |
| M | | | 0.68 | | | 0.027 |
| S | 8° (max) | | | | | |

(1) D and F do not include mold flash or protrusions. Mold flash or potrusions shall not exceed 0.15mm (.006inch).

## OUTLINE AND MECHANICAL DATA



## SO14



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