

Intelligent CCFL Inverter Controller

FEATURES

- Supports wide-range voltage input applications (8v to 20v)
- Built-in intelligence to manage ignition and normal operation of CCFLs
- Reduces the number of components and board size by 30% compared with conventional designs
- 85% efficiency vs. typical 70% efficiency of conventional designs
- Zero-voltage-switching full bridge topology
- Built-in internal open-lamp and over-voltage protections
- Integrated burst mode control, and wide dimming range (10% to 100%) with integrated burst mode control
- Supports multiple CCFL lamps
- Simple and reliable 2-winding transformer design
- Constant-frequency design eliminates interference with LCDs
- Low stand-by power

quality waveform received, at the CCFL voltage and current.

The OZ960 operates at a single, constant frequency in a phase-shift PWM mode. Intelligent open-lamp and over-voltage protections provide design flexibility so various transformer models/manufacturers may be used. The built-in burst mode control provides a wide dimming range and simplifies the application circuit designs. Both operating and burst-mode frequencies are user-programmable parameters.

The single stage design results in a low cost, reliable transformer without expensive, less reliable secondary fold-back treatment. The transformer does not require a more expensive center tapped primary.

The OZ960 is available in a 20-pin SSOP package. It is specified over the commercial temperature range of 0°C to +70°C, and the industrial temperature range of -40°C to +85°C.

ORDERING INFORMATION

OZ960S - 20-pin plastic SSOP 150mil
OZ960IS - 20-pin plastic SSOP 150mil
OZ960G - 20-pin plastic SOP 300mil
OZ960IG - 20-pin plastic SOP 300mil
OZ960D - 20-pin plastic DIP 300mil
OZ960ID - 20-pin plastic DIP 300mil

GENERAL DESCRIPTION

The OZ960 is a unique, high-efficiency, Cold Cathode Fluorescent Lamp (CCFL) backlight inverter controller that is designed for wide input voltage inverter applications. Additionally, the OZ960 performs the lamp dimming function with an analog voltage or low frequency Pulse Width Modulation (PWM) control.

Operating Principle:

Operating in a zero-voltage switching, full-bridge configuration, the inverter circuit achieves a very high efficiency power conversion. In addition, the transformer in the OZ960 does not require any specific gap-less arrangement. The simple, low cost transformer provides designers a high degree of design flexibility in specifying transformers. Setting the switching frequency higher than the resonant frequency of a high-quality-factor resonant tank circuit yields a good-

FUNCTIONAL BLOCK DIAGRAM

Refer to the functional block diagram in Figure 2, page 3, and the Pin Description Table on page 4.

A precision reference provides a reference voltage for both internal and external uses. An oscillator circuit generates a user-programmable operating frequency with an external capacitor and a timing resistor. In addition, another resistor to program striking frequency is provided. The drive circuit consists of four outputs. These are designed to achieve zero-voltage switching, full-bridge applications. An error amplifier is provided to regulate the CCFL current. The Soft-start circuit offers a gradual increase of the power to the CCFL during the ignition period. The over-voltage protection block offers a regulated striking voltage for CCFLs. The striking time is programmable simply through an external component. The open-lamp protection is integrated in the protection block. This block intelligently differentiates the striking condition and open-lamp condition. ENA circuitry enables the operation of the IC through a TTL signal interface. Wide-dimming control is achieved through the burst-mode control block.

TYPICAL APPLICATION CIRCUIT

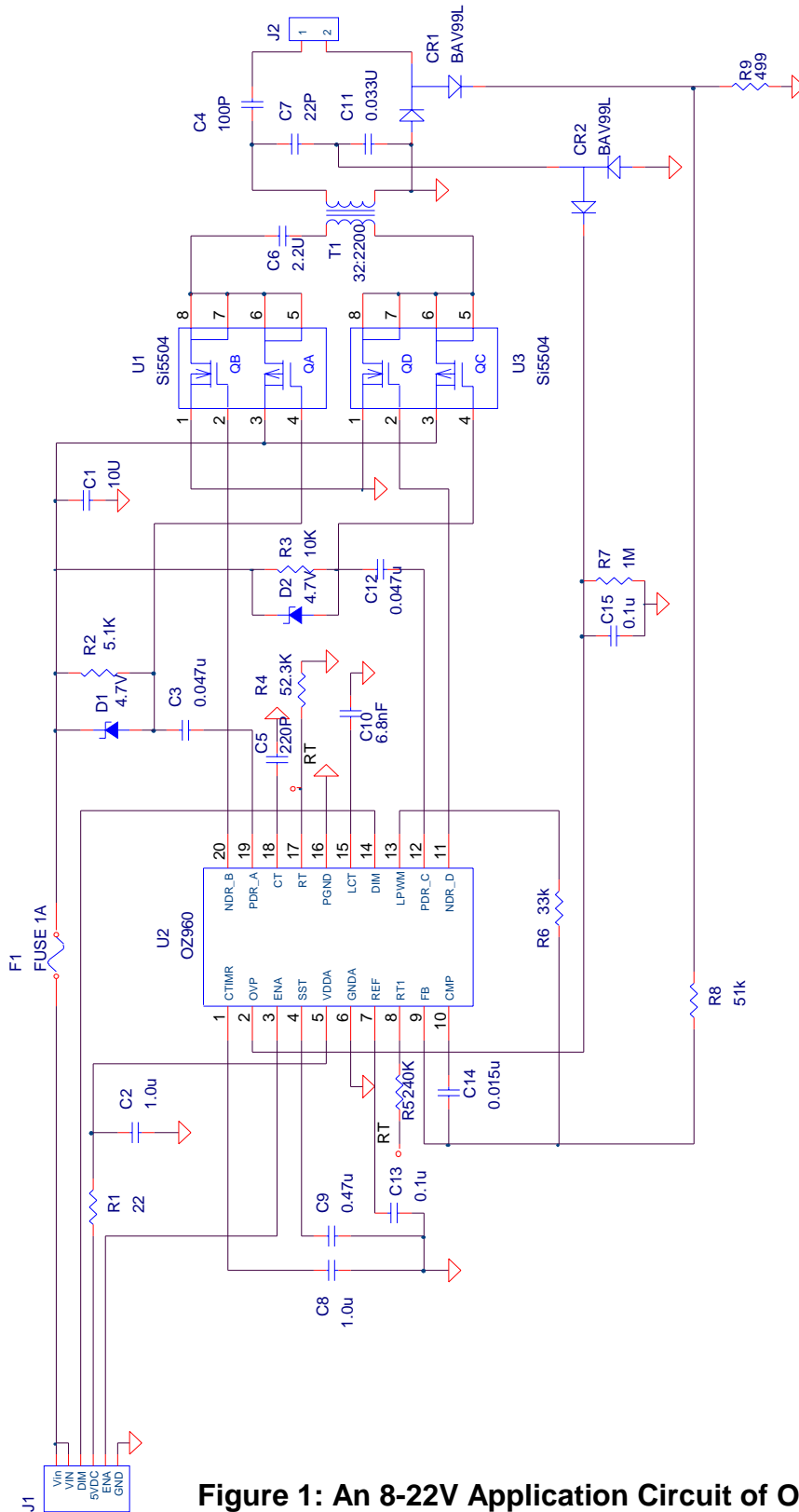


Figure 1: An 8-22V Application Circuit of OZ960

VIN: 8.0V--22V
 ENA: 0V--1.0V Disable; 2.0V--3.3V Enable
 DIM: 3V Max. Brightness; 1.2V Min. Brightness
 Striking frequency: 74KHz - 82KHz
 Operating frequency: 56KHz - 64KHz

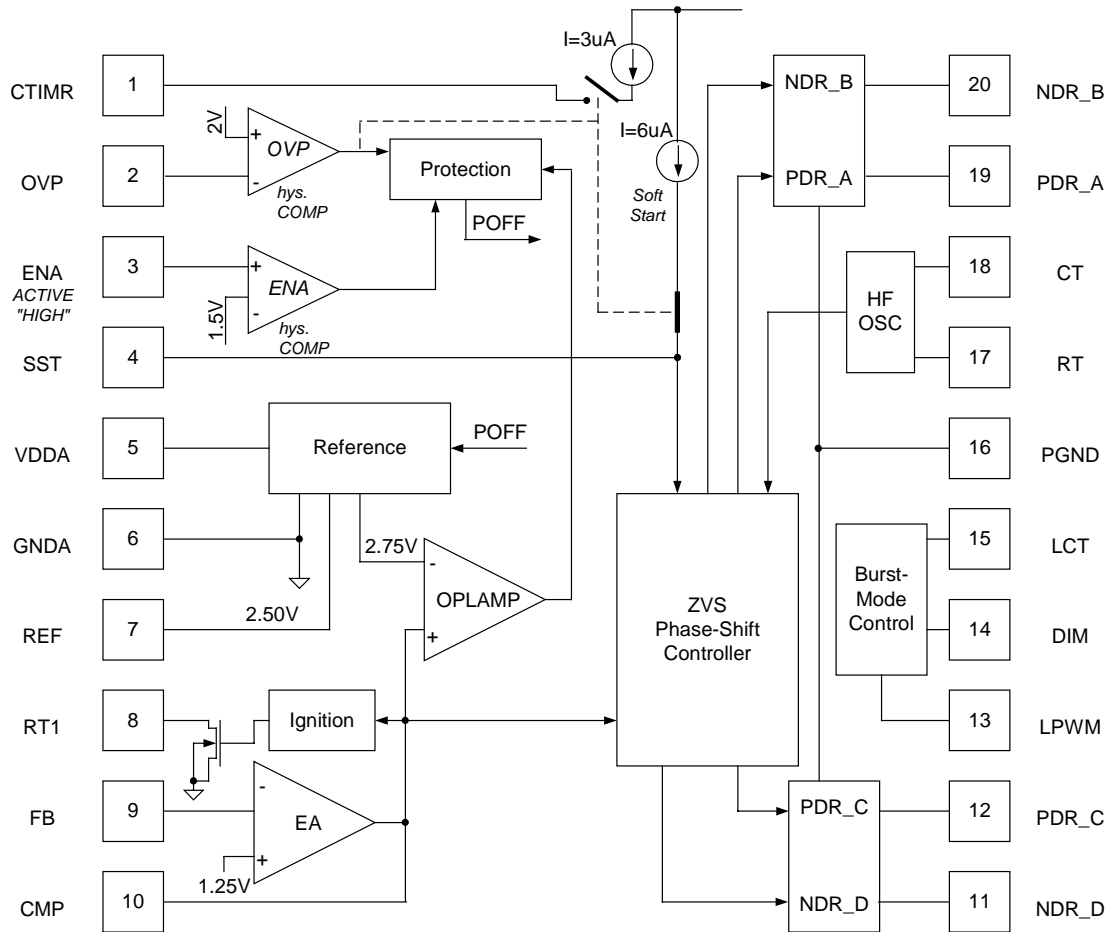


Figure 2. Functional Block Diagram

PIN DESCRIPTION

| Names | Pin No. | I/O | Description |
|-------|---------|-----|---|
| CTIMR | 1 | I | Capacitor for CCFL ignition duration |
| OVP | 2 | I | Output voltage sense $V_{th}=2.0V$ |
| ENA | 3 | I | Enable input; TTL signal is applicable |
| SST | 4 | I | Soft-start capacitor |
| VDDA | 5 | I | Voltage source for the IC |
| GND A | 6 | I | Analog signal ground reference |
| REF | 7 | O | Reference voltage output; 2.5V typical |
| RT1 | 8 | I | Resistor for programming ignition frequency |
| FB | 9 | I | CCFL current feedback signal |
| CMP | 10 | O | Compensation output of the current error amplifier |
| NDR_D | 11 | O | NMOSFET drive output |
| PDR_C | 12 | O | PMOSFET drive output |
| LPWM | 13 | O | Low-frequency PWM signal for burst-mode dimming control |
| DIM | 14 | I | Input analog signal for burst-mode dimming control |
| LCT | 15 | I | Triangular wave for burst-mode dimming; frequency |
| PGND | 16 | I | Power ground reference |
| RT | 17 | I | Timing resistor set operating frequency |
| CT | 18 | I | Timing capacitor set operating frequency |
| PDR_A | 19 | O | PMOSFET drive output |
| NDR_B | 20 | O | NMOSFET drive output |

ABSOLUTE MAXIMUM RATINGS WITH RESPECT TO INPUT POWER SOURCE RETURN REFERENCE

| | | |
|--------------|--|---------------------|
| VDDA | | 7.0V ⁽¹⁾ |
| GND A, PGND | | +/- 0.3V |
| Logic inputs | | -0.3V to VDD +0.3V |

| | OZ960 | OZ960I |
|-----------------|-------------|---------------|
| Operating temp. | 0°C to 70°C | -40°C to 85°C |

| | | |
|--------------------------|--|------------------|
| Operating junction temp. | | 150 °C |
| Storage temp. | | -55 °C to 150 °C |

RECOMMENDED OPERATING RANGE

| | | |
|------|--|-------------------|
| VDDA | | 4.7V ~ 5.5V |
| Fosc | | 30 KHz to 150 KHz |
| Rosc | | 50 k to 150 k |

Note ⁽¹⁾: The "Absolute Maximum Ratings" are those values beyond which the safety of the device cannot be guaranteed. The device should not be operated at these limits. The "Functional Specifications" table will define the conditions for actual device operation. Exposure to absolute maximum rated conditions for extended periods may affect device reliability.

FUNCTIONAL SPECIFICATIONS

| Parameter | Symbol | Test Conditions | Limits | | | Unit |
|---|------------------|--|---------------------|------|----------|--------|
| | | | Min | Typ | Max | |
| VDDA=5V; Tamb = 25°C | | | Min | Typ | Max | |
| Reference Voltage | | | | | | |
| Nominal voltage | Vref | I _{load} = 0.1mA | 2.37 | 2.5 | 2.63 | V |
| Line regulation | | VDDA = 4.7V – 5.3V | - | 4 | - | mV/V |
| Load regulation | | I _{load} = 0.025 mA to 0.25 mA | - | 2 | - | mV/mA |
| High Frequency Oscillator | | | | | | |
| Initial accuracy | fosc | CT = 100pF, RT = 120k ⁽¹⁾ | 53 | 57 | 60 | KHz |
| Ramp peak | | | - | 3.0 | - | V |
| Ramp valley | | | - | 1.0 | - | V |
| Temp. stability | | TA = 0 °C to 70°C | - | 200 | - | ppm/°C |
| Low Frequency Oscillator | | | | | | |
| Initial accuracy | | | See Table 1, page 6 | | | |
| Ramp peak | | | 2.85 | 3.0 | 3.15 | V |
| Ramp valley | | | 0.94 | 1.0 | 1.06 | V |
| Low Frequency PWM | | | | | | |
| Duty Cycle Range | | | 0 | - | 100 | % |
| Error Amplifier | | | | | | |
| Input offset voltage | | | - | 7 | - | mV |
| Input voltage range | | | 0 | - | VDD-1.5V | V |
| Offset current at FB pin | | | - | - | 100 | nA |
| Reference voltage at non-inverting input pin (internal) | V _{ADJ} | | 1.19 | 1.25 | 1.31 | V |
| Open loop voltage gain | | | - | 80 | - | dB |
| Unity gain bandwidth | | | - | 1.0 | - | MHz |
| Power supply rejection | | | - | 60 | - | dB |
| Threshold | | | | | | |
| Over Voltage Protection | | | 1.90 | 2 | 2.15 | V |
| Supply | | | | | | |
| Supply current | I _{OFF} | ENA = low | - | 150 | 200 | µA |
| Supply current | I _{ON} | ENA = high; VDDA = 5V; Vdim = 2V; LPWM = 50k ⁽²⁾ Ca=Cb=Cc=Cd=2nF ⁽³⁾ HF = 60kHz; LF = 185Hz | - | 4.4 | 5.5 | mA |
| SST current | | | See Table 1, page 6 | | | |
| CTIMR current | | | See Table 1, page 6 | | | |
| NDR-PDR Output | | | | | | |
| Output resistance | Rp | Current source | - | 27 | - | Ω |
| Output resistance | Rn | Current sink | - | 14 | - | Ω |

| Parameter | Symbol | Test Conditions | Limits | | | Unit |
|--|--------|--|--------------------|-----|-----|------|
| Max. / Min. Overlap | | | | | | |
| | | VDDA = 5V; Tamb = 25°C | Min | Typ | Max | |
| Min. Overlap between diagonal switches | | HF = 60kHz Ca=Cb=Cc=Cd=2nF ⁽³⁾ | 3.0 | 4.5 | 5.5 | % |
| Max. Overlap between diagonal switches | | HF = 60kHz Ca=Cb=Cc=Cd=2nF ⁽³⁾ | 78 | 81 | 84 | % |
| Brake before Make | | | | | | |
| PDR_A / NDR_B | | | See Table 1, below | | | |
| PDR_C / NDR_D | | | See Table 1, below | | | |

| | | OZ960 | | | | | OZ960I | | | |
|---------------------------------|--------------------|--|--------|------|------|------|--------|------|------|------|
| Parameter | Symbol | Test Conditions | Limits | | | Unit | Limits | | | Unit |
| | | | Min | Typ | Max | | Min | Typ | Max | |
| Low Frequency Oscillator | | | | | | | | | | |
| Initial accuracy | f _{osc} | LCT = 6.8nF, LPWM = 50k ⁽²⁾ | 160 | 220 | 250 | Hz | 150 | 220 | 340 | Hz |
| Supply | | | | | | | | | | |
| SST current | I _{SST} | | 4.9 | 7.5 | 10 | μA | 4.9 | 6.0 | 12 | μA |
| CTIMR current | I _{CTIMR} | | 2.2 | 3.3 | 4.5 | μA | 2.0 | 3.0 | 5.2 | μA |
| Brake before Make | | | | | | | | | | |
| PDR_A / NDR_B | | HF = 60kHz | 250 | 380 | 530 | ns | 250 | 380 | 565 | ns |
| PDR_C / NDR_D | | HF = 60kHz | 250 | 380 | 520 | ns | 250 | 380 | 545 | ns |
| Threshold | | | | | | | | | | |
| Enable | | | 1.35 | 1.50 | 1.65 | V | 1.25 | 1.50 | 1.65 | V |

Table 1. Low Frequency Oscillator, Supply and Brake before Make Specifications for OZ960 and OZ960I

Note ⁽¹⁾

CT: capacitor from CT (Pin 18) to ground
RT: resistor from RT (Pin 17) to ground

Note ⁽²⁾

LCT: capacitor from LCT (Pin 15) to ground
LPWM: resistor from LPWM (Pin 13) to ground

Note ⁽³⁾

Ca: capacitor from PDR_A (Pin 19) to VDDA
Cb: capacitor from NDR_B (Pin 20) to ground
Cc: capacitor from PDR_C (Pin 12) to VDDA
Cd: capacitor from NDR_D (Pin 11) to ground

FUNCTIONAL INFORMATION

1. Steady-State Operation

Refer to the schematic shown in Figure 1, the OZ960 drives a full-bridge power train where the transformer couples the energy from the power source to the secondary CCFL load. The switches in the bridge denoted as QA, QB, QC and QD are configured such that QA and QB, QC and QD are turned on complementarily. The duration of QA and QD, QB and QC turn on simultaneously determines an amount of energy put into the transformer which in turn delivers to the CCFL. The current in CCFL is sensed via resistor R9 and regulated through the adjustment of the turn-on time for both diagonal switches. This is accomplished through an error amplifier in the current feedback loop. A voltage loop is also established to monitor the output voltage so that a programmable striking voltage is achieved. The OVP represents the peak-detect signal of the voltage on the output of the transformer. A soft-start circuit ensures a gradual increase in the input and output power. The soft-start capacitor determines the rate of rise of the voltage on SST pin where the voltage level determines the on-time duration of QA and QD, QB and QC diagonal switches. This minimizes the surge impacts in circuit designs.

Apply enable signal to the ENA pin of the IC after the bias voltage applied to VDDA initiates the operation of the circuit. The output drives, include PDR_A, NDR_B, PDR_C and NDR_D put out a complementary square pulse. The frequency is determined by R4 and C5 where they are connected to RT and CT pins respectively. Initially, the energy converted from the power source to the CCFL is low due to the soft start function. It increases as soft start capacitor voltage increases linearly with time. The voltage at the secondary side of the transformer T1 increases correspondingly. This process continues until the CCFL current is detected and reaches a regulated value. The output of the error amplifier, CMP, follows the feedback signal, commands a proper switching among the four output drives to maintain current regulation. The operations of the four switches are implemented with zero-voltage-switching to provide a high-efficiency power conversion.

In the case of open-lamp condition, the OZ960 provides a programmable striking-frequency intelligence to optimize the ignition scheme. This is implemented through resistor R5. Effectively, R5 is in parallel with R4 to yield a required striking frequency. In addition, the striking time is also programmable through the capacitor C8. Striking voltage, or the open-lamp voltage, is

regulated through a voltage feedback loop where output voltage is monitored. The signal, being sent to the OVP pin, commands the output drives to provide the desired output voltage. This design provides high degree of flexibility while maintaining OZ960 a very high integration device.

One protection feature needed is removing the lamp during normal operation. The OZ960 senses the missing current signal through current amplifier, it shuts off the output drives and stay in the latched mode. This is differentiated intelligently with turning on the inverter while CCFL is not connected. Recycle of the IC power is necessary to resume normal operation.

Dimming control: dimming control of the inverter is implemented by adjusting the amount of energy processed and delivered to the CCFL. A PWM burst-mode scheme is internally generated which provides 0% to 100% wide dimming control. An input analog voltage signal is fed into DIM pin and determines the dimming level of the CCFL. The burst-mode frequency is programmable through a capacitor C10 as shown in the schematic.

The OZ960 inverter operates in a constant frequency mode. This eliminates any undesired interference between inverter and LCD panels where the interference is usually associated with variable-frequency designs.

Symmetrical drive to the power transformer gives a very dynamic choice of selecting transformers. This vulnerable design offers flexibility to the system designers to choose transformer sources. There is no limitation to the gap-less transformer.

2. CCFL Ignition Time

Ignition time for CCFLs varies with CCFL length, diameter, module package and temperature. The OZ960 provides a flexible design where a capacitor is connected to CTIMR pin to determine the necessary striking time. An approximate of the timing calculation is:

$$T[\text{second}] = C[\mu\text{F}]$$

This capacitor remains reset at no charge if lamp is connected and at normal operation.

3. Protection

Open-lamp protection in the ignition period is provided through both OVP and CTIMR to ensure a rated voltage is achieved and a required timing is satisfied. Removal of the CCFL during normal operation will trigger the current amplifier output and shuts off the inverter. This is a latch function.

4. OVP

The OVP threshold is set at 2V nominal. When the output voltage reaches the threshold, it commands the PWM controller to maintain the driving level. This ensures that output gets sufficient striking voltage while operating the power transformer safely.

5. ENA

Applying positive TTL logic to the ENA pin enables the operation of the IC. The threshold of the ENA is set at 1.5V. Apply logic low to the ENA pin will disable the operation of the inverter. Toggle this signal allows the on/off tests for the inverter.

6. Soft-Start -- SST

The soft-start function is provided with a capacitor connected to SST pin. The soft-start time is not related to the striking time for the CCFL. It simply provides a rate of rise for the pulse width where diagonal switches are turned on. Normally, a 0.47uF capacitor is connected.

7. Error Amplifier

The CCFL current is regulated through this error amplifier. It also provides an intelligence of differentiating open-lamp striking versus removing the lamp during normal operation. The non-inverting reference is at 1.25V nominal.

8. Operating frequency

A resistor RT and a capacitor CT determine the operating frequency of OZ960. The frequency is calculated as:

$$f[\text{kHz}] = \frac{68.5 \cdot 10^4}{C_T[\text{pF}] \cdot R_T[\text{k}\Omega]}$$

The OZ960 also provides an optional striking frequency as desired. CCFL in a LCD module possesses parasitic that may require different

striking voltage and frequency. This add-on feature could optimally accomplish the ignition process so that the CCFL life could be extended. When RT1 is used, it is connected in parallel with RT during the ignition period.

9. Burst-Mode Dimming Control

The OZ960 integrates a burst-mode dimming function to perform a wide dimming control for the CCFLs. The burst-mode frequency is determined by a capacitor C10 connected to LCT pin. The frequency can be calculated approximately by:

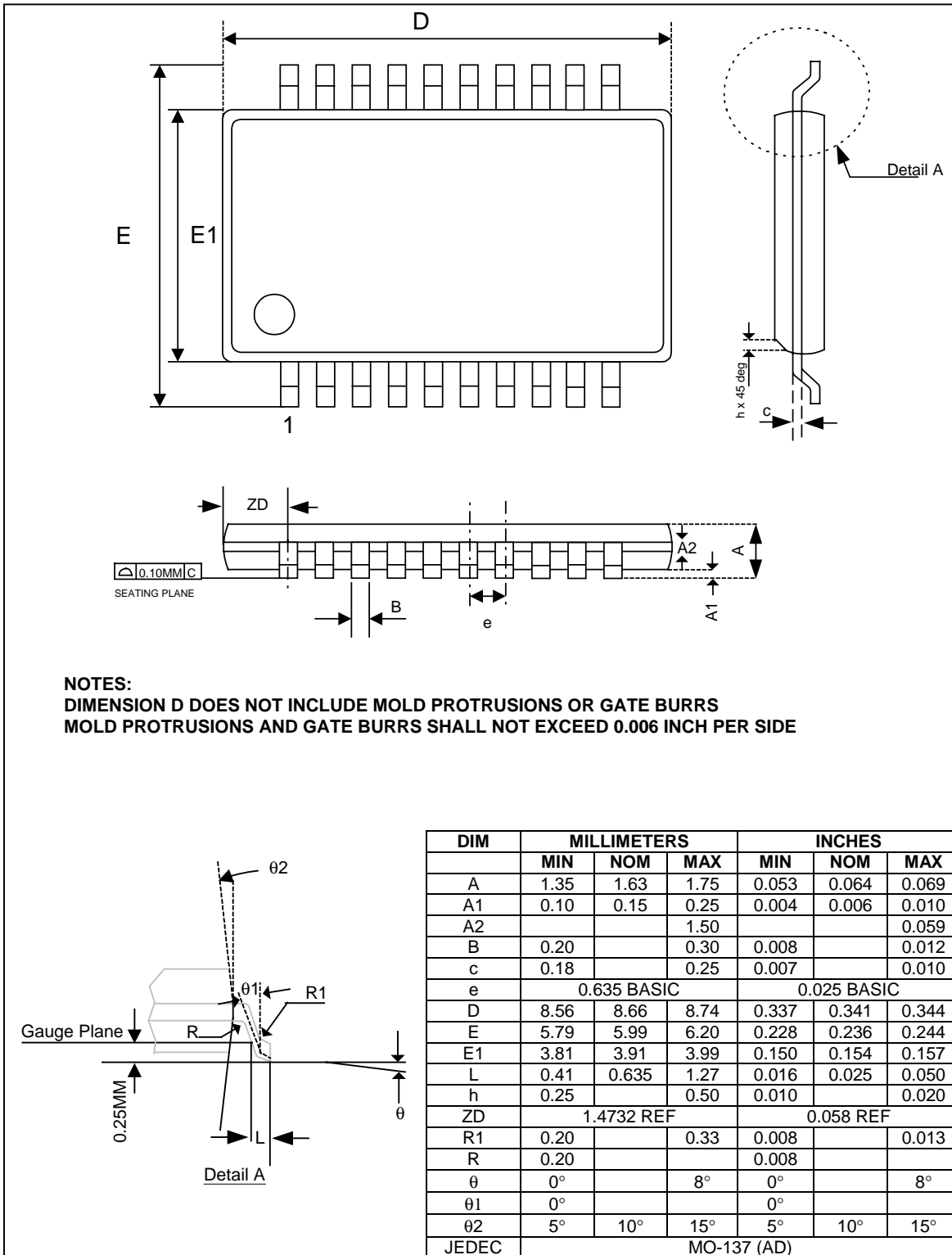
$$f[\text{Hz}] = \frac{1496}{C_{LCT}[\text{nF}]}$$

The Dim pin compares with the triangle wave in LCT and yields a proper pulse width to modulate the CCFL current. This pulse can also be monitored through LPWM pin. The peak and valley of the LCT signal is 3V and 1V respectively.

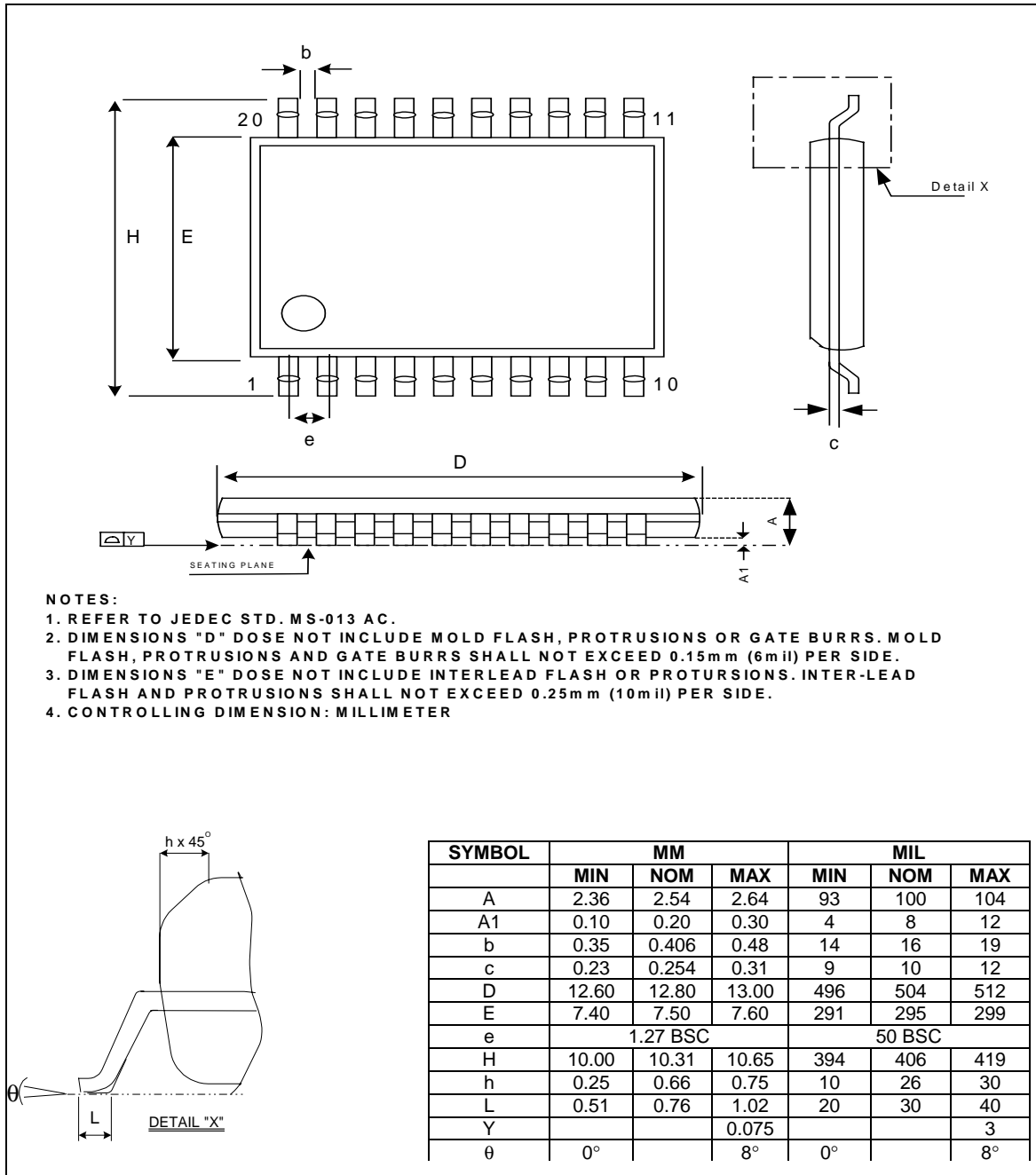
10. Output Drives

The four output drives are designed so that switches QA and QB, QC and QD never turn on simultaneously. These include two NMOS and two PMOS transistors. The configuration prevents any shoot-through issue associated with bridge-type power conversion applications. Adjusting the overlap conduction between QA and QD, QB and QC, the CCFL current regulation is achieved. This overlap is also adjusted while the voltage applied from the battery varies. At a specific CCFL current, the input power is maintained almost constant.

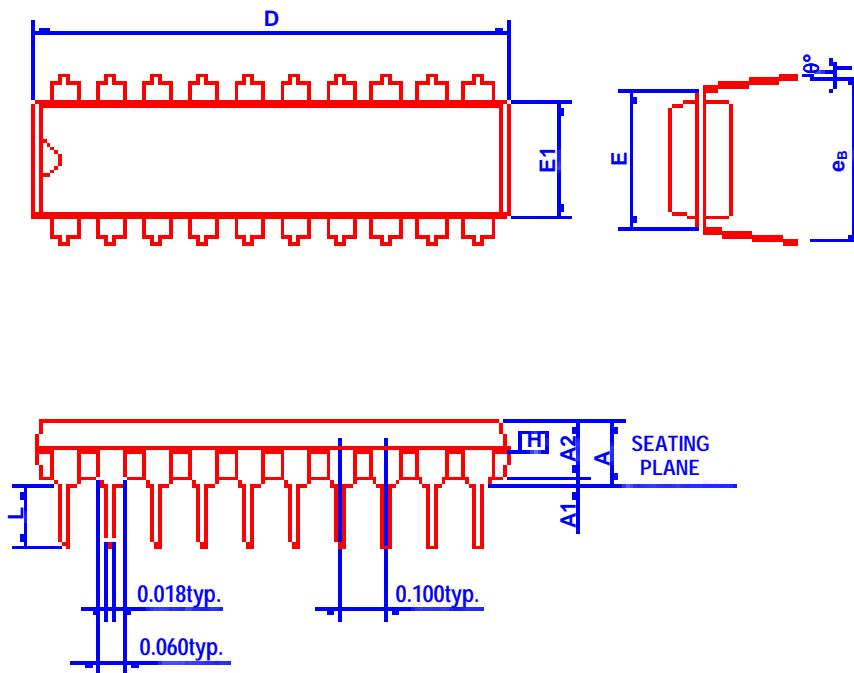
PACKAGE INFORMATION (SSOP 150mil)



PACKAGE INFORMATION (SOP 300mil)



PACKAGE INFORMATION (DIP 300mil)



| SYMBOL | MIN | NOR | MAX |
|----------|-----------|-------|-------|
| A | - | - | 0.210 |
| A1 | 0.015 | - | - |
| A2 | 0.125 | 0.130 | 0.135 |
| D | 0.98 | 1.030 | 1.060 |
| E | 0.300 BSC | | |
| E1 | 0.245 | 0.250 | 0.255 |
| L | 0.115 | 0.130 | 0.150 |
| e_B | 0.335 | 0.355 | 0.375 |
| θ | 0° | 7° | 15° |

NOTES:

1. JEDEC OUTLINE: MS-001 AD
2. "D", "E" DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED .010 INCH
3. e_B IS MEASURED AT THE LEAD TIPS WITH THE LEADS UNCONSTRAINED.
4. POINTED OR ROUNDED LEAD TIPS ARE PREFERRED TO EASE INSERTION.
5. DISTANCE BETWEEN LEADS INCLUDING DAM BAR PROTRUSIONS TO BE .005 INCH MINIMUM.
6. DATUM PLANE H COINCIDENT WITH THE BOTTOM OF LEAD, WHERE LEAD EXITS BODY.

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