# HIGH VOLTAGE LED DRIVER

## APPLICATIONS

- General Illumination Displays
- Industrial & Decorative LED Lighting
- Automotive Applications
- DC/DC or AC/DC LED Driver Applications
- Constant Current Source
- SMPS Switching Controller
- LED Backlighting
- Security, Street & Parking Garage Lighting

## FEATURES

- 11V to 480V Input Voltage Range
- Over 95% Efficiency
- Drives from 1 to 100s of LEDs in Serial & Parallel Combinations
- Constant LED Drive Current
- Linear or PWM Luminance Dimming Control
- Light Sense & Motion Detection Inputs to Control the LEDs
- Resistor Programmable Oscillator Frequency
- RoHS & REACH Compliant

## MECHANICAL CHARACTERISTICS

- QFN-16 Package
- Approximate Weight: 0.043 grams
- Lead-Free Pure-Tin Plating (Annealed)
- Solder Reflow Temperature:
  Pure-Tin - Sn, 100: 260-270°C
- 12mm Tape and Reel Per EIA Standard 481
- Flammability Rating UL 94V-0

## DESCRIPTION

The PA5711 is a high-efficiency LED driver with multiple dimming options that include Pulse Width Modulation (PWM), Linear Dimming (LD), Motion Detection (MD) and Light Sense (LS) inputs. The PA5711 features a direct gate driver control through an active high enable pin. It has an internal oscillator, whose frequency can be set externally through a resistor.

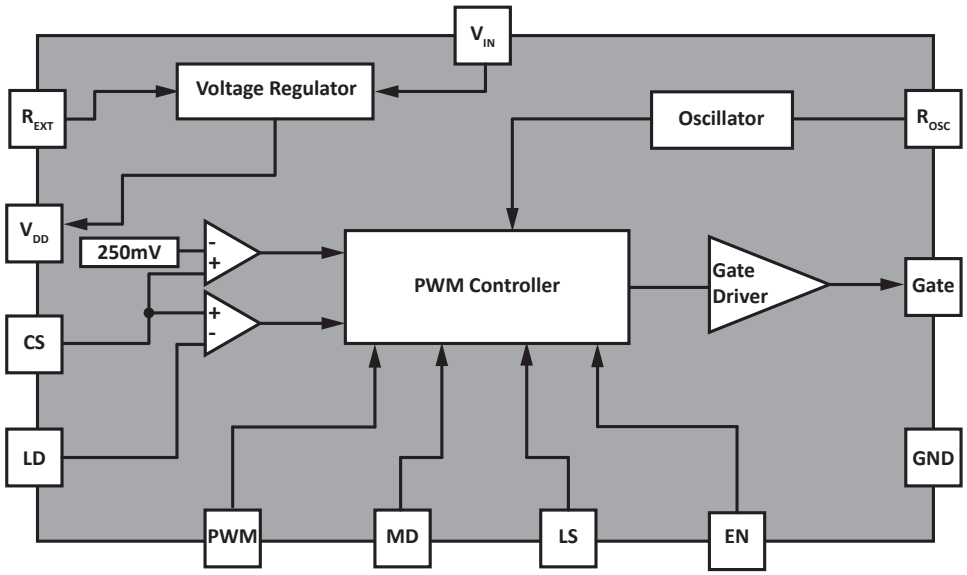
The PA5711 in fly-back mode can be used as a current controlled LED driver (isolated), driving an LED load at fixed current from a few mA to over 1.4A.

The PA5711 allows the user to introduce a leading edge blanking upon the desired delay requirements. In addition, this device can be used to control the duty cycle of the driver.

The LD pin allows the user to set the threshold beneath the pre-set 280mV, for smaller duty cycles and reduced dissipation across the CS resistors.

The PA5711 has a PWM dimming option that through an externally programmed control signal, with a duty ratio of 0-100% and a frequency of a few kilohertz, can control the LED brightness.

## BLOCK DIAGRAM

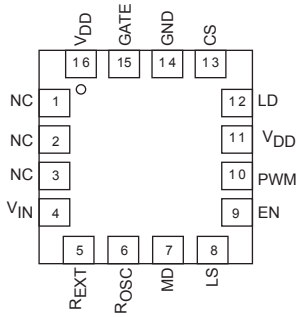


## TYPICAL DEVICE CHARACTERISTICS

| MAXIMUM RATINGS @ 25°C Unless Otherwise Specified | | | |
|---|---|---|---|
| **PARAMETER** | **SYMBOL** | **VALUE** | **UNITS** |
| Input Voltage | $V_{IN}$ | -0.5 to 500 | Volts |
| Input and Output Voltage to Ground | CS, LD, PWN, MD, EN, Gate | -0.3 to $V_{DD}$ +0.3 | Volts |
| VDD, Externally Applied | $V_{DD-EXT}$ | 8 | Volts |
| Power Dissipation | $P_D$ | 3.45 | Watts |
| Maximum Junction Temperature | $T_{JMAX}$ | 168 | °C |
| Operating Temperature | $T_A$ | -40 to +85 | °C |
| Junction Temperature | $T_J$ | -40 to +150 | °C |
| Thermal Resistance Junction to Ambient | $\theta_{JA}$ | 12 | °C/W |
| Storage Temperature | $T_{STG}$ | -55 to +150 | °C |

**NOTES**
1. Continuous operation at or beyond these conditions may permanently damage the device.

| PIN DESCRIPTION | | | |
|---|---|---|---|
| **PIN #** | **NAME** | **FUNCTION** | **PIN CONFIGURATION (TOP VIEW)** |
| 1 | NC | No Connect | |
| 2 | NC | No Connect | |
| 3 | NC | No Connect | |
| 4 | $V_{IN}$ | Supply Voltage 11V-480V | |
| 5 | $R_{EXT}$ | Pin for current limiting resistor between $V_{IN}$ and $R_{EXT}$ | |
| 6 | $R_{OSC}$ | Resistor to ground sets the oscillator frequency | |
| 7 | MD | Motion detection signal input; connect to $V_{DD}$ when unused | |
| 8 | LS | Light sense signal input; connect to ground when unused | |
| 9 | EN | Gate driver enable; connect to $V_{DD}$ to enable the gate driver output | |
| 10 | PWM | $P_{WM}$ input to control the gate output; connect to $V_{DD}$ when unused | |
| 11 | $V_{DD}$ | 5V regulated supply voltage output<br>Requires a storage capacitor to ground<br>External source can be connected to power the chip | |
| 12 | LD | Linear dimming, used to reduce the threshold voltage lower than 250mV; connect to $V_{DD}$ when unused | |
| 13 | CS | LED Current Sense Input | |
| 14 | GND | Chip Ground | |
| 15 | Gate | Gate Driver Output | |
| 16 | $V_{DD}$ | 5V regulated supply voltage output | |



## TYPICAL DEVICE CHARACTERISTICS

| ELECTRICAL CHARACTERISTICS @ 25°C Unless Otherwise Specified | | | | | | |
|---|---|---|---|---|---|---|
| **PARAMETER** | **SYMBOL** | **MIN** | **TYP*** | **MAX** | **UNITS** | **CONDITIONS** |
| Input DC Voltage Range | $V_{INDC}$ | 11 | | 480 | Volts | DC input voltage into the $V_{IN}$ pin |
| Shut-Down Mode Supply Current | $I_{INSD}$ | | 1.46 | 1.57 | mA | EN to GND; $V_{DD}$=5; $R_{OSC}$=1MΩ |
| Internal DC Voltage Regulator | $V_{DD}$ | | 5 | | V | $V_{IN}$=15~450V; $I_{DD(EXT)}$=0; Gate Output Open |
| Maximum Voltage to $V_{DD}$ Pin | $V_{DD(Max)}$ | | | 7 | V | External voltage applied to $V_{DD}$ pin |
| $V_{DD}$ Current Available for External Circuitry | $I_{DD(EXT)}$ | | | 1.0 | mA | Limited by package power dissipation |
| PWM Pull-Down Resistance | $R_{EN}$ | 55 | 67 | 72 | kΩ | $V_{PWM}$=5V |
| Current Sense Threshold Voltage | $V_{CS(HIGH)}$ | 245 | 250 | 255 | mV | T=25°C |
| Gate High Output Voltage | $V_{GATE(HIGH)}$ | $V_{DD}$ - 0.2 | | $V_{DD}$ | V | $I_{OUT}$=10mA; $V_{IN}$=20V |
| Gate Low Output Voltage | $V_{GATE(LOW)}$ | 0 | | 2.0 | mV | $I_{OUT}$=10mA; $V_{IN}$=20V |
| Oscillator Frequency | $f_{OSC}$ | 196 | 200 | 204 | kHz | $R_{OSC}$=150kΩ |
| | | 32 | 34 | 35 | kHz | $R_{OSC}$=1MΩ |
| Oscillator PWM Duty Cycle | D | 0 | | 100 | % | External voltage provided to PWM |
| Linear Dimming Voltage Range | $V_{LD}$ | 0 | | 250 | mV | External voltage provided to the LD pin |
| Delay from CS trip to gate low | $t_{DELAY}$ | | 18 | 22 | ns | |
| Gate Output Rise Time | $t_{RISE}$ | | 25 | | ns | |
| Gate Output Fall Time | $t_{FALL}$ | | 5 | | ns | |
| Quiescent Current | $I_Q$ | 1.4 | 1.5 | 1.6 | mA | No load; $V_{DD}$=5 |
| Pin LS Input Low | $V_{LS(LOW)}$ | | | 600 | mV | $V_{DD}$=5 |
| Pin LS Input High | $V_{LS(HIGH)}$ | 580 | | | mV | $V_{DD}$=5 |
| Pin EN Input Low | $V_{EN(LOW)}$ | | | 2.7 | V | $V_{DD}$=5 |
| Pin EN Input High | $V_{EN(HIGH)}$ | 3.4 | | | V | $V_{DD}$=5 |
| Pin MD Input Low | $V_{MD(LOW)}$ | | | 2.6 | V | $V_{DD}$=5 |
| Pin MD Input High | $V_{MD(HIGH)}$ | 3.4 | | | V | $V_{DD}$=5 |
| Pin PWM Input Low | $V_{PWM(LOW)}$ | | | 2.6 | V | $V_{DD}$=5 |
| Pin PWM Input High | $V_{PWM(HIGH)}$ | 3.2 | | | V | $V_{DD}$=5 |
| *Typical values should not be used for specification limits. | | | | | | |

## APPLICATION INFORMATION

## FUNCTIONAL DESCRIPTION

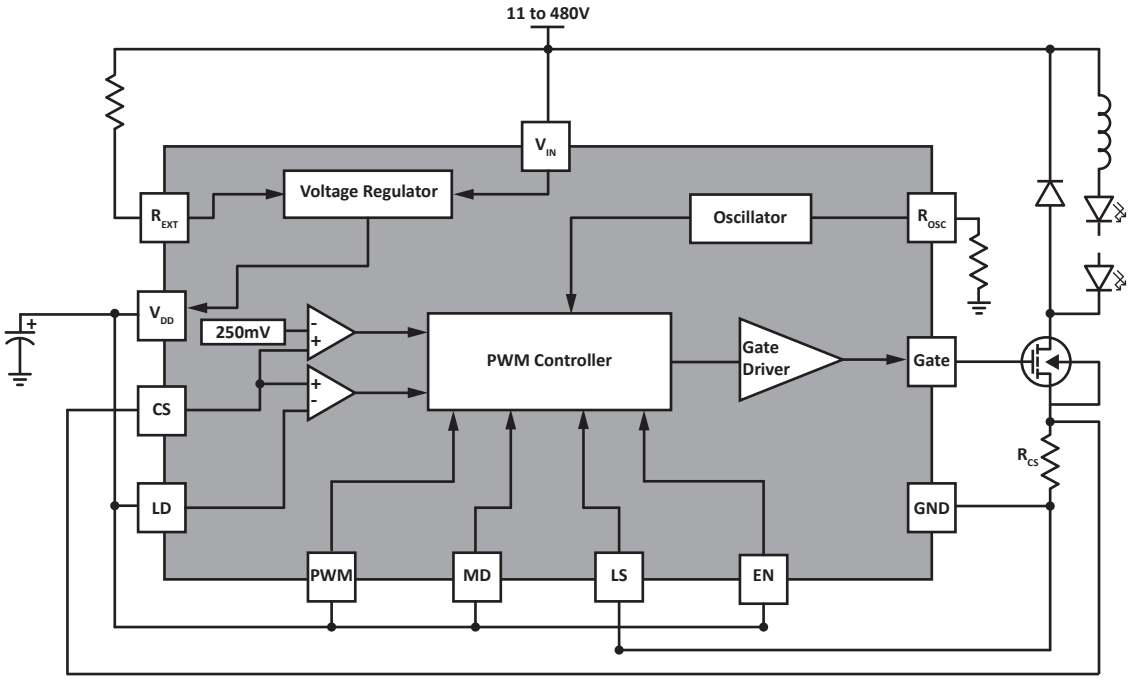



**FIGURE 1**
**TYPICAL APPLICATION CIRCUIT**

## OVERVIEW

The PA5711 is a high efficiency, low cost, off-line LED driver with multiple inputs for controlling the LED under various environmental conditions. The PA5711 driver utilizes a high voltage process for a broad input voltage range. This flexibility allows for a wide range of operations from 11V to 480V DC. This enables the PA5711 to drive the applications such as decorative lighting, signage and RGB backlighting.

The PA5711 in the buck topology (as shown in Figure 1) is a common choice to use the controller in non-isolated LED lighting. The PA5711 can drive multiple LEDs in a string or in parallel. This set-up provides a good efficiency and constant current drive with minimal external components.

The LEDs can be dimmed using voltage 0-250mV on the LD pin or by a low frequency on the PWM.

To save energy by turning the LEDs off, the LEDs can be controlled via external signals to MD, LS, and EN pins. The sense resistor at CS controls the peak current through the LED string.

## APPLICATION INFORMATION

### LED DRIVER - THEORY OF OPERATION

The gates of PWM, EN, MD and LD are enabled when they are connected to the $V_{DD}$ pin. The LS must be connected to ground. In such a configuration, the LED current is solely controlled by the CS resistor. Each positive edge of the oscillator turns the gate driver output high, turning on the external MOSFET. This ramps the inductor current and increases the voltage drop across the CS resistor. When the drop exceeds $V_{CS}$, the gate driver output is low. This turns off the MOSFET, decaying the inductor current until the next positive edge of the clock cycle.

The current threshold limit is set by comparing the voltage developed across the $R_{CS}$ to $V_{CS}$, which is 250mV for the PA5711. The default threshold level can be reduced applying a voltage lower than $V_{CS}$ at the LD pin. The lower of these two thresholds limits the peak current in the inductor.

### VOLTAGE REGULATOR

The PA5711 has an internal voltage regulator that can regulate 11V to 480V input voltage, with an appropriate current limiting resistor at $R_{EXT}$, down to 5V. The $V_{DD}$ pin needs to have a holding cap of 22µF to provide filtering against bounces and a 0.1µF to bypass any high frequency switching noise. The PA5711 $V_{DD}$ pin can supply 1mA for external circuitry.

The internal voltage regulator can be bypassed by providing a voltage higher than the internal $V_{DD}$. This feature reduces the power dissipation and can be implemented in an application where an auxilary supply can power the PA5711

The total input current from the $V_{IN}$ supply is the sum of the quiescent current of the PA5711 (~1.87mA) and the gate driver current. The gate driver current is dependent on the gate charge of the external MOSFET and switching frequency.

The input current approximation can be done by using the following equation:

$$I_{IN} \sim 1.87mA + (Q_{GATE} * f_s)$$

Where $Q_{GATE}$ is the total gate charge of the external MOSFET.

| $R_{EXT}$ IN kΩ | $V_{IN}$ RANGE IN VOLTS |
|---|---|
| 10 | 11-50 |
| 20 | 30-100 |
| 100 | 75-200 |
| 330 | 175-300 |
| 560 | 290-400 |
| 750 | 400-480 |

**NOTES**
1. An indicative table to choose the approximate value of $_{REXT}$ depending on $V_{IN}$.

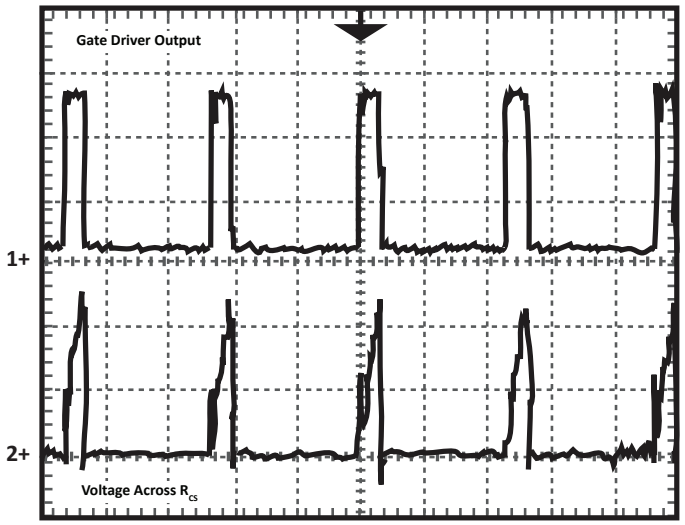
### CURRENT SENSE RESISTOR

The peak LED current is set by the external sense resistor connected from the CS pin to ground. The value of the resistor is determined by the average LED current, the inductor ripple current and the internal threshold voltage. The inductor is selected to keep the inductor ripple current less than 30% of the average LED current. The dissipation across the resistor is given by the following formula:

$$P = R_{CS} * I_{LED}^2$$

It is a safe practice to select the resistor with at least twice the power rating that is calculated.

**FIGURE 2**
**PA5711 WAVEFORM**




### CURRENT SENSE BLANKING

The PA5711 has no internal current sense blanking circuit. This allows the user to choose and introduce the right time delay that fits the application. The user can add a RC delay network on the CS path, i.e., between the $R_{CS}$ and the CS pin. A time delay approximation can be made using the following formula:

$$\tau = 5 * R * C$$

Where R and C are the delay elements.

### ENABLE/DISABLE

The Enable pin (EN) of the PA5711 is active high. If this pin is grounded then the driver is disabled and the chip will consume minimal current. The gate driver is disabled and the LEDs cannot be driven during this period. For normal operation, the Enable pin must be connected high.

## APPLICATION INFORMATION

### LINEAR DIMMING

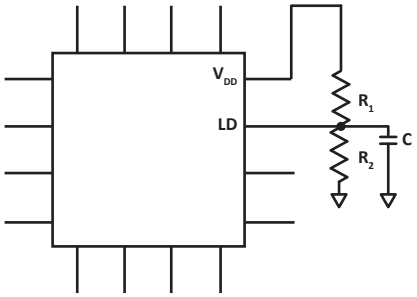
The PA5711 comes with a linear dimming function, which is one of the four different ways the LED can be controlled. While $V_{CS}$ is the maximum threshold against which the current sense resistor voltage drop is compared against, the LD pin can be used to reduce this threshold. An external resistive divider setup will allow the user to adjust the LED light intensity.

The $R_{CS}$ voltage drop is compared against the lower of these two voltages. Hence, decreasing the voltage provided at LD below 250mV would reduce the intensity of the LED light. This allows the user to choose from available resistors rather than calculating the resistor value in accordance with the internal threshold.

Since a voltage lower than the internal threshold can enable linear dimming, it is advisable to connect LD to $V_{DD}$ when linear dimming is not required.

A soft start function can be implemented on the PA5711 by using an RC network to slowly ramp the voltage applied to the LD pin from GND potential to over 300mV, at which the $V_{CS}$ overrides the linear dimming function.

**FIGURE 3**
**SOFT-START RC ARRANGEMENT**




The LD pin can also be used as a feedback to the chip, specially in an isolated driver application. A feedback from the isolated portion can be applied to the LD pin to achieve greater control over the calculate current drive.

### PWM DIMMING

Pulse Width Modulation (PWM) dimming can be implemented on the PA5711 by using a low frequency square wave signal to drive the PWM pin. The square wave frequency can be in the range of a few hundred hertz. In this setup the PWM wave will be directly driving the output of the gate driver.

PWM signals can be generated by using a microcontroller or pulse generators. The duty cycle of the input PWM is directly proportional to the intensity of the LED light. If the PWM input is driven low, the LEDs are turned off.

### LIGHT SENSE

The PA5711 has a Light Sense (LS) input to accept signal from an external light sensor. The LEDs are turned on/off dependent on the signal from the light sensors. The pin must be connected to ground if not used.

### MOTION DETECTION

The PA5711 has a Motion Detection (MD) input. An external motion detector can drive the pin to turn the LEDs on/off. The pin needs to be connected to $V_{DD}$ when not used.

### GATE DRIVER

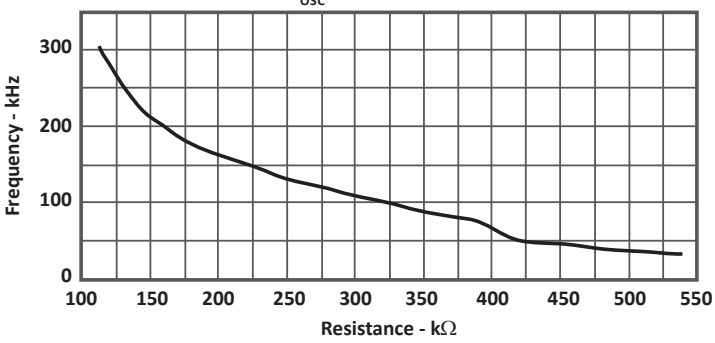
The PA5711 can drive external MOSFETs with a gate capacitance of up to 600pF.

### OSCILLATOR

The PA5711 operates at a constant frequency. The external resistor $R_{OSC}$ determines the oscillator frequency. The inductor size, total chip power dissipation and filter capacitors are the basis on which the switching freqency is decided.

The internal oscillator has a 20% frequency accuracy. In a non-isolated mode the drive switching frequency is between 30kHz and 200kHz. The large operating range gives the designer a reasonable compromise between switching frequency and inductor size.

**FIGURE 4**
**$R_{OSC}$ VS FREQUENCY**



## APPLICATION INFORMATION

### INDUCTOR DESIGN

The LED ripple current, along with factors such as Maximum $T_{ON}$, Minimum Input Voltage and Total Forward Voltage drop ($V_F$), across the LEDs at the desired average LED current, decide the value of the inductor. The minimum voltage is dependent on the specific application and the Maximum $T_{ON}$ is determined by the duty cycle and the switching frequency.

The Maximum Duty Cycle - $D_{Max}$ is given by the following formula:

$$D_{Max} = V_{LEDString}/V_{IN}$$

Where $V_{LEDString}$ is the desired forward voltage drop across the LED string at the designed LED current and $V_{IN}$ is the minimum input voltage.

The maximum duty cycle must be maintained below 50% to maintain open loop stability and sub-harmonic oscillations.

The Maximum On-Time can be calculated as follows:

$$t_{ONMax} = D_{Max}/f_s$$

Where fs is the switching frequency.

The size of the inductor can be calculated using the following formula:

$$L_{Min} = t_{ONMax}(V_{IN} - V_{LEDString})/(I_{LED} * \gamma)$$

Where $\gamma$ is the inductor ripple.

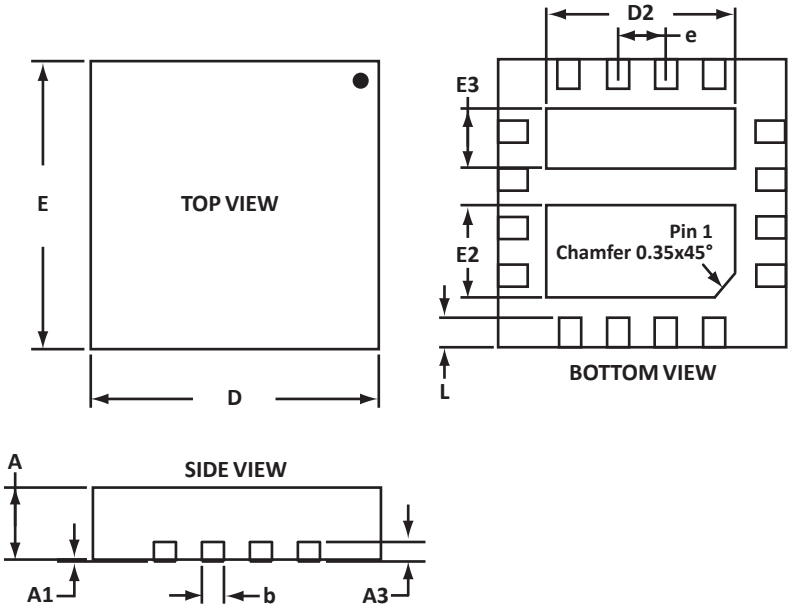
The peak inductor current is given by the following formula:

$$I_{LMax} = I_{LED} * [1 + (\gamma/2)]$$

## QFN-16 PACKAGE INFORMATION

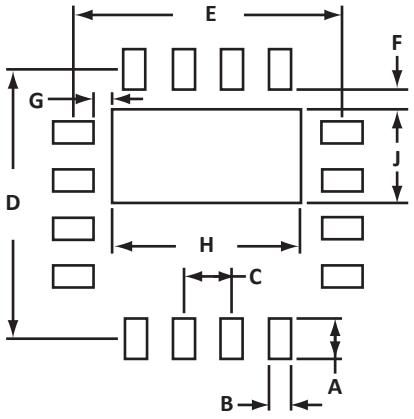
| OUTLINE DIMENSIONS | | | | |
|---|---|---|---|---|
| DIM | MILLIMETERS | | INCHES | |
| | MIN | MAX | MIN | MAX |
| A | 0.85 | 0.95 | 0.034 | 0.038 |
| A3 | 0.203 REF | | 0.008 REF | |
| A1 | 0.00 | 0.05 | 0.000 | 0.002 |
| b | 0.20 | 0.30 | 0.008 | 0.012 |
| D | 3.90 | 4.10 | 0.154 | 0.162 |
| D2 | 2.65 | 2.75 | 0.105 | 0.109 |
| E | 3.90 | 4.10 | 0.154 | 0.162 |
| E2 | 1.21 | 1.31 | 0.048 | 0.052 |
| E3 | 0.84 | 0.94 | 0.034 | 0.038 |
| e | 0.70 BSC | | 0.028 BSC | |
| L | 0.25 | 0.35 | 0.010 | 0.014 |

**NOTES**
1. Dimensions are exclusive of mold flash and metal burrs.
2. Controlling dimension: millimeters.

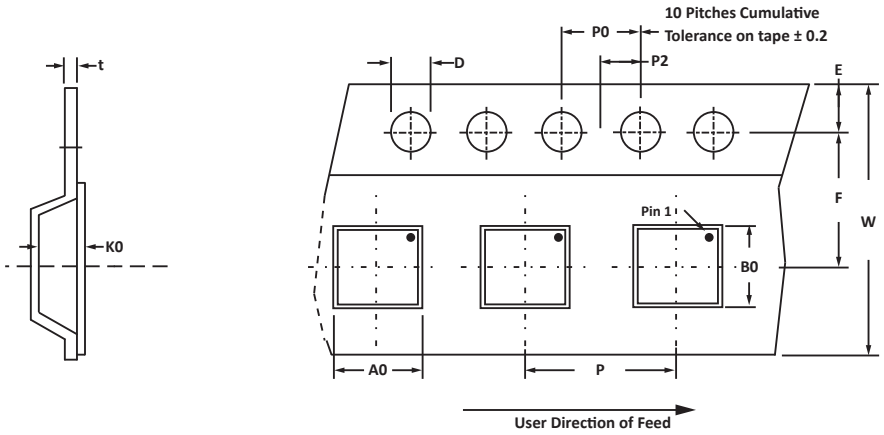



| PAD LAYOUT DIMENSIONS | | | | |
|---|---|---|---|---|
| DIM | MILLIMETERS | | INCHES | |
| | MIN | MAX | MIN | MAX |
| A | 0.59 | 0.61 | 0.022 | 0.026 |
| B | 0.34 | 0.36 | 0.012 | 0.016 |
| C | 0.70 BSC | | 0.028 BSC | |
| D | 3.89 | 3.91 | 0.152 | 0.156 |
| E | 3.89 | 3.91 | 0.152 | 0.156 |
| F | 0.24 | 0.26 | 0.008 | 0.012 |
| G | 0.24 | 0.26 | 0.008 | 0.012 |
| H | 2.71 | 2.81 | 0.108 | 0.112 |
| J | 1.35 | 1.37 | 0.052 | 0.056 |

**NOTES**
1. Controlling dimension: millimeters



## TAPE AND REEL




| SPECIFICATIONS | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| REEL DIA. | TAPE WIDTH | A0 | B0 | K0 | D | E | F | W | P0 | P2 | P | tmax |
| 178mm (7") | 12mm | 6.50 ± 0.10 | 5.40 ± 0.10 | 2.00 ± 0.10 | 1.50 ± 0.10 | 1.75 ± 0.10 | 5.50 ± 0.05 | 12.00 ± 0.30 | 4.00 ± 0.12 | 2.00 ± 0.10 | 4.00 ± 0.10 | 0.25 |

**NOTES**
1. Dimensions are in millimeters.
2. Surface mount product is taped and reeled in accordance with EIA-481.
3. Suffix - T7 = 7" Reel - 1,000 pieces per 12mm tape.
4. Suffix - T13 = 13" Reel - 2,500 pieces per 12mm tape.
5. Bulk product shipped in tubes of 98 pieces per tube.
6. Marking on Part - part number, date code, logo and pin one defined by dot on top of package.

| ORDERING INFORMATION | | | | | |
|---|---|---|---|---|---|
| BASE PART NUMBER | LEADFREE SUFFIX | TAPE SUFFIX | QTY/REEL | REEL SIZE | TUBE QTY |
| PA5711 | N/A | -T7 | 1,000 | 7" | 98 |
| PA5711 | N/A | -T13 | 2,500 | 13" | 98 |
| This device is only available in a Lead-Free configuration. | | | | | |

## COMPANY INFORMATION

### COMPANY PROFILE

In business more than 20 years, ProTek Devices™ is a privately-held company located in Tempe, Arizona, that offers a product line of transient voltage suppressors (TVS); avalanche breakdown diodes; steering diode TVS arrays and other surge suppressor component products. These TVS devices protect electronic systems from the effects of lightning, electrostatic discharge (ESD), nuclear electromagnetic pulses (NEMP), inductive switching and EMI / RFI. ProTek Devices also offers high performance interface and linear products that include analog switches; multiplexers; LED drivers; audio control ICs; RF and related high frequency products. The analog devices work in a host of consumer; industrial; automotive and other applications.

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