Lead-free Green

AL1771/1772

PFC CONTROLLER + SINGLE/DUAL DIMMABLE LINEAR LED DRIVER

Description

The DIODES™ AL1771/1772 is a high integration chip with an Offline High Power Factor Correction (PFC) controller and a single/dual-channel Linear LED driver in one package. AL1771/1772 implements an optimized 2-stage topology for a wide power range of Connected Lighting applications. It is targeted for 1-Channel Dimmable and 2-Channel Tunable White and various Connected Lighting applications.

Based on Primary Side Regulation (PSR) implementation, the PFC controller does not require Opto-coupler and any secondary feedback circuit to save overall BOM cost and it operates at Quasi-Resonant (QR) mode where MOSFET is turned on at the valley of the drain voltage, which minimizes switching loss and results in high efficiency.

The key merits of the Single/Dual Dimmable Linear LED driver attribute to excellent dimming performance, low standby power, ease of system implementation, and great product scalability. It supports E-flicker free High Frequency PWM dimming with Deep Dimming Capability: Support 40kHz down to 4%, 10kHz down to 1.0%, 4kHz down to 0.4%, or 1kHz down to 0.1% with good dimming linearity. When no PWM signal is detected by AL1771/1772, the LED driver Section will automatically enter the low-power mode for power saving purpose to be in compliance with Energy Star standby power requirement for Connected Lighting. Integrates Adaptive Thermal Management (ATM) scheme to minimize non-productive power dissipation.

The AL1771/1772 has protection features to ensure robust and safety operation of the Connected Lighting systems. The AL1771/1772 can support applications with LED current (Up 1500mA) and is available in low thermal resistance package TSSOP-16EP (Type DX).
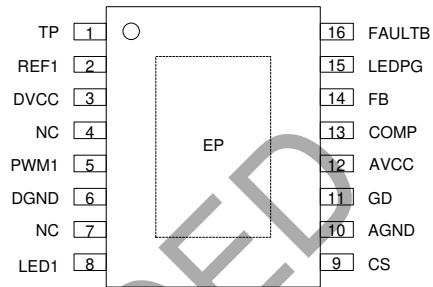
Features

- High PFC Controller and Dimmable Linear LED Driver in One Package
- Valley Detection to Achieve Low Switching Loss and High Efficiency
- Input Voltage Range for LED Driver (DVCC): 6.5V to 30V
- Each Channel Independent PWM Dimming Control
- Adjustable Reference Current by External Reference Resistors
- LED Current Accuracy ≤ ±4%
- Maximum LED Current 1500mA for AL1771 and 750mA Per channel to AL1772
- Adaptive Thermal Management (ATM) Scheme to Minimize Power Dissipation
- Low Standby Power Mode with Automatically Enter and Exit
- High Frequency E-Flicker Free PWM Dimming with Deep Dimming Capability
- Protections:
  PFC controller:
  - Under Voltage Lockout (UVLO)
  - Over Voltage Protection (OVP)
  - Over Current Protection (OCP)
  - Output Short Protection (OSP)
  - Over-Temperature Protection (OTP): Thermal Shutdown and Auto Thermal Recovery
  Dimmable Linear LED Driver:
  - Under Voltage Lockout (UVLO)
  - LED String Open/Short Protection
  - Over-temperature Protection (OTP): Thermal Shutdown and Auto Thermal Recovery
- Fault Reports: UVLO, OTP, LED Open/Short
- Low System BOM
- Ambient Temperature Operating Range -40°C to +125°C TSSOP-16EP (Type DX): Available in "Green" Molding Compound (No Br, Sb)
- **Totally Lead-Free & Fully RoHS Compliant (Notes 1 & 2)**
- **Halogen and Antimony Free. "Green" Device (Note 3)**
- **For automotive applications requiring specific change control (i.e. parts qualified to AEC-Q100/101/104/200, PPAP capable, and manufactured in IATF 16949 certified facilities), please contact us or your local Diodes representative. https://www.diodes.com/quality/product-definitions/**

Pin Assignments

(Top View)

TP	1	16	FAULTB
REF1	2	15	LEDPG
DVCC	3	14	FB
NC	4	13	COMP
PWM1	5	12	AVCC
DGND	6	11	GD
NC	7	10	AGND
LED1	8	9	CS

EP

TSSOP-16EP (Type DX) (AL1771)

(Top View)

REF2	1	16	FAULTB
REF1	2	15	LEDPG
DVCC	3	14	FB
PWM2	4	13	COMP
PWM1	5	12	AVCC
DGND	6	11	GD
LED2	7	10	AGND
LED1	8	9	CS

EP
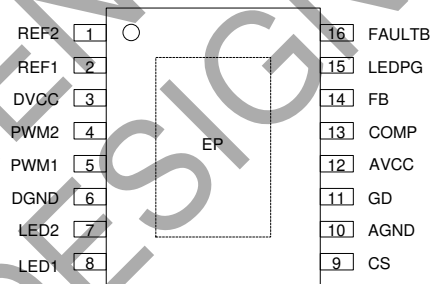
TSSOP-16EP (Type DX) (AL1772)

Applications

- 1-channel dimmable connected light bulbs
- 2-channel tunable white connected bulbs
- Smart connected LED tubes, panel lights, troffers, and ceiling lights

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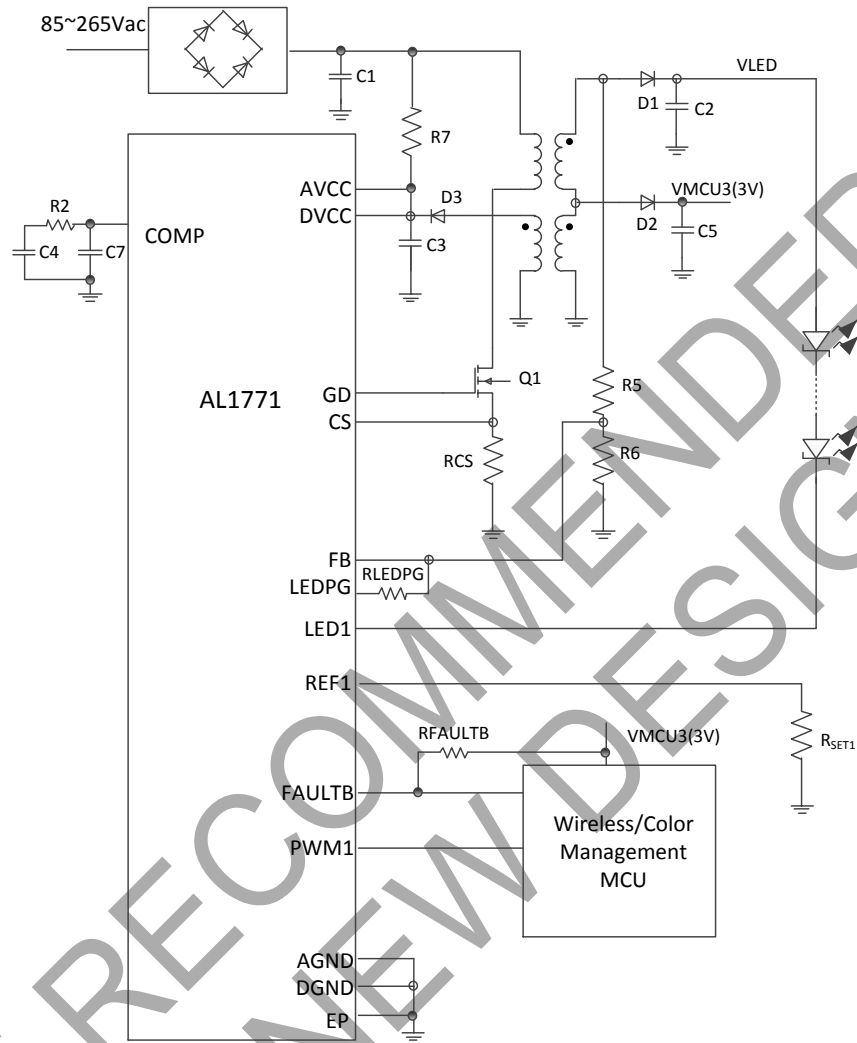
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Typical Applications Circuit

Figure 1. 1-Channel Dimmable White

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Typical Applications Circuit (continued)
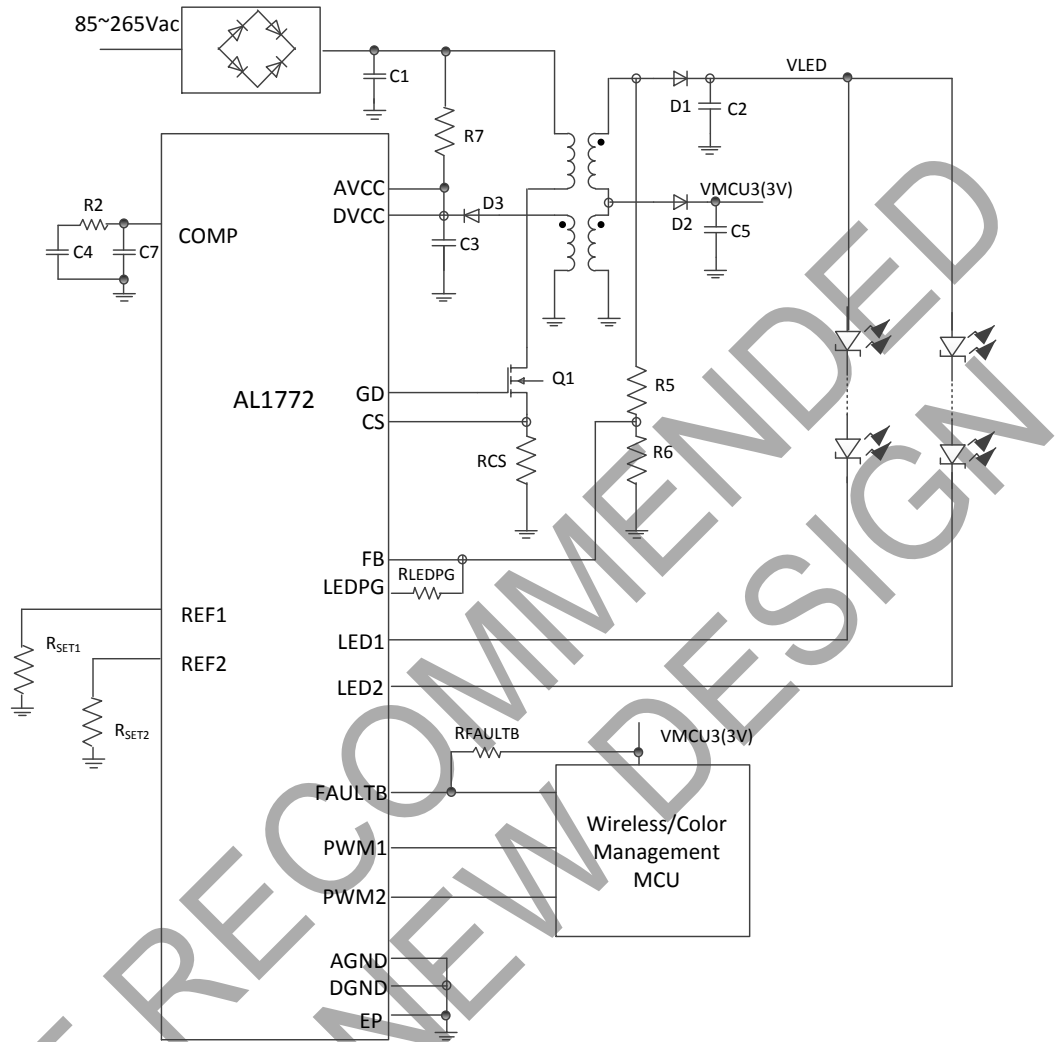
Figure 2. 2-Channel Tunable White

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Typical Applications Circuit (continued)
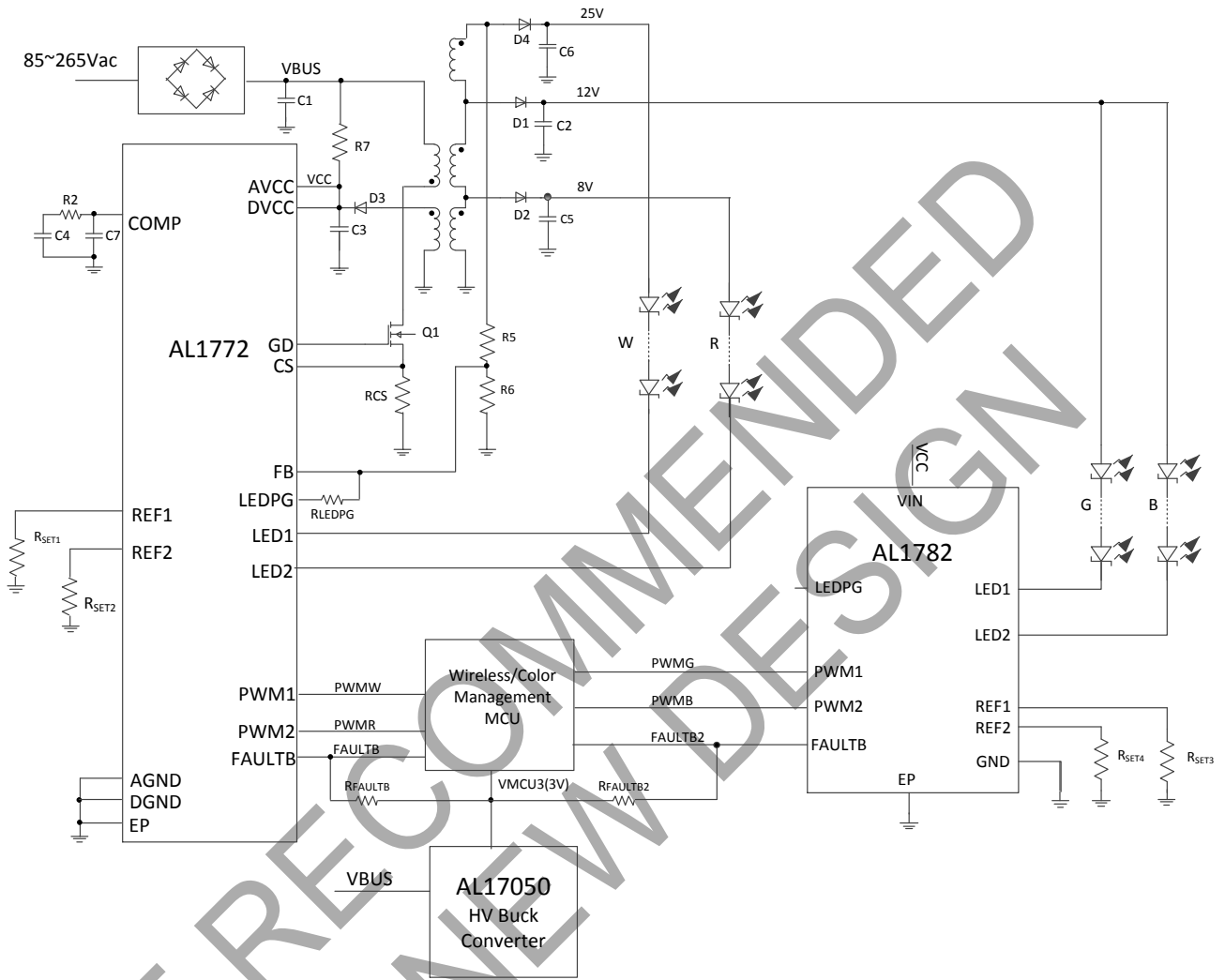
Figure 3. 4-Channel White + RGB

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Pin Descriptions

| Pin Number	Pin Name		Function
	AL1771	**AL1772**	
1	TP	REF2	Reference Current Setting through External Resistor (R_{SET2}) for AL1772; TP pin is a test pin for AL1771, not to input any voltage to TP pin.
2	REF1	REF1	Reference Current Setting through External Resistor (R_{SET1})
3	DVCC	DVCC	Power Supply for LED Driver Section
4	NC	PWM2	PWM Signal Input for Channel-2, Internally Pulled Down for AL1772; Not Connected for AL1771.
5	PWM1	PWM1	PWM Signal Input for Channel-1, Internally Pulled Down.
6	DGND	DGND	Ground for LED Driver Section
7	NC	LED2	Channel-2 LED Cathode for AL1772; Not Connected for AL1771.
8	LED1	LED1	Channel-1 LED Cathode
9	CS	CS	Current Sense for PFC controller
10	AGND	AGND	Ground Pin for PFC Controller
11	GD	GD	Gate Drive for PFC Controller
12	AVCC	AVCC	Power Supply for PFC Controller
13	COMP	COMP	PFC Loop Compensation
14	FB	FB	PFC output voltage feedback and inductor current zero-crossing detection pin.
15	LEDPG	LEDPG	Adaptive thermal management adjusting current output. Tied to FB to adjust PFC output voltage.
16	FAULTB	FAULTB	Fault Report. Asserted Low to report faulty conditions. Needs an external pull-up resistor.
Exposed PAD	EP	EP	Exposed pad. It should be externally connected to Ground and thermal mass for enhanced thermal impedance. It should not be used as electrical conduction path.

Functional Block Diagram
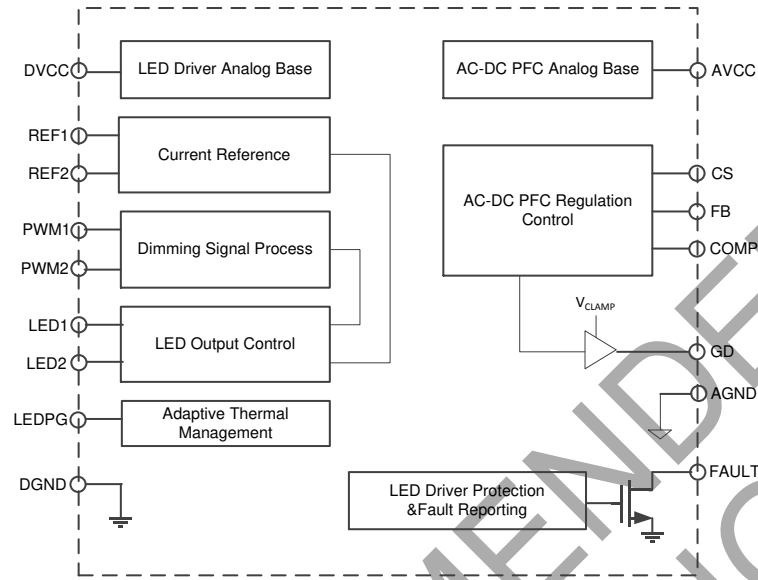
Figure 4. Functional Block Diagram of AL1772 (Note 4)

Note 4:   REF2, PWM2 and LED2 are not applicable to AL1771.

Absolute Maximum Ratings (@T$_A$ = +25°C, unless otherwise specified.)

Symbol		Parameter	Ratings	Unit
ESD	HBM	Human Body Model ESD Protection	4000	V
	CDM	Charged Device Model ESD Protection	1000	V
V$_{IN\_DVCC}$	Input Voltage for DVCC		33	V
V$_{IN\_AVCC}$	Input Voltage for AVCC		30	V
V$_{LEDx}$	LEDx Voltage		33	V
V$_{PWMx}$, V$_{FAULTB}$, V$_{LEDPG}$	PWMx, FAULTB, and LEDPG Voltage		7	V
V$_{FB}$, V$_{COMP}$, V$_{CS}$	FB, COMP and CS Voltage		6	V
V$_{REFx}$	REFx Voltage		5	V
V$_{GD}$	GD Voltage		Self-limiting	V
T$_{J(MAX)}$	Maximum Junction Temperature		+160	°C
T$_{ST}$	Storage Temperature Range		-65 to +150	°C

Caution: Stresses greater than the '*Absolute Maximum Ratings*' specified above can cause permanent damage to the device. These are stress ratings only;
functional operation of the device at these or any other conditions exceeding those indicated in this specification is not implied. Device reliability can be
affected by exposure to absolute maximum rating conditions for extended periods of time.
Semiconductor devices are ESD sensitive and can be damaged by exposure to ESD events. Suitable ESD precautions should be taken when handling
and transporting these devices.

Recommended Operating Conditions (@T$_A$ = +25°C, unless otherwise specified.)

Symbol	Parameter	Min	Max	Unit
V$_{IN\_AVCC}$	Input Voltage at AVCC	9	25	V
V$_{IN\_DVCC}$	Input Voltage at DVCC	6.5	30	V
T$_A$	Operating Ambient Temperature	-40	+125	°C
V$_{IH}$	High-Level Input Voltage on PWMx	1.4	5.5	V
V$_{IL}$	Low-Level Input Voltage on PWMx	0	0.4	V

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Electrical Characteristics ($@T_A$ = +25°C, V_{AVCC}, V_{DVCC} = 12V, unless otherwise specified.)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
PFC Section						
V_{AVCC_ST}	AVCC Startup Threshold Voltage	V_{AVCC} Rising	—	19	—	V
$V_{AVCC\_OPR\_MIN}$	AVCC Minimal Operating Voltage	V_{AVCC} Falling (After Startup)	7.0	—	8.5	V
V_{AVCC_OVP}	AVCC OVP Voltage	—	—	30	—	V
I_{AVCC_ST}	AVCC Startup Current	V_{CC} = V_{ST} -0.5V, Before Start-up	—	3	—	µA
I_{AVCC_OPR}	AVCC Operating Current	Static - No Switching (V_{CS} = 0.6V)	—	500	—	µA
I_{AVCC_OVP}	AVCC Shunt Current in OVP mode	V_{CC} = 15V after V_{CC} >V_{CC_OVP} Triggered	—	2.5	—	mA
V_{GD_H}	GD High Level	V_{AVCC} = 18V	12	13.5	15	V
V_{GD_L}	GD Low Level	I_{GD_SINK} = 20mA, V_{AVCC} = 12V	—	—	1	V
t_{GD_R}	GD Voltage Rise Time	C_L = 1nF	—	100	—	ns
t_{GD_F}	GD Voltage Fall Time	C_L = 1nF	—	50	—	ns
$t_{GD\_ON\_MIN}$	GD Minimum On Time	—	—	0.7	—	µs
$t_{GD\_ON\_MAX}$	GD Maximum On Time	—	—	17	—	µs
$t_{GD\_OFF\_MIN}$	GD Minimum Off Time	—	—	1.2	—	µs
$t_{GD\_OFF\_MAX}$	GD Maximum Off Time	—	—	40	—	µs
f_{GD_MAX}	GD Maximum Frequency	—	—	120	—	kHz
V_{CS_OCP}	Primary Current OCP	—	—	0.5	—	V
GM_{COMP}	COMP Transconductance	—	—	100	—	µA/V
$I_{MAX\_COMP\_SOURCE}$	COMP Maximum Source Current	V_{FB} = 0.8V	—	16	—	µA
$I_{MAX\_COMP\_SINK}$	COMP Maximum Sink Current	V_{FB} = 1.5V	—	16	—	µA
V_{FB_CV}	FB CV Threshold Voltage	—	1.15	1.2	1.25	V
V_{FB_OVP}	FB OVP Threshold Voltage	—	—	1.35	—	V
LED Driver Section						
V_{DVCC_UVLO}	DVCC UVLO Voltage	V_{DVCC} Rising	—	6	—	V
V_{DVCC_UVHYS}	DVCC UVLO Hysteresis	V_{DVCC} Falling	—	300	—	mV
V_{DVCC_OVP}	DVCC OVP Voltage	V_{DVCC} Rising when I_{DVCC} > 5mA	—	33	—	V
$I_{MAX\_DVCC\_OVP}$	Maximum DVCC OVP Current	V_{DVCC} > V_{DVCC_OVP}	—	7	—	mA
$I_{DVCC\_Low\_Power}$	DVCC Supply Current at Low-Power Mode	Low-Power Mode, PWMx are "L"	—	300	—	µA
I_{DVCC_Q}	DVCC Quiescent Supply Current	Enabled, LEDx floating, PWMx are "H", R_{SETx} is 12kΩ	—	1.5	—	mA
$V_{IL(PWMx)}$	PWM Low Voltage	—	—	—	0.4	V
$V_{IH(PWMx)}$	PWM High Voltage	—	1.4	—	—	V
f_{PWMx}	PWM Frequency	—	0.5	—	40	kHz
$I_{(PWMx-PD)}$	PWM Internal Pulldown	V_{PWMx} = 5V	0.35	—	3.5	µA
$t_{PWMx\_MIN.\ ON}$	Minimum PWMx On Time	—	—	2.5	—	µs
$t_{PWMx\_Low\_Power}$	Low-Power Time	—	—	4	—	ms
V_{REFx}	Reference Voltage	—	1.47	1.5	1.53	V
I_{REFx}	Reference Current	R_{SETx} = 12kΩ	—	125	—	µA
I_{LED1_NOM}	Regulation Current for Channel 1 (AL1771)	R_{SETx} = 12kΩ	—	500	—	mA
I_{LED1_NOM}	Regulation Current for Channel 1 (AL1772)	R_{SETx} = 12kΩ	—	250	—	mA
I_{LED2_NOM}	Regulation Current for Channel 2	R_{SETx} = 12kΩ	—	250	—	mA
V_{LEDx_REG}	Minimum LED Regulation Voltage	I_{LEDx} = 250mA	—	250	—	mV
I_{LEDx_LEAK}	LEDx Leakage Current	V_{PWMx} = 0V, V_{LEDx} = 12V	—	0.1	2	µA
$I_{LEDx\_ACCURACY}$	LEDx Current Accuracy	R_{SETx} = 12kΩ	-4.0	—	4.0	%
$V_{LEDxSHP}$	LED Short Protection Threshold	—	—	9	—	V
$t_{LEDxSHDG}$	Short-detection Deglitch	100% duty-cycle	—	4	—	ms

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Electrical Characteristics (continued)

Symbol	Parameter	Test Conditions	Min	Typ	Max	Unit
N$_{LEDxSHDG}$	—	PWM Dimming (count the number of continuous cycles when LED short is detected)	—	15	—	Cycles
t$_{LEDxSH\_HICCUP}$	LED Short Protection Hiccup Time	—	—	128	—	ms
t$_{LEDxOPDG}$	Open-detection Deglitch	100% duty-cycle	—	6	—	ms
N$_{LEDxOPDG}$		PWM Dimming (count the number of continuous cycles when LED open is detected)	—	15	—	Cycles
t$_{LEDxOP\_HICCUP}$	LED Open Protection Hiccup Time	—	—	128	—	ms
t$_{SS}$	Soft-start Time	V$_{PWMx}$ = 5V, 90% of I$_{LEDx\_NOM}$	—	200	—	µs
I$_{LEDPG\_FULL}$	LEDPG Full Current	—	—	32	—	µA
I$_{LEDPG\_LSB}$	LEDPG LSB Current	—	—	0.5	—	µA
t$_{LEDPG\_ADJUST}$	LEDPG Adjust Time	—	—	512	—	ms
T$_{SHDN}$	Thermal Shutdown Threshold	—	—	+160	—	°C
T$_{HY}$	Temperature Hysteresis	—	—	+30	—	°C
V$_{FOL}$	FAULTB Output Low Voltage	I$_{FAULTB}$ = 1mA	—	—	180	mV
I$_{FOH}$	FAULTB Leakage Current	V$_{FAULTB}$ = 5V	—	—	1	µA
θ$_{JA}$	Thermal Resistance Junction-to-Ambient	TSSOP-16EP (Type DX) (Note 5)	—	50	—	°C/W
θ$_{JC}$	Thermal Resistance Junction-to-Case	TSSOP-16EP (Type DX) (Note 5)	—	15	—	°C/W

Note 5: Device mounted on 2" x 2" FR-4 substrate PCB, 2oz copper, with minimum recommended pad on top layer and thermal vias to bottom layer ground plane.

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Typical Performance Characteristics

AVCC Startup Threshold Voltage vs. Ambient Temperature
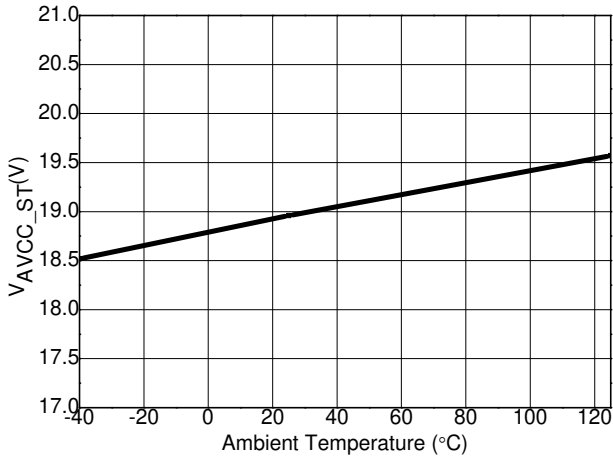
AVCC Operating Current vs. Ambient Temperature
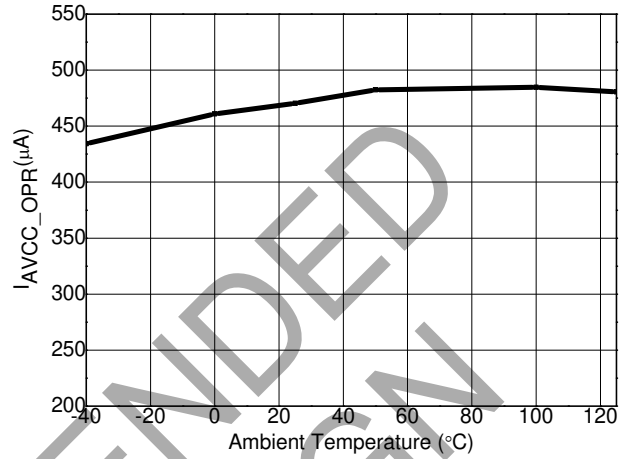
AVCC Minimal Operating Voltage vs. Ambient Temperature
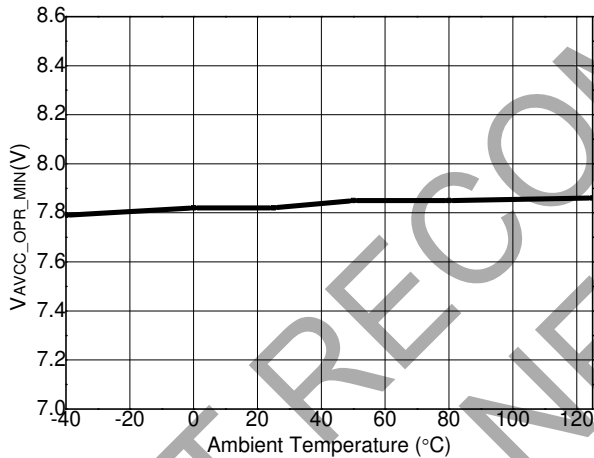
FB CV Threshold vs. Ambient Temperature
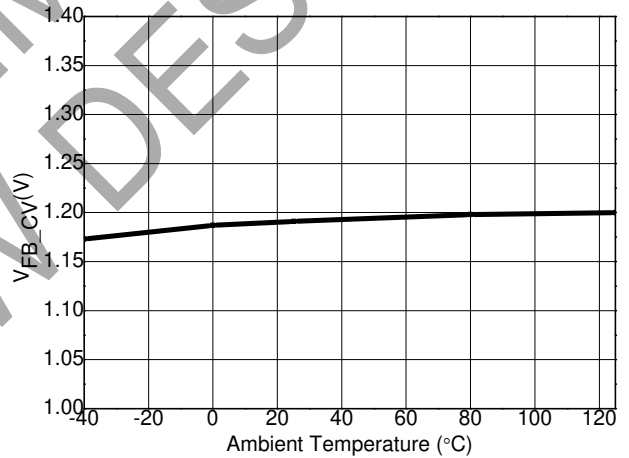
DVCC UVLO Voltage vs. Ambient Temperature
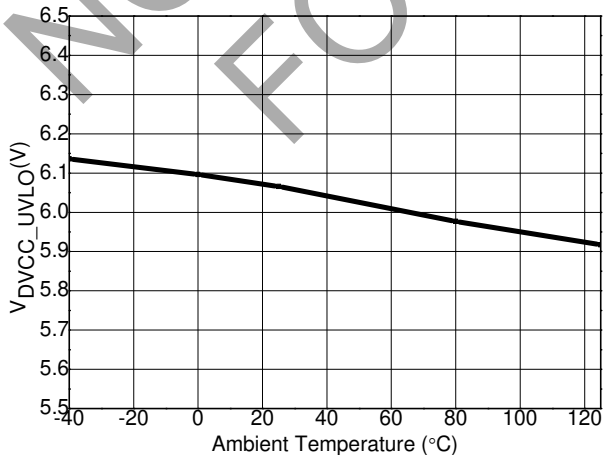
DVCC OVP Voltage vs. Ambient Temperature

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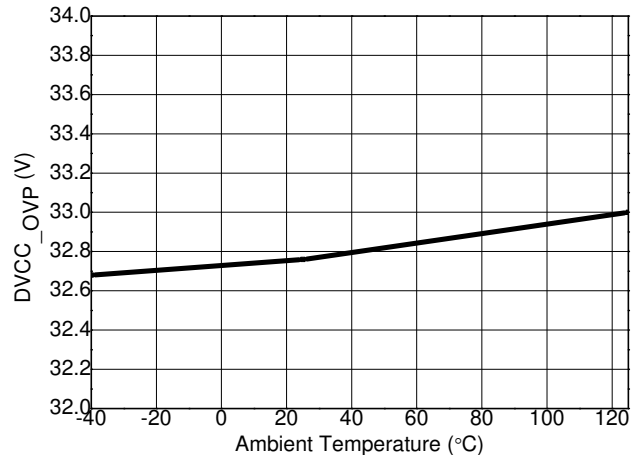
Typical Performance Characteristics (continued)

**Reference Voltage for Channel 1
vs. Ambient Temperature**
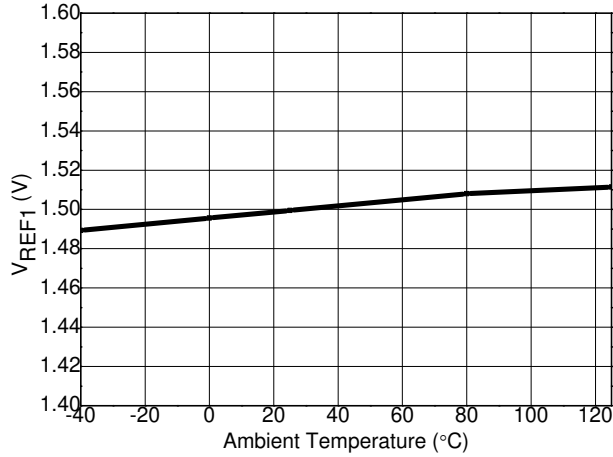
**Regulation Current for Channel 1
vs. Ambient Temperature**
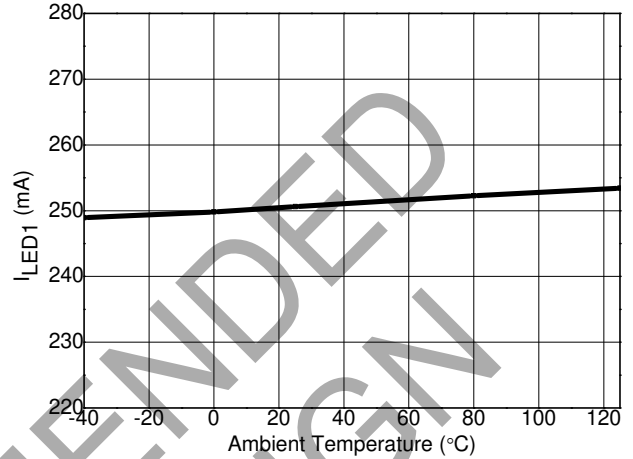
LED Current vs. PWM Duty (f = 4kHz, 0~100%)

LED Current vs. PWM Duty (f = 4kHz, 0~10%)
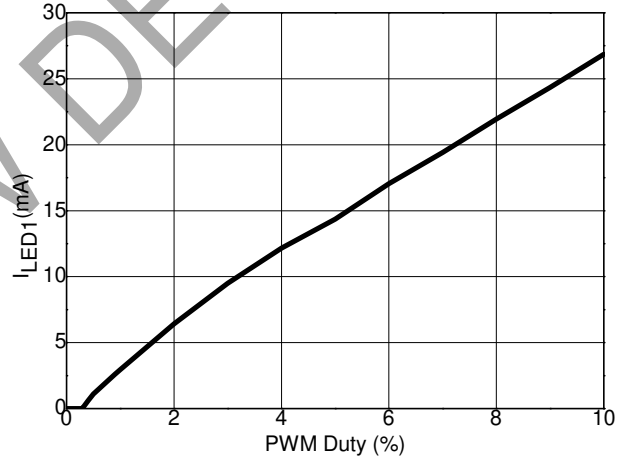
Functional Description

The AL1771 and AL1772 are PFC controller +single/dual-channel constant-current regulators optimized for 1-channel Dimmable White and 2-channel Tunable White Smart Connected Lighting (SCL) applications. AL1771/1772 implements a 2-stage 1-chip topology optimized for Smart Connected Lighting (SCL) applications. It integrates both Stage 1 (High PFC AC-to-Constant Voltage CV Power Conversion) and Stage 2 (CV-to-Constant Current CC for Channel Current Mixing) inside a single chip (TSSOP-16EP (Type DX). The PFC Controller provides high Power Factor Correction (PFC) while consuming low standby current to meet Energy Star low standby power requirement for SCL products. The Linear LED driver regulates the LED currents and supports high performance PWM dimming.

PFC Controller

The PFC constant voltage controller operates with constant on time to achieve high power factor. It adopts the Quasi-Resonant (QR) mode valley switching method to reduce switching loss and improve EMI performance.

1. Start-up

After AC supply is powered on, the capacitor C3 across AVCC and GND pins will be charged up by BUS voltage through a start-up resistor R7. Once AV_{CC} reaches V_{AVCC_ST}, the internal blocks start to work. AV_{CC} will be supplied by V_{BUS} until the auxiliary winding of Flyback transformer could supply enough energy to maintain AV_{CC} above $V_{AVCC\_OPR\_MIN}$. If AV_{CC} voltage is lower than $V_{AVCC\_OPR\_MIN}$, the switch will be turned off.

To accelerate the start-up process, the COMP voltage is internally pulled up and clamped high, leading to large MOSFET duty cycle and fast climbing up of the output voltage. When the FB voltage reaches the reference voltage V_{FB_CV}, the start-up process ends and the COMP voltage turns to be modulated by the external compensation network.
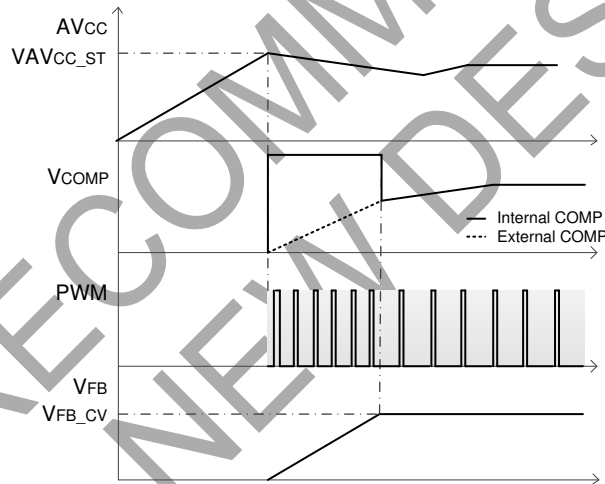
Figure 5. Start Up Waveform

2. Constant Voltage Operation

As to constant-voltage (CV) operation mode, the PFC controller detects the auxiliary winding voltage at FB pin to regulate the output voltage. The auxiliary winding voltage is coupled with secondary side winding voltage, so the auxiliary winding voltage at D3 conduction time is:

$$V_{AUX} = \frac{N_{AUX}}{N_S} \times (V_O + V_D) \quad (1)$$

$$V_{FB\_CV} = V_{AUX} \times \left(\frac{R6}{R5 + R6}\right) \quad (2)$$

Where: V_O is the output voltage

   V_D is the output rectifier diode forward voltage drop

   N_{AUX} is the turns of auxiliary winding

   N_S is turns of the secondary winding

   V_{FB_CV} is the output voltage setting

   R_5 and R_6 that is shown as Figure 1 divide reflected voltage.

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Functional Description (continued)
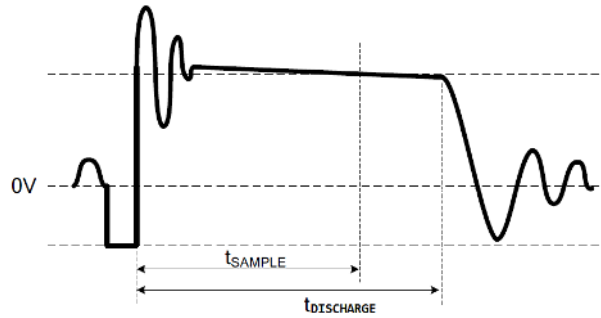
Figure 6. Auxiliary Voltage Waveform

Figure 6 shows the voltage waveform of the auxiliary winding. To accurately sample the divided auxiliary winding voltage, the FB pin delays a t_{SAMPLE} time before sampling. And $t_{DISCHARGE}$ is the demagnetization time for the transformer.

3. Load Transition Operation

To obtain good load transition performance, the COMP regulation mechanism is optimized. When the load changes from heavy to light causing the FB voltage reaching V_{FB_OVP} (typically 1.35V), the IC will pull down the COMP voltage and enter the max-off-time mode, accelerating the discharge of the output voltage. When the load changes from light to heavy leading to the FB voltage touching 1.0V, the IC will charge up the COMP voltage and raise the MOSFET on time, quickening the increase of the output voltage.
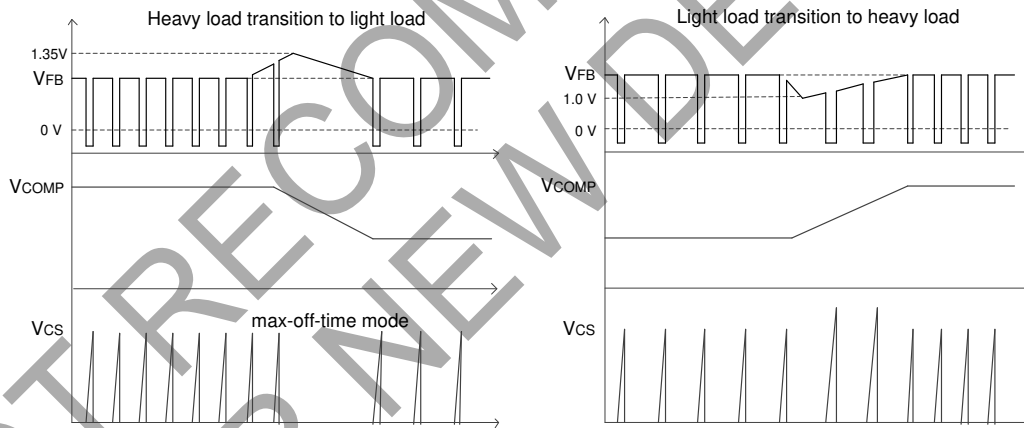
Figure 7. Load Transition Waveform

4. Protections

Output-Open Protection (AVCC_OVP; VFB_OVP)

The output voltage is reflected by the voltage on transformer's auxiliary winding. Both FB pin and AVCC pins have OVP function.

When there is a rapid line and load transient, the output voltage may exceed the regulated value. If V_{FB} exceeds V_{FB_OVP}, the OVP will be triggered, and then PFC controller increases the OFF time to reduce output voltage.

If AV_{CC} exceeds V_{AVCC_OVP} the OVP will be triggered, the switch will be turned off and AV_{CC} will be discharged. Once AV_{CC} is below $V_{AVCC\_OPR\_MIN}$, the PFC controller will shut down and power on again by BUS voltage through start up resistor.

Output Short Protection (OSP)

When the output is shorted, the output voltage is clamped to zero. The output voltage of the auxiliary winding, which is proportional to the secondary winding, will drop down too. Once AV_{CC} is below $V_{AVCC\_OPR\_MIN}$, the IC will shut down and power on again by the BUS voltage through the startup resistor.

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Functional Description (continued)

Over Current Protection (OCP)

The PFC controller has a built-in cycle-by-cycle OCP of primary inductor current. When CS pin voltage reaches the voltage V_{CS_OCP}, the switch will be turned off until the next switch period. The maximum peak current ($I_{PEAK\ (MAX)}$) of the inductor can be calculated as below:

$$I_{PEAK(MAX)} = \frac{V_{CS\_OCP}}{R_{CS}} \quad (3)$$

Where: V_{CS_OCP} means primary current clamp voltage that is 0.5V

R_{CS} is current sense resister shown as Figure 1

Over Temperature Protection (OTP)

The PFC controller has built-in OTP function. When the junction temperature goes up to shut down temperature, the OTP will be triggered, the switch will be shutdown. Until the junction temperature falls to the recovery temperature, the PFC controller will be restarted.

Single/Dual Dimmable Linear LED driver

The Single/Dual Channel Linear LED driver supports E-flicker free High Frequency PWM dimming with Deep Dimming Capability: Support 40KHz down to 4%, 10KHz down to 1.0%, 4KHz down to 0.4%, or 1KHz down to 0.1% with good dimming linearity. When no PWM signal is detected by the Linear LED driver, it will automatically enter the low-power mode for power saving purpose to be in compliance with Energy Star standby power requirement for SCL bulbs. It also integrates Adaptive Thermal Management (ATM) scheme to minimize non-productive power dissipation. The Linear LED driver has abundant of protection features, including Under-Voltage-Lockout (UVLO), LED string Open/Short protection and Over-temperature protection (OTP); when detecting these fault conditions, it will report the fault status on FAULTB pin.

1. Enable and Soft-Start LED Drivers

The Linear LED driver is enabled when the voltage at any PWMx pin is greater than approximately 2.5V, and disabled when all PWMx are lower than 0.4V. Upon any PWMx pin is asserted and DVCC pin is ramped up beyond minimum operation voltage, a soft start will be performed with a slew-rate-controlled current ramp over 200µs at LEDx output pins to minimize current overshoot through LED strings for optimal system reliability. When all PWMx are inactive for 4ms, The LED Driver will enter Low-Power mode with ultra-low standby power.

2. LED Current Setting and Capability

(1) LED Current Setting

The Linear LED driver is designed to have individual channel current set by its corresponding current setting R_{SET} resistor. The LED channel current level is expressed as below:

For AL1771:

$$ILED1 = 4000 * \frac{V_{REF}}{R_{SET1}}$$

For AL1772:

$$ILED1 = 2000 * \frac{V_{REF}}{R_{SET1}}$$

$$ILED2 = 2000 * \frac{V_{REF}}{R_{SET2}}$$

$$where\ V_{REF} = 1.5V\ nominally\ for\ all\ devices$$

For example, when an R_{SET} of 6kΩ is used, Channel 1 of AL1771 provides current of 1000mA. For the same R_{SET} setting, each channel of AL1772 provides same current amount of 500mA.

(2) LED Current Capability

The maximum current of each channel can drive up to 750mA with a total driving current up to 1500mA (refer to Table 1 below). The minimum channel current is recommended as in Table 2 in order to meet channel current accuracy and short protection specifications. Each channel can still be individually controlled by digital PWM dimming. The integrated low-side current sinks allow LED common-anode connections for cost effectiveness or different anode voltages for efficiency optimization.

—	Channel 1	Channel 2	Total IC Current
AL1771	1500mA	Not Applicable	1500mA
AL1772	750mA	750mA	1500mA

Table 1. Recommended Maximum Channel Current and Total IC Current for AL1771/1772

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Functional Description (continued)

—	Channel 1	Channel 2	Total IC Current
AL1771	300mA	Not Applicable	300mA
AL1772	150mA	150mA	300mA

Table 2. Recommended Minimum Channel Current and Total IC Current for AL1771/1772

Along with bus-mode fault reporting, multiple devices can be employed together to increase current driving capability or channel count versatility. The maximum LED current for the channel can be adjusted up to 1500mA via R$_{SET}$ resistor for AL1771 and 750mA for AL1772.

Any two or more channels can be tied together to drive one LED string with aggregated current. So when current needed for any channel is greater than the maximum value the device can provide, two or more channels or devices can be paralleled together to provide the drive current needed.

3. High Performance PWM Dimming

(1) Support High Frequency e-Flicker Free Dimming

For PWM-dimmed Light Sources, there are two important performance aspects to pay attention, namely, PWM frequency and deep dimming performance. While human eyes could not discern any flickering caused by PWM-dimming light sources over 200Hz, Electronic devices such as camera for smartphones could detect flickering (referred as e-Flicker) caused by certain much higher PWM-dimmed light sources. Generally speaking, the higher the PWM dimming signals applied to the light source, the less visible e-Flicker detected by electronic components.

The AL1771/1772 provides PWM dimming control. The PWM frequency is recommended to be greater than 500Hz. For e-Flicker free operation, 4kHz or higher frequency is recommended. High level of PWM signal will turn on the current sink to flow through the LED and low level of PWM signal will turn it off. Consequently, the LED current and LED brightness of each corresponding channel can be adjusted.

(2) Deep Dimming Capability

Measured light is linearly proportional to the measured current and PWM duty cycle. The perceived light by human eyes has a non-linear relationship with measured light. Human eyes are also found to be more sensitive to low light situations. For example, 10% measured light is perceived to be 32% of the original full light. 5% measured light is perceived to be 22% of the original full light. 1% measured light is perceived to be 10% of the original full light. Therefore, deep dimming capability is required to save significant energy as well as to provide adequate visible light output.

The pulse width of PWM signal applied to AL1771/1772 can be as low as 1µs to support down to 0.1%@1kHz deep dimming capability still with good linearity. Further deeper dimming through higher frequency PWM signals is possible which maintains reasonable linearity – 0.1%@1kHz, 0.4%@4kHz, or 1.0%@10kHz. PWM signals can be driven static low or high to turn off or on the corresponding channels constantly.

4. Low-Power Mode and Adaptive Thermal Management (ATM)

(1) Automatic Entrance/Exit to/ from Low-Power Mode

For SCL applications, the brightness and CCT tuning are done through LED emitter light mixing by changing average current through associated PWM signal of each emitter channel. When no PWM signal is detected by the Linear LED driver, it will automatically enter the low-power mode for power saving purpose. When in this low-power mode, the power consumption of the Linear LED driver is reduced to I$_{DVCC\_Low\_Power}$ (DVCC supply Current at Low-Power mode) * DVCC (Supply Voltage for Linear LED driver circuit). In the case of R$_{SET}$ is 6kΩ (for 500mA channel current in AL1772, I$_{DVCC\_Low\_Power}$ is 0.3mA) and DVCC is 25V, or 7.5mW for the LED driver portion. To be in compliance with Energy Star standby power requirement for SCL bulbs, this power saving is very significant.

When any PWM signal is detected, the Linear LED driver will automatically exit the low power mode and perform it designated functions properly.

(2) Adaptive Thermal Management (ATM) Scheme

The Input Voltage to drive all attached Emitter Strings needs to maintain voltage level over required total V$_F$ of emitter string plus minimum voltage headroom (VLED_REG). On the other hands, excessive voltage headroom provided needs to be absorbed by AL1771/1772, which increases heat dissipation to complicate thermal management. Power Good reporting serves as a mechanism to detect the LED power supply condition and adjust the supply voltage to LEDs through AC-DC voltage feedback in order to minimize unnecessary overdrive voltage to the LED Driver and optimize the efficiency.

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Functional Description (continued)

AL1771/1772 constantly detects and reports V_{LEDx} (voltage measured at Pin LEDx) output headroom condition by ejecting a voltage-adjustment current out of LEDPG pin. If the V_{LEDx} in any channel is lower than or close to the dropout voltage required by the regulator (V_{LED_REG}) while the channel is enabled with PWMx, there will be no voltage-adjustment current. During PWMx low period, internal LEDPG will not report insufficient headroom for that channel. If the V_{LEDx} voltage in each channel is higher than the dropout voltage required by the regulator (V_{LEDx_REG}), the LEDPG will inject the adjustment current. The ATM scheme utilizes LEDPG information and providesfeedback information to the power conversion circuitry to fine tune the LED power, to ensure minimum voltage headroom to drive emitter strings while maintain regulation channel current.

5. Protection Features and Fault Reporting

(1) Under Voltage Lockout

Under-voltage lockout function (UVLO) guarantees that the device is initially off during start-up. The Linear LED driver is not turned ON until the DVCC power supply has reached 6V. Whenever the DVCC input voltage falls below approximately 5.7V, the device is turned off. The UVLO circuit has a hysteresis of 300mV. During UVLO, a FAULTB status will be reported.

(2) LED Open and Short Protection

The AL1771/1772 detects the LED status by monitoring the current and voltage status of the LED strings. When an abnormal condition occurs (LED Open or LED Short), FAULTB is asserted low for 128ms and the abnormal channel will be retested afterward to check if the abnormal condition is cleared. LED driver will be re-activated if the abnormal condition is cleared. In the case of LED Open or Short, all non-affected channels remain in the normal operating condition.

(3) Over Temperature Protection

Thermal protection prevents the Linear LED driver from damage when the die temperature exceeds safe margins. The Linear LED driver features Over Temperature Protection (OTP). When the junction temperature reaches +160ºC, the Linear LED driver will enter thermal shut down mode in which all current sinks are shut down and no current flows to LED strings. The normal current level can be automatically restored to its set current from OTP by triggering a Soft Start when the temperature lowers down below +130ºC. LED Driver's Thermal Shutdown Mode will also be reported as a FAULTB.

(4) Fault Reports

Fault reporting serves as a good communication channel between LED drivers and intelligent MCU unit. AL1771/1772 detects and reports the FAULTB status upon the occurrence of Thermal Shutdown in OTP, LED Short, LED Open, and UVLO. FAULTB pin is an open-drain output design. Multiple devices can share a single FAULTB signal by connecting all FAULTB pins together with an external pull-up resistor. Any FAULTB assertion from any device pulls the signal down and informs MCU of the faulty condition.

Application Information

6. Examples of Smart Light Bulb and LED Panel Light

(1) System Configurations

Emerging smart LED light bulbs, including Tunable White and Tunable Color products used in either wired or wireless control applications, address human needs for energy saving, light quality scene setting and entertainment light management. Typical block diagram of a smart light bulb, consisting of four major functional blocks - PFC Power Conversion, Wireless/Color Management MCU, LED driver and an emitter module. AL1771/1772 fits well with emerging Smart Connected Light bulbs illustrating as below:

- 1-Channel Dimmable White (Figure 1) Brightness adjustment with Fixed Correlated Color Temperature (CCT) White
- 2-Channel Tunable White (Figure 2) CCT Tuning with range from 2,700k to 6,500k
- 4-Channel White+RGB (Figure 3) White +RGB color mixing

For wireless-enabled Smart Connected LED Panel Lights, Troffers, and Ceiling Lights, AL1771/1772 can be used to drive emitter string(s) for either 1-channel Dimmable White or 2-channel Tunable White applications as shown in Figure 1 and Figure 2. The AL1771/1772 can also be used to drive White+RBG 4-channel LEDs combined with AL1782 for color mixing application as shown in Figure 3.

(2) Interface with Emitter Strings and AL1771/1772

The AL1771/1772 PFC Power Conversion circuitry provides necessary output constant voltages (CVs) to power the MCU and the Linear LED Driver blocks of the entire smart light bulbs. Typical applications for smart light bulbs might require 3.3V for MCU and 12/24V for LED emitter strings of mainstream smart light bulbs. Anodes of top LED emitter strings are connected to 12/24V power supply. And cathodes of bottom LED emitter strings are connected to LEDx pins of AL1771/1772.

(3) Interface with Wireless/Color Management MCU and AL1771/1772

The main physical interfaces between MCU and AL1771/1772 are PWMx pins and FAULTB. MCU activates the PWMx (asserted high) to turn on AL1771/1772 in active state for normal LED lighting operation. When PWMx pins are asserted low for 4ms, the entire AL1771/1772 enters Low-Power mode with minimum power consumption. For typical light dimming or mixing operations, MCU generates proper PWM signals output through PWMx pins. In case of any general fault occurs in AL1771/1772, FAULTB pin is asserted LOW to interrupt MCU for proper actions.

(4) LED Driver Design Topology and Implementation

For AL1771/1772-powered LED Driver/Emitter block adopts a multi-channel LED driver structure with PWM dimming control for each channel. The parallel LED driver channel structure covers mainstream applications for Smart Connected Lighting products. Given the maximum allowable input voltage of 30V, AL1771/1772 can support a LED string up to 8 emitters of W, B, G (assuming LED Emitter Forward Voltage Drop, V_F~3.1V) or 10 emitters of R (assuming V_F~2.2V) in series typically. It is still possible to driver more than 8 emitters by slitting LED Emitter string voltage and AVCC/DVDD as long as AVCC and DVCC are below 30V.

For 1-channel Dimmable White (Figure 1), the Reference Current (I_{REF1}) of AL1771 is set by an external resistor R_{SET1}. In the case using 10kΩ as R_{SET1}, Channel 1 of AL1771 will be driving emitter string(s) with a total constant current of 600mA.

As an example of a 2-channel Tunable White light bulb design (Figure 2), an AL1772 drives two emitter strings, namely, CCTcold (6,500k) and CCTwarm (2,700k). Using R_{SET1} and R_{SET2} of 8.2kΩ, the maximum current for Channel 1 and Channel 2 will be 365mA if each PWM signal is turned on. The associated MCU could generate suitable PWM patterns to meet the required CCT tuning to target light output. The associated MCU could generate suitable PWM patterns to meet the required CCT tuning to target light output. R_{SET1} and R_{SET2} can also be set at different values to obtain different channel current if desired. However, the total channel current is advised not to exceed a total of 1,500mA with hard-limit to 750mA maximum for each channel.

Figure 3 describes how designer can use AL1772+AL1782 to drive more than two channel LEDs, specially in this case, to drive White+RGB LEDs for color mixing application. The AL1772 PFC CV stage produces three voltage outputs for white and RGB LED connections. 25V is used to connect with White LED Anode, 12V is for Green and Blue LEDs, and 8V is for Red LED. The White LED and Red LED cathodes are connected with AL1772 channel 1 and channel 2 respectively, and the Green and Blue LED cathodes are connected with AL1782 channels. In Figure 3, AL17050 high voltage BUCK converter is used to produce MCU power supply voltage 3.3V for high efficiency and low standby power considerations.

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Application Information (continued)

(5) Support Higher Current

While the recommended maximum ILED1 and ILED2 are at 750mA for AL1772, by setting R_{SET1} and R_{SET2} at 4kΩ, the system design can drive an LED string with higher current by connecting the cathodes of the LED emitter string to two or more LED channel outputs (LEDx) and associated PWM pins (PWMx) with the same PWM signal from the MCU. The result current through the LED emitter string is the sum of each current through the individual channels.

Similarly, it is also possible to further increase the current for a specific channel by connecting two or more AL1771/1772 IC chips in parallel and drive all associated PWM pins with a common PWM signal.

(6) Special System Design Considerations

Three key Smart Light Bulb system design issues need to be carefully planned for system efficiency consideration. Any headroom voltage (over total voltage drops for all LED emitters in a string) in each channel will result in additional power consumption for AL1771/1772, which needs to be dissipated by AL1771/1772. System designers are advised to carefully plan for well forward-voltage-matched LED strings with Constant Voltage (CV) regulators to ensure that AL1771/1772 can properly dissipate heat for normal operations.

V_F Matching for Emitter Strings:
It is crucial to match the total forward voltage drop (V_F) of each LED string attached to a CV for optimal system efficiency.

Multiple CVs to Match Emitter Module Design:
The PFC Power Conversion block may need to support multiple CV outputs to power all emitter strings in a Smart Light Bulb design.

Overall Thermal Management:
Though there are various protection mechanism built-in AL1771/1772, it is good practice to check maximum dimming pattern to avoid Thermal Shutdown (when AL1771/1772 junction temperature exceeds +160ºC). Thermal resistivity θ_{JA} (Junction-to-Ambient) of AL1771/1772 is 50 ºC/Watt. AL1771/1772 has to absorb any additional voltage headroom provided by the voltage input to the emitter strings. Therefore, thermal management of AL1771/1772 must follow the following guidelines:

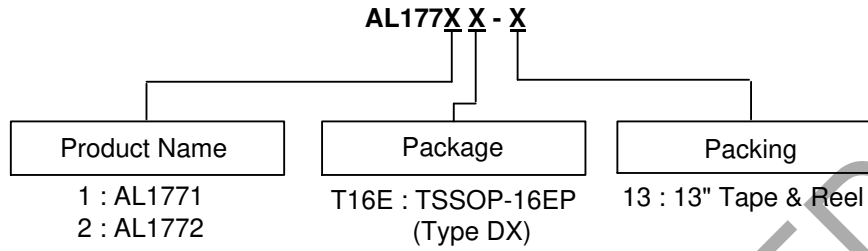PDmax (Maximum Power Dissipation of AL1771/1772) = (160ºC Junction Shutdown Temperature - Ambient Temperature, e.g. 85ºC) / 45ºC/W = 1.5Watts
PAmax (Power to be Absorbed by AL1771/1772) = $\Sigma(V_{LEDx}$ * Current through the emitter string * Associated PWM Dimming Duty Cycle) for all channels
Thermal Management Guideline   PAmax < PDmax

Ordering Information (Note 6)

AL177X X - X

Product Name	Package	Packing
1 : AL1771	T16E : TSSOP-16EP	13 : 13" Tape & Reel
2 : AL1772	(Type DX)	

Part Number	Package Code	Package	Packing	
			Qty.	Carrier
AL1771T16E-13	T16E	TSSOP-16EP (Type DX)	2500	13" Tape & Reel
AL1772T16E-13	T16E	TSSOP-16EP (Type DX)	2500	13" Tape & Reel

Note 6:   For packaging details, go to our website at https://www.diodes.com/design/support/packaging/diodes-packaging/.

Marking Information

(1) TSSOP-16EP (Type DX)

(Top View)

Logo

Part Number
AL1771
AL1772

YY : Year : 15,16,17~
WW : Week : 01~52; 52
represents 52 and 53 week
X X : Internal Code
E : TSSOP-16EP
(Type DX)

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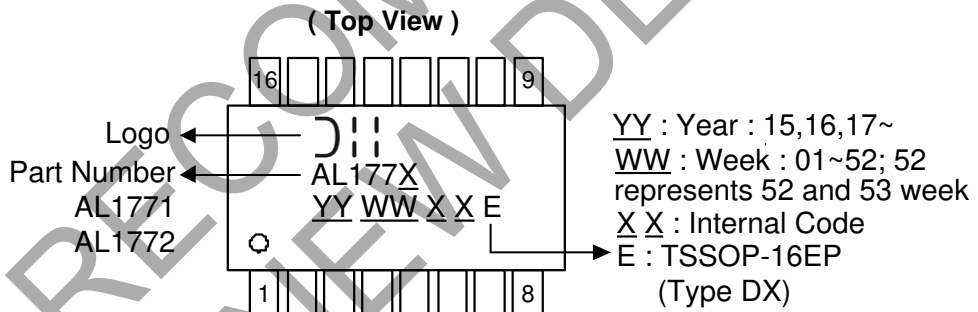
Package Outline Dimensions

Please see http://www.diodes.com/package-outlines.html for the latest version.

TSSOP-16EP (Type DX)

TSSOP-16EP (Type DX)			
Dim	**Min**	**Max**	**Typ**
A	--	1.08	--
A1	0.05	0.15	--
A2	0.80	0.93	--
b	0.19	0.30	--
c	0.09	0.20	--
D	4.90	5.10	--
D2	2.70	--	--
E	6.40 BSC		
E1	4.30	4.50	--
E2	2.50	--	--
e	0.65 BSC		
L	0.45	0.75	--
L1	1.00 REF		
L2	0.25 BSC		
R	0.09	--	--
R1	0.09	--	--
θ	0°	8°	--
θ1	5°	15°	--
θ2	0°	--	--
All Dimensions in mm			
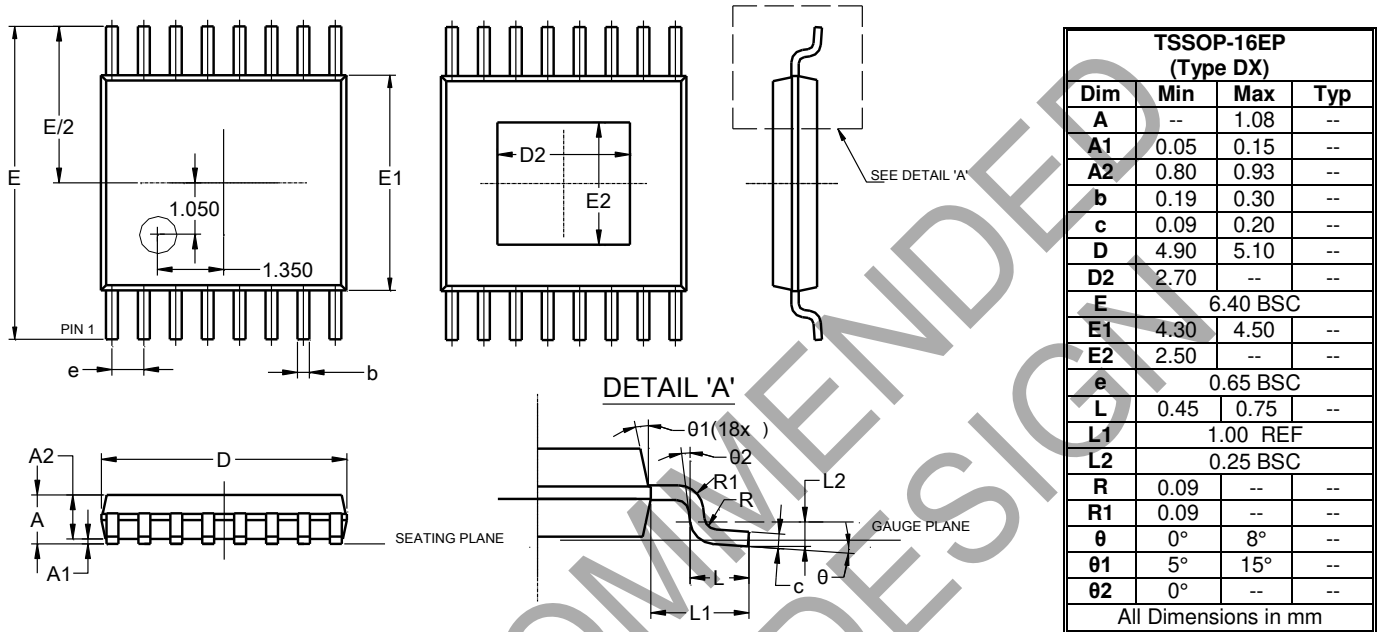
Suggested Pad Layout (Notes 7, 8)

Please see http://www.diodes.com/package-outlines.html for the latest version.

TSSOP-16EP (Type DX)

Dimensions	Value (in mm)
C	0.65
X	0.35
X1	2.94
X2	2.45
X3	4.90
Y	1.40
Y1	2.00
Y2	2.72
Y3	6.80
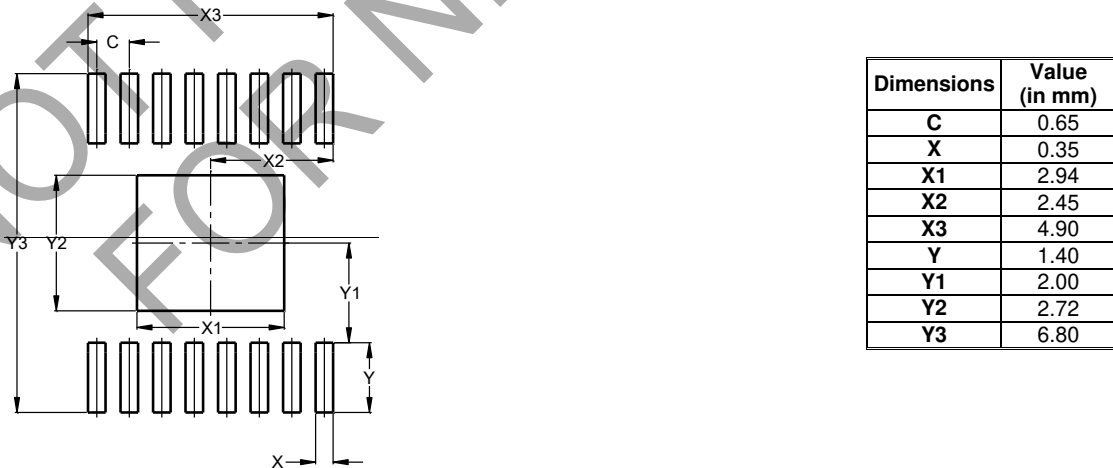
Notes: 7. The suggested land pattern dimensions have been provided for reference only, as actual pad layouts may vary depending on application. These dimensions may be modified based on user equipment capability or fabrication criteria. A more robust pattern may be desired for wave soldering and is calculated by adding 0.2 mm to the 'Z' dimension. For further information, please reference document IPC-7351A, Naming Convention for Standard SMT Land Patterns, and for International grid details, please see document IEC, Publication 97.

8. For high voltage applications, the appropriate industry sector guidelines should be considered with regards to creepage and clearance distances between device Terminals and PCB tracking.

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Minimum Packing Quantity (Notes 9, 10, 11)

| —	Quantity	Tape Width	Part Number Suffix
13" Reel	2,500	12mm	-13

Notes: 9. Package quantities given are for minimum packaging quantity only, not minimum order quantity. For minimum order quantity, please contact Sales department.
10. No mixed date codes or partial quantity (less than minimum packaging quantity) per packaging is allowed.
11. In no case shall there be two or more consecutive components missing from any reel for any reason.

Device Tape Orientation (Notes 12, 13)

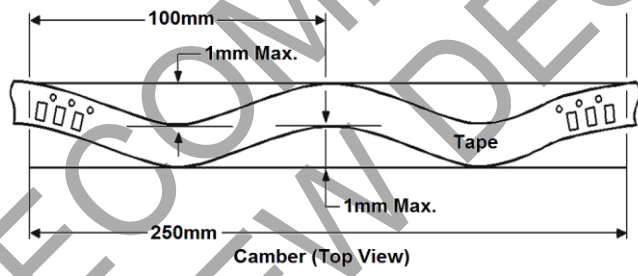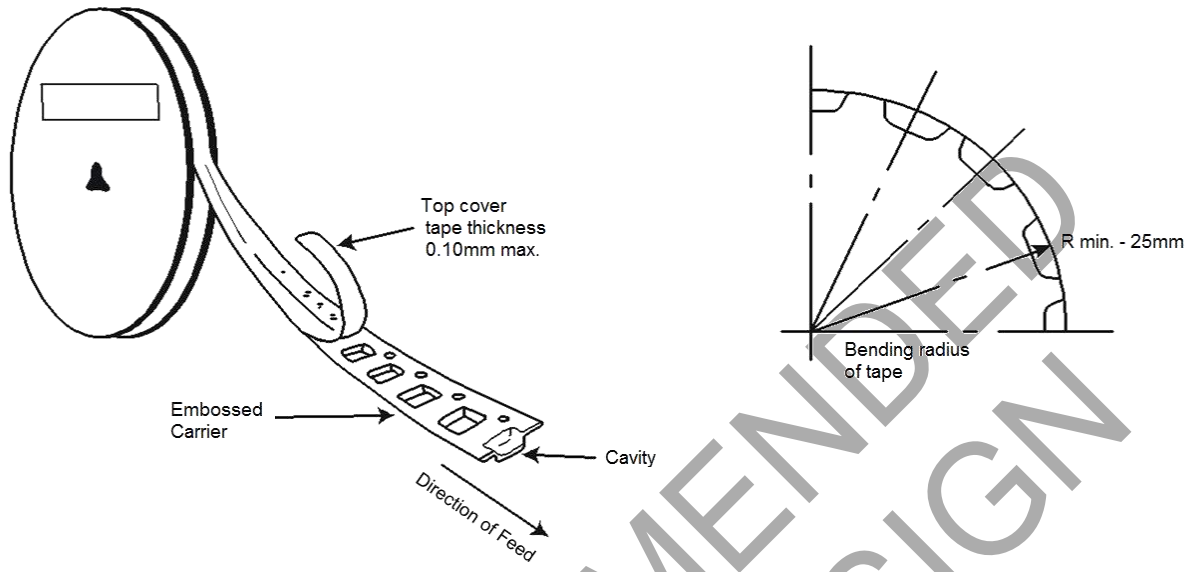| Tape Width	Part Number Suffix	Tape Orientation
12mm	-13	
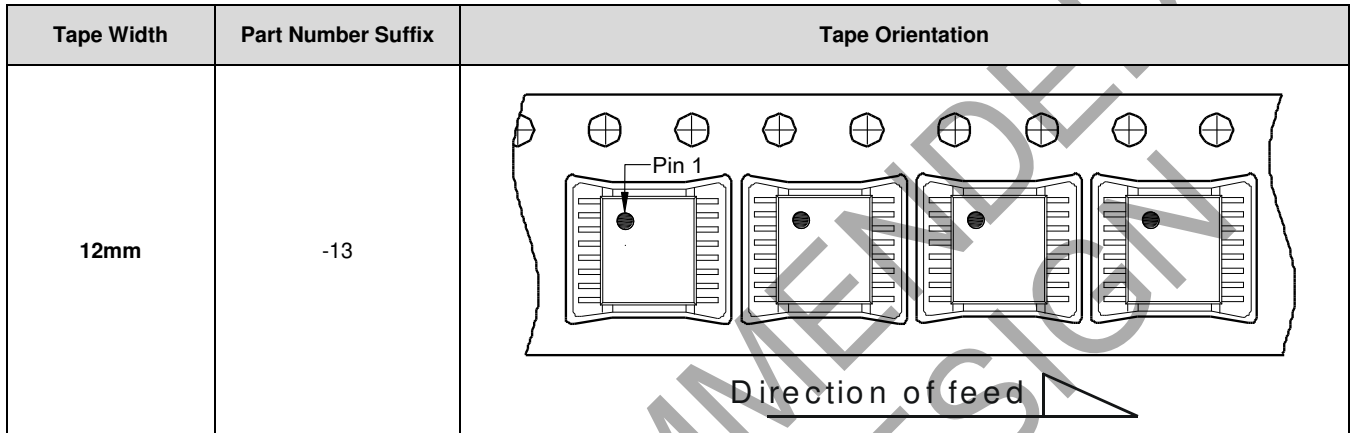
Notes: 12. For part marking, refer to product datasheet.
13. Tape and package drawings are not to scale and are shown for device tape orientation only.

Embossed Carrier Tape Specifications
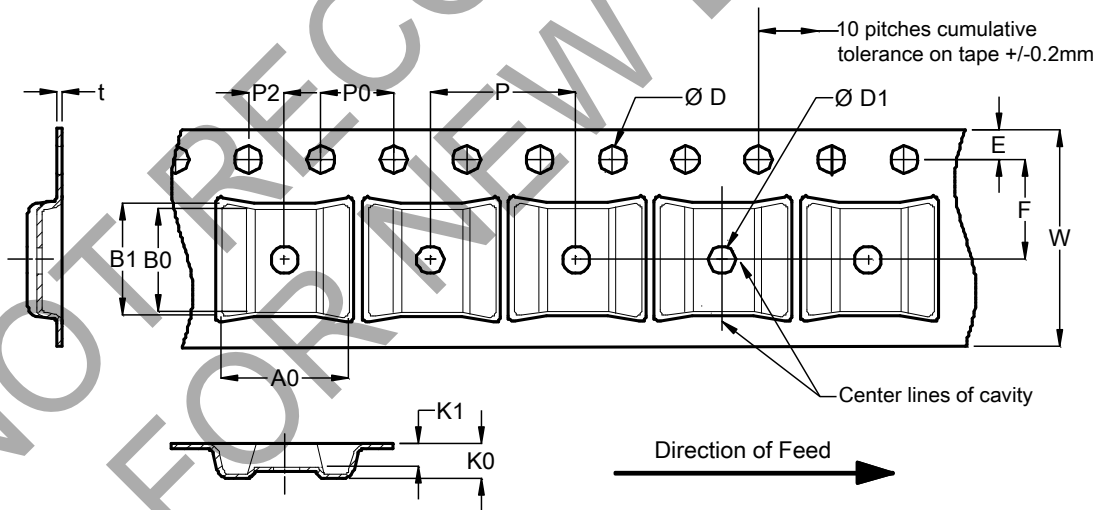
Tape Width (W)	Dimension	Value (mm)	Dimension	Value (mm)	Dimension	Value (mm)
12mm	A0	6.95	E	1.75 ± 0.10	P0	4.0 ± 0.10
	B0	5.60	F	5.50 ± 0.05	P2	2.0 ± 0.05
	B1	6.30	K0	1.60	t	0.30 ± 0.05
	D	1.50 + 0.1/-0.0	K1	1.20	W	12.0 ± 0.30
	D1	1.50 min	P	8.0 ± 0.10	—	—
	A0 B0 K0	The clearance between the component and the cavity must comply to the rotational and lateral movement requirement provided in figures in the "Maximum Component Movement in Tape Pocket" section.				

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Embossed Carrier Tape Specifications (continued)

Top cover
tape thickness
0.10mm max.

Embossed
Carrier

Cavity

Direction of Feed

R min. - 25mm

Bending radius
of tape

100mm

1mm Max.

Tape

250mm

1mm Max.

Camber (Top View)

Allowable camber to be 1mm/100mm tape, non-cumulative

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Maximum Component Movement in Tape Pocket

Component Lateral Movement
8mm Tape

0.5mm maximum

0.5mm maximum
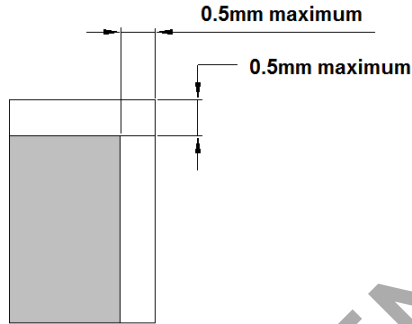
Maximum Component Rotation
Top View

20°

Typical Pocket Centerline

A0

B0

Typical Component Centerline
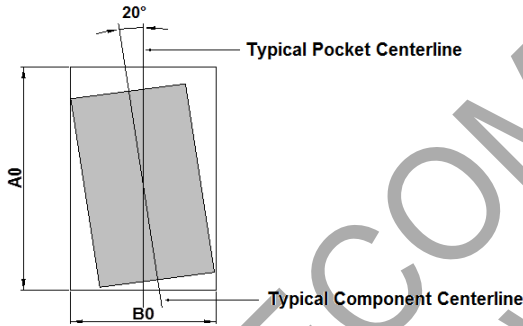
Maximum Component Rotation
Side View

20°

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Surface Mount Reel Specifications
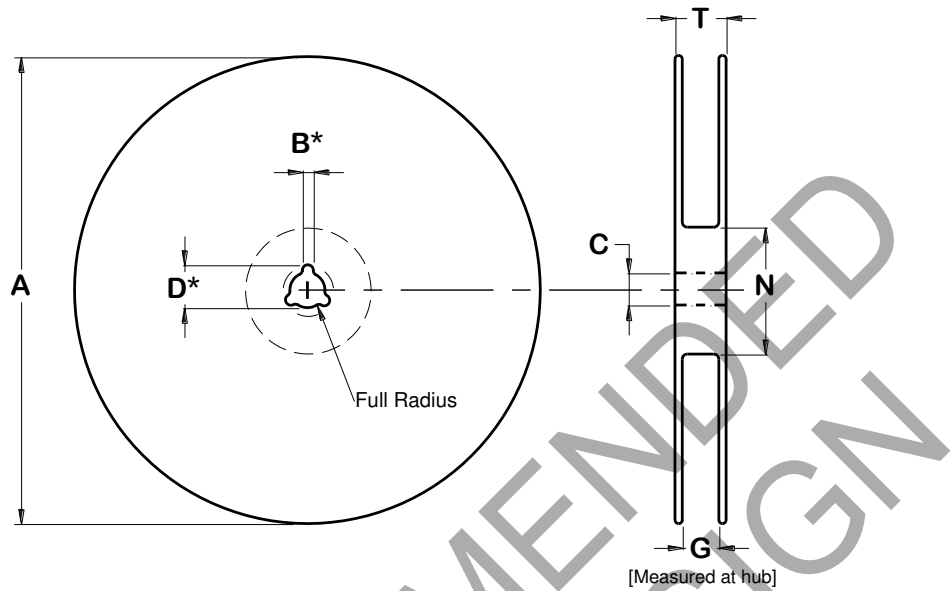
* Drive spokes optional. If used, dimensions with asterisks apply.

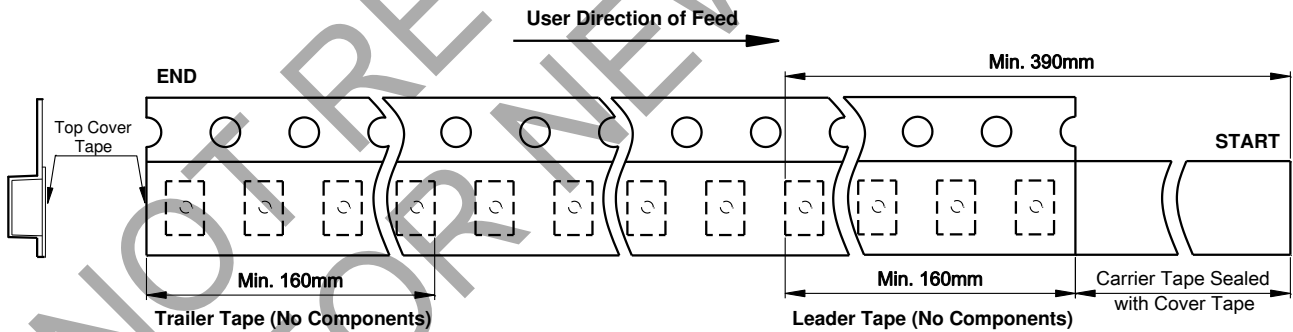| Tape Width	Reel Size	A (mm)	B Max (mm)	C (mm)	D Max (mm)	N Min (mm)	G (mm)	T Max (mm)
12mm	13"	330 ± 2	2.0 +0.5 -0	13 +0.5 -0.2	20.5 ± 0.2	100 ± 2	12.4 +2.0 -0.0	18.4

Tape Leader and Trailer Specifications (Notes 14, 15)

Notes: 14. There shall be a leader of at least 230mm which may consist of carrier tape and/or cover tape or a start tape followed by at least 160mm of empty carrier tape sealed with cover tape.
15. There shall be a trailer of at least 160mm of empty carrier tape sealed with cover tape. The entire carrier tape must release from the reel hub as the last portion of the tape unwinds from the reel without damage to the carrier tape and the remaining components in the cavities.

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