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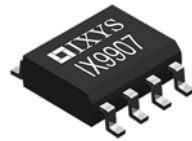

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IX9907
High Voltage, Dimmable
LED Driver with PFC Control

IXYS
INTEGRATED CIRCUITS DIVISION

Features

- Internal 650V, 2Ω power MOSFET
- Single stage, primary control with PFC and dimming features
- >90% efficiency
- Power factor >98%
- Wide operating voltage range
- Digital soft-start
- Foldback correction and cycle-by-cycle peak current control
- Output over-current and over-voltage protection
- Over-temperature protection
- Under-voltage lockout

Applications

- Incandescent Bulb Replacement
- Solid State Lighting
- Industrial and Commercial Lighting

Description

The IX9907 is a quasi-resonant controller optimized for phase-cut dimmable, off-line LED applications. Precise PWM generation supports phase-cut dimming and power factor correction.
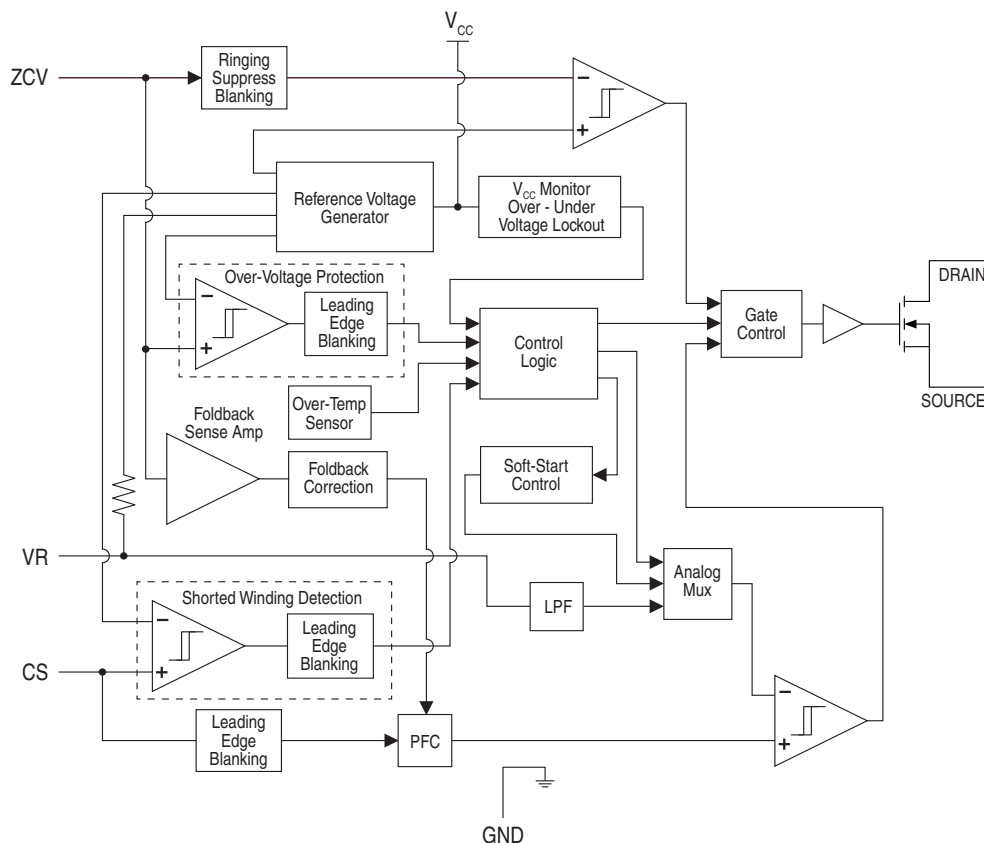
The IX9907 incorporates an internal 650V power MOSFET. It has a wide voltage operating range and low power consumption. Multiple safety features ensure full system protection under fault conditions. With its strong feature set and low cost, the IX9907 is an excellent choice for quasi-resonant, off-line flyback LED bulb designs.

The IX9907 is available in a standard 8-pin SOIC package.

Ordering Information

Part	Description
IX9907N	8-Pin SOIC (100/Tube)
IX9907NTR	8-Pin SOIC (2000/Reel)

IX9907 Functional Block Diagram

1. Specifications

1.1 Package Pinout

```
ZCV     [1]    ○        [8]  GND
VR      [2]             [7]  V_CC
CS      [3]             [6]  NC
SOURCE  [4]             [5]  DRAIN
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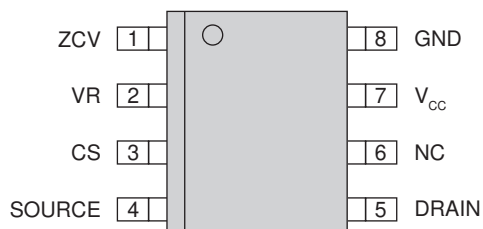
1.3 Pin Description

Pin#	Name	Description
1	ZCV	Zero crossing
2	VR	Voltage sense
3	CS	Current sense (Internally connected to SOURCE)
4	SOURCE	Power switch MOSFET source
5	DRAIN	Power switch MOSFET drain
6	NC	Not connected
7	V_{CC}	Controller power supply
8	GND	Controller ground

1.2 Absolute Maximum Ratings

Parameter	Symbol	Ratings	Unit
DRAIN Voltage	V_D	650	V
DRAIN Current	I_D	1.7	A
V_{CC} Supply Voltage	V_{CC}	-0.3 to 40	V
VR Voltage	V_{VR}	-0.3 to 5	V
ZCV Voltage	V_{ZCV}	-0.3 to 5	V
CS Voltage	V_{CS}	-0.3 to 5	V
SOURCE Voltage	V_S	-0.3 to 5	V
Maximum Current From ZCV Pin	I_{ZCVmax}	3	mA
Junction Temperature	T_J	- 40 to +150	°C
Storage Temperature	T_{STG}	- 55 to +150	°C
Thermal Impedance Junction to Ambient	θ_{JA}	125	°C/W

Absolute maximum electrical ratings are at 25°C.

1.4 Electrical Characteristics

T_J = - 25°C to +125°, V_{CC}=18V unless otherwise noted.

1.4.1 Power Supply

Parameter	Conditions	Symbol	Minimum	Typical	Maximum	Unit
Supply Current in Normal Operation	Power Switch OFF	I_{CC}	-	1.8	2.9	mA
V_{CC} Turn-On Threshold	-	V_{CCon}	17	18	19	V
V_{CC} Turn-Off Threshold	-	V_{CCoff}	9.8	10.5	11.2	V
V_{CC} Turn-On/Off Hysteresis	-	V_{CChys}	-	7.5	-	V

1.4.2 Internal Voltage Reference

Parameter	Conditions	Symbol	Minimum	Typical	Maximum	Unit
Internal Reference Voltage	Measured at VR Pin, I_{VR}=0	V_{VR}	4.8	5	5.2	V

1.4.3 PWM Section

Parameter	Conditions	Symbol	Minimum	Typical	Maximum	Unit
VR Pull-Up Resistor	-	R_{VR}	11	19	27	kΩ
PWM-OP Gain	-	G_{PWM}	2.95	3	3.05	-
Offset for Voltage Ramp	-	V_{PWM}	0.7	0.77	0.85	V
Maximum On-Time in Normal Operation	-	t_{onMax}	22	30	41	µs

1.4.4 Current Sense

Parameter	Conditions	Symbol	Minimum	Typical	Maximum	Unit
Current Sense Threshold	-	V_{CSTH}	0.97	1.03	1.09	V
Leading Edge Blanking Time	-	t_{BLKCS}	270	450	630	ns

1.4.5 Soft Start

Parameter	Conditions	Symbol	Minimum	Typical	Maximum	Unit
Soft-Start Time	-	t_{SS}	8.5	12	-	ms
Soft-Start Time Step	-	t_{SS-S}	-	3	-	ms
Internal Regulation Voltage at First Step	-	V_{SS1}	-	1.76	-	V
Internal Regulation Voltage Step at Soft Start	-	V_{SS-S}	-	0.56	-	V

1.4.6 Foldback Point Correction

Parameter	Conditions	Symbol	Minimum	Typical	Maximum	Unit
ZCV Current First Step Threshold	-	I_{ZCV_FS}	0.35	0.5	0.621	mA
ZCV Current Last Step Threshold	-	I_{ZCV_LS}	1.3	1.85	2.3	mA
CS Threshold Minimum	I_{ZC} = 2.3 mA, V_{VR} = 3.0V	V_{CSMF}	-	0.66	-	V

1.4.7 Digital Zero Crossing

Parameter	Conditions	Symbol	Minimum	Typical	Maximum	Unit
Zero Crossing Voltage	-	V_{ZCVCT}	50	100	170	mV
Ringing Suppression Threshold	-	V_{ZCVRS}	-	0.7	-	V
Minimum Ringing Suppression Time	$V_{ZC} > V_{ZCRS}$	t_{ZCRS1}	1.62	2.5	4.5	µs
Maximum Ringing Suppression Time	$V_{ZC} < V_{ZCRS}$	t_{ZCRS2}	-	42	-	µs
Maximum Restart Time in Normal Operation	-	t_{OffMax}	30	42	57.5	µs

1.4.8 Protection

Parameter	Conditions	Symbol	Minimum	Typical	Maximum	Unit
V_{CC} Overvoltage Threshold	-	V_{CCOVP}	23	25	26	V
Output Overvoltage Detection Threshold at the ZCV Pin	-	V_{ZCVOVP}	3.3	3.45	3.6	V
Blanking Time for Output Overvoltage Protection	-	t_{ZCVOVP}	-	100	-	µs
Threshold for Short Winding Protection	-	V_{CSSW}	1.58	1.68	1.78	V
Blanking Time for Short Winding Protection	-	t_{CSSW}	-	190	-	ns
Thermal Shutdown Temperature	Temperature Increasing	T_{JTSD}	-	140	-	°C

1.4.9 Output Switch

Parameter	Conditions	Symbol	Minimum	Typical	Maximum	Unit
Drain-Source On-State On-resistance	I_{DRAIN}=50mA, T_J=25°C	$R_{DS(ON)}$	-	2.0	2.3	Ω
	I_{DRAIN}=50mA, T_J=125°C		-	3.4	4	
Drain-Source Leakage Current	V_{DRAIN}=650V	I_{DSS}	-	0.6	100	µA

2. Functional Description

**Figure 1   IX9907 Typical Application**
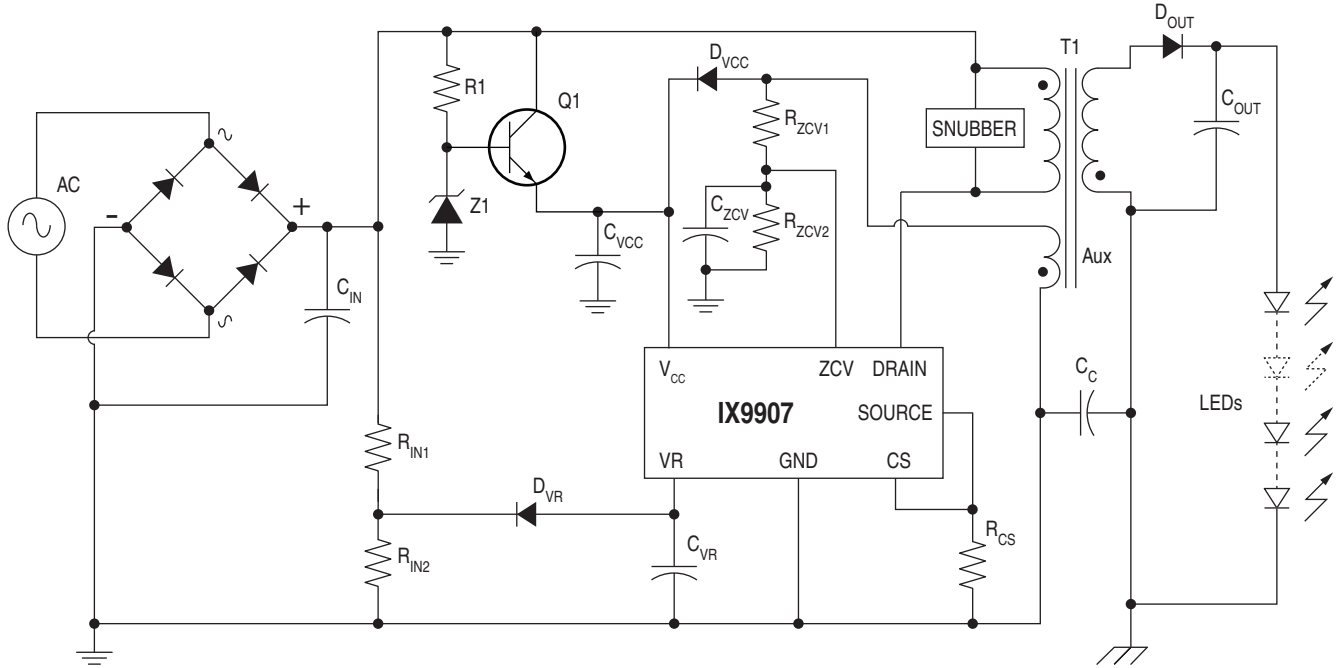
2.1 Soft Start

Once the main input voltage is applied, a rectified voltage will appear across C_{IN}. V_{CC} capacitor (C_{VCC}) will be charged during the power-up phase of operation through an external transistor. Once V_{CC} reaches $V_{VCC\_}$on (typically 18V), the device will

initiate a soft-start sequence. This is intended to minimize the electrical stresses on the device's MOSFET power switch, D_{OUT}, D_{VCC}, and the transformer. The soft-start operates as shown in **Figure 2**. The duration of this soft-start is 12mS nominal and steps V_{CS}, the current sense voltage, to four values, as shown.

Figure 2   Start-Up

Maximum Current (Sense Voltage) During Soft-Start
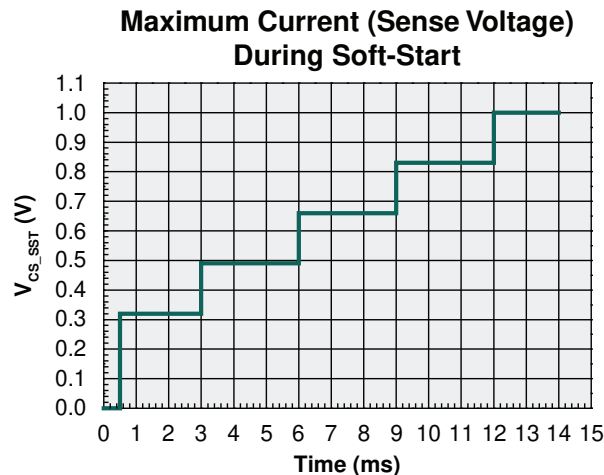
2.2 Normal Operation

Because the IX9907 employs quasi-resonant operation, its PWM switch-on is set by the zero crossing of the auxiliary winding voltage, and the switch-off is set by the current sense voltage.

2.2.1 Zero Crossing & Switch-On Determination

The application example in **Figure 1** shows that the voltage from the auxiliary winding is connected to the zero crossing pin, ZCV, through an RC network. This network provides a delay so that switch-on can occur at a voltage valley, thus enhancing efficiency. The required time delay, Δt, should be approximately one-fourth of the oscillation period (determined by the inductance of the transformer's primary and the drain-source capacitance of the built-in power switch MOSFET) minus the propagation delay from zero-cross detect to power switch-on, t_{delay}.

$$\Delta t = \frac{t_{OSC}}{4} - t_{delay}$$

This time delay, Δt, should be matched by adjusting the RC network.

$$t_{RC} = C_{ZCV} \bullet \frac{R_{ZCV1}}{R_{ZCV2}}$$

After the power switch is turned off, its V_{DS} will show some oscillation. This will also show on the ZCV input. To avoid a mis-triggered switch turn-on, a ringing suppression circuit is implemented. The suppression time has two values that depend on the voltage at ZCV. If V_{ZCV} is greater than 0.7V, then the time is 2.5μs nominal. If V_{ZCV} is less than 0.7V, then the time

is 42μs nominal. Turn-on of the power switch cannot occur during the suppression time, but does occur after a zero-crossing is detected. In the case of a missed zero-crossing, a maximum off-time is implemented. After the power switch has been off for 42μs nominal (t_{offMax}), it is turned back on.

2.2.2 Switch-Off Determination

In the application circuit the primary current is sensed by R_{CS}. The voltage across this resistor, V_{CS}, is applied to the CS input of the device. It is processed internally ($V_{CSINT} = V_{CS(3)} + 0.7V$), and compared to the voltage at the VR pin, which is a scaled version of the rectified line voltage. When $V_{CSINT} > VR$, the power switch is turned off.

Leading-edge blanking is used to prevent a false trigger caused by the voltage spike across R_{CS} at the moment of power switch turn-on. This blanking time, t_{BLKCS}, is nominally 450nS. To prevent transformer saturation, a maximum on-time circuit is implemented. Max on-time for the power switch is 30μs nominal.

2.2.3 Foldback Point Correction

When the AC line voltage increases, the power switch on-time decreases, which increases the operating frequency. As a result, with a constant primary current limit, the output power increases. To provide output power regulation with respect to line voltage, the internal foldback point correction circuit varies the V_{CS} limit. The V_{CS} limit is decreased in response to an increase in AC line voltage. The relationship between V_{CSMax} and V_{IN} is shown in **Figure 3**.

Figure 3 V_{CSMax} vs. V_{IN}

Variation of V_{CS} Limit Voltage With Respect to V_{IN}
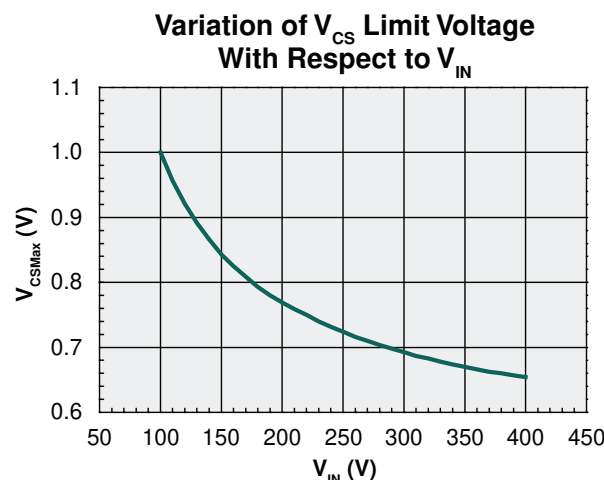
The variation in AC line voltage is sensed by way of the auxiliary winding and an internal clamp and current sense circuit. When the power switch is on, a negative voltage proportional to the line voltage is coupled to the auxiliary winding; the IX9907 will hold the ZCV pin very close to ground during this time. The

line voltage is thus sensed indirectly through the current in R_{ZCV1}. This current is given by:

$$I_{ZCV} = \frac{V_{IN} \bullet Na}{R_{ZCV1} \bullet Np}$$

The device uses I_{ZCV} to vary the V_{CS} limit as shown in **Figure 4**. The actual implementation is digital and is shown below.

Figure 4 V_{CS} vs. I_{ZC}
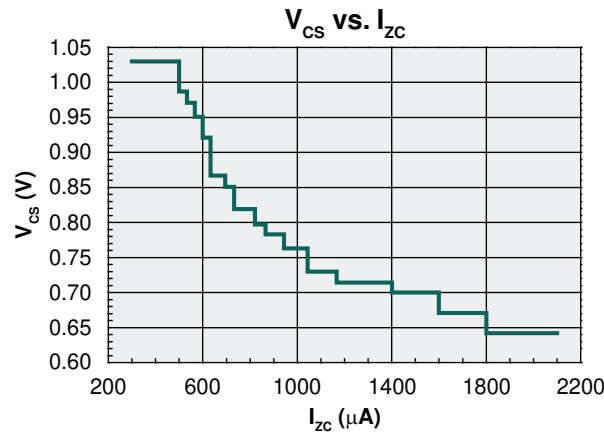
2.2.4 Protection Functions

The IX9907 provides comprehensive protection features. They are summarized in the table below:

Fault Condition	Action Taken
Output Over-Voltage	Power Switch Latched Off
Shorted Winding	Power Switch Latched Off
Over-Temperature	Auto-Restart Mode
V_{CC} Over-Voltage	Power Switch Latched Off
V_{CC} Under-Voltage	Auto-Restart Mode

OUTPUT OVER-VOLTAGE

During the power switch off-time the auxiliary winding voltage (V_{AUX}) will swing positive and in proportion to the secondary voltage. V_{AUX} is connected to ZCV through a resistor divider. If the voltage at ZCV exceeds a preset threshold (V_{ZCVOVP}) for longer than the blanking time (t_{ZCVOVP}), then the IC is latched off.

SHORTED WINDING

If the voltage at CS exceeds a preset threshold (V_{CSSW}) during the power switch on time the device is latched off.

OVER-TEMPERATURE

If the die temperature exceeds 140°C, then the device will enter the Auto-Restart Mode.

V_{CC} OVER-VOLTAGE / UNDER-VOLTAGE

The IX9907 continuously monitors the V_{CC} voltage. In case of an over-voltage event, the power switch is turned off and V_{CC} will begin to fall. Once V_{CC} goes below V_{CCoff} (10.5V nominal), and is recharged up to V_{CCon} (18.0V nominal), the device initiates a new soft-start. For an under-voltage event the operation is the same except that the sequence begins with $V_{CC} < V_{CCoff}$ so the power switch is off and V_{CC} starts to be charged through an external transistor. This operation describes the Auto-Restart Mode.

During Latch-Off Mode, the line voltage must be turned off and on again to begin normal operation.

3. Manufacturing Information

3.1 Moisture Sensitivity

All plastic encapsulated semiconductor packages are susceptible to moisture ingression. IXYS Integrated Circuits Division classifies its plastic encapsulated devices for moisture sensitivity according to the latest version of the joint industry standard, **IPC/JEDEC J-STD-020**, in force at the time of product evaluation. We test all of our products to the maximum conditions set forth in the standard, and guarantee proper operation of our devices when handled according to the limitations and information in that standard as well as to any limitations set forth in the information or standards referenced below.

Failure to adhere to the warnings or limitations as established by the listed specifications could result in reduced product performance, reduction of operable life, and/or reduction of overall reliability.

This product carries a **Moisture Sensitivity Level (MSL)** classification as shown below, and should be handled according to the requirements of the latest version of the joint industry standard **IPC/JEDEC J-STD-033**.

Device	Moisture Sensitivity Level (MSL) Classification
IX9907	MSL 1

3.2 ESD Sensitivity

This product is **ESD Sensitive**, and should be handled according to the industry standard **JESD-625**.

3.3 Soldering Profile

Provided in the table below is the Classification Temperature (T_C) of this product and the maximum dwell time the body temperature of this device may be above (T_C - 5)ºC. The classification temperature sets the Maximum Body Temperature allowed for this device during lead-free reflow processes. For through hole devices, and any other processes, the guidelines of **J-STD-020** must be observed.

| Device	Classification Temperature (T_C)	Dwell Time (t_p)	Max Reflow Cycles
IX9907	260°C	30 seconds	3

3.4 Board Wash

IXYS Integrated Circuits Division recommends the use of no-clean flux formulations. Board washing to reduce or remove flux residue following the solder reflow process is acceptable provided proper precautions are taken to prevent damage to the device. These precautions include but are not limited to: using a low pressure wash and providing a follow up bake cycle sufficient to remove any moisture trapped within the device due to the washing process. Due to the variability of the wash parameters used to clean the board, determination of the bake temperature and duration necessary to remove the moisture trapped within the package is the responsibility of the user (assembler). Cleaning or drying methods that employ ultrasonic energy may damage the device and should not be used. Additionally, the device must not be exposed to flux or solvents that are Chlorine- or Fluorine-based.
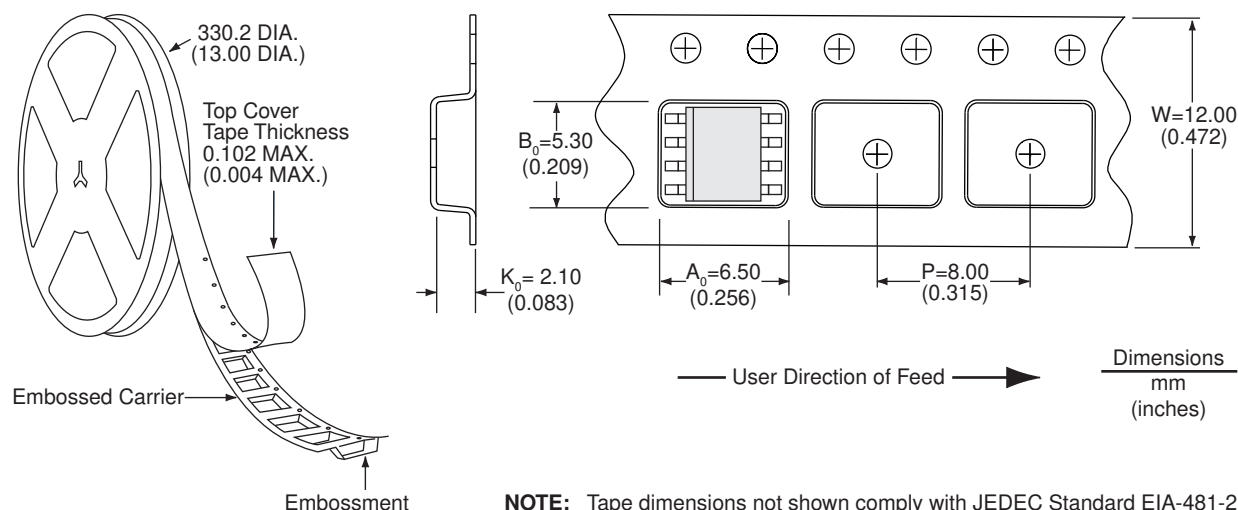
3.5 Package Dimensions
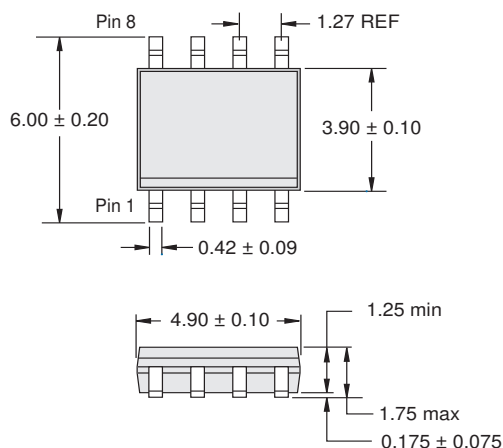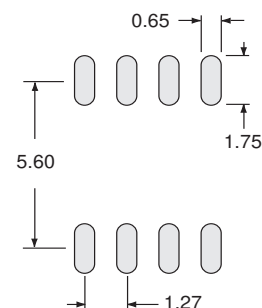
NOTES:
1. Complies with JEDEC Standard MS-012.
2. All dimensions are in millimeters.
3. Dimensions do not include mold flash or burrs

3.6 Tape & Reel Dimensions

NOTE: Tape dimensions not shown comply with JEDEC Standard EIA-481-2

For additional information please visit www.ixysic.com