Mains LED Driver IC – INDICE0101

- **Dimmable (Leading and Trailing edge)**
- **Zero voltage switching, resonant topology**
- **Active Temperature Management**

KEY FEATURES

- 204VAC – 264VAC for 240V systems and 90VAC – 130VAC for 110V systems
- High power factor: > 0.92 (over 0.975 can be configured)
- High efficiency: Typically 85% including all system losses such as the rectifier and EMC filter
- Zero voltage switching topology allows >500KHz switching frequency
- Current inrush limiting brake dramatically reducing need for over voltage silicon
- Programmable temperature regulation, from 67 to 92 ℃.
- Clock-less, asynchronous operation of primary switching reduces EMI test compliance issues.
- Compatible with leading edge and trailing edge phase cut dimmer circuits
- Small module size allows an easy integration into final products.
- Drive power scalable from 20W to 100W with the correct selection of switching silicon and magnetic parts.
- Suitable for a wide variety of LED string voltages

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1 Introduction

1.1 Overview

The Indice Light Emitting Diode (LED) Driver Chip offers a fast development path to deliver a product to market quickly for mains (110V or 240V) voltage lighting solutions. Unique to Indice is our direct dimmer compatibility technology which takes the headaches out of the product development by providing a fully functional reference design. The chip allows for the production of module that offers manufacturers a compact and flexible high power source, extremely efficient driver for LED lighting. The module is compatible with nearly all leading and trailing edge phase cut[1]. Features include high speed, asynchronous control scheme and configurable output for matching LED voltage and power requirements.

1.2 Implementation benefits

Indice's implementation of the mains voltage controller is a derivative of a Class E, offering significant advantages and benefits over conventional implementations of hard switched or quasi soft switched circuits.

The circuit operates with zero voltage switching (ZVS) virtually eliminating switching losses. This combined with asynchronous operation results in a great reduction in broad band EMI. The ability to operate at higher frequencies means smaller, lighter and cheaper magnetic components. Tank current is near sinusoidal so the stress on the output rectifiers is low. The voltage waveforms are semi sinusoid across main switching devices which further reduce broadband EMI. Another major advantage is that the peak voltage stress across these devices occurs at very low currents. In the event of line surges avalanche events occur with little energy dissipation compared to conventional circuit options. Transient suppression is an inherent part of the circuit which dramatically reduces the need for expensive over voltage silicon.

The flat input current draw is friendly to dimmer circuits and has minimal inherent turn on transients due to very low rectifier capacitance (typically >10nF). Power factor is naturally > 0.92 which reduces implementation cost and only requires 1 stage for implementation. The control costs are an order of magnitude lower than other published control schemes, supporting low end consumer applications such as LED lighting.

The Indice patent pending self-resonating, digital control scheme overcomes inherent instabilities with traditional Class E approaches. This means that the unit can be programmed to suit low end consumer applications.

1.3 Chip Benefits

The Indice LED Driver Chip is a leading edge silicon device that has the following benefits:

- **Small Package:** The control chip is supplied in a 16 pin QFN package to minimize consumed board space.
- **Low Voltage Supply:** The controller chip operates on a stable 3.3V supply.
- **Low Power:** The control chip implements power saving features which significantly reduce its power consumption during normal operation.
- **Temperature Select:** The temperature select pin allows engineers to customize the target temperature regulation for normal operation.
- **Output Power Select:** The output power select pin allows engineers to customize the maximum desired output power before thermal management is engaged.
- **Power Normalisation:** Allows system power draw on varying supplies to be normalized to a more consistent value.

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[1] Dependent upon total power draw on dimmer

- **Asynchronous Drive:** The controller chip switches asynchronously, which helps to reduce Electro-Magnetic Interference (EMI) by spreading emissions over a large frequency band.

1.4 System Benefits

Indice LED Driver Chip is also available in customized control modules with the following unique benefits:

- **Dimmable:** Our control chip provides dimming with most existing dimmers globally[1].
- **High power factor:** Greater than 0.92 meeting the US Energy Star requirements.
- **EMC Compliance:** Meets Class B requirements for CISPR 15/22, FCC Part 15 and EN55022.
- **Active temperature management:** Our controller continuously monitors the operating temperature of the lamp adjusting power accordingly which maximises LED life and brightness.
- **Active Power Management**: Our control chip actively monitors the current through the LED ensuring that it runs within the manufacturer's specification.

1.5 Suggested Applications

- LED panel drivers requiring dimming
- Incandescent or halogen lamp replacement drivers
- Architectural lighting
- Emergency lighting systems.

1.6 Support Contacts

The following key contacts should be used for any additional correspondence and queries in response to this document.

Email	support@indicesemi.com
Phone	+1 971 317 8886 (9am – 5pm, Mon – Fri, US Pacific Time)

[1] Refer to the Indice dimmer compatibility chart for complete details.

1.7 Device Pin Out

Below in Figure 1 and Table 1 are details on the pin out and pin functions for the Indice LED Driver Chip.

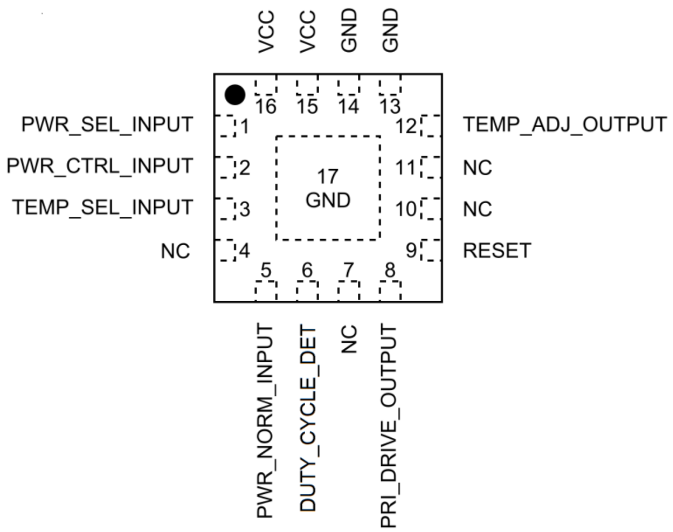

Figure 1: Top view of Indice LED Driver Chip QFN 16 package, with pins labelled. Dotted Lines indicate pins on bottom of chip.

Name	Pin Number	I/O	A/D	Description
PWR_SEL_INPUT	1	I	A	Control power select input pin.
PWR_CTRL_INPUT	2	I	A	Power control input pin.
TEMP_SEL_INPUT	3	I	A	Temperature level select pin.
NC	4	-	-	Pin not connected. (Reserved for later expansion.)
PWR_NORM_INPUT	5	I	D	Power normalisation input pin.
DUTY_CYCLE_DET	6	I	D	Duty cycle detect
NC	7	-	-	Pin not connected. (Reserved for later expansion.)
PRI_DRIVE_OUTPUT	8	O	D	Primary drive output pin.
RESET	9	I	D	Reset input pin.
NC	10	-	-	Pin not connected. (Reserved for later expansion.)
NC	11	-	-	Pin not connected. (Reserved for later expansion.)
TEMP_ADJ_OUTPUT	12	O	D	Temperature adjustment output pin.
GND	13	-	-	Ground reference.
GND	14	-	-	Ground reference.
V_{CC}	15	-	-	3.3 V supply voltage.
V_{CC}	16	-	-	3.3 V supply voltage.
GND	17	-	-	Ground reference.

Table 1: Pin functions of Indice LED Driver Chip. I/O column indicates either I – Input or O – Output. A/D column indicates either A – Analogue or D – Digital.

1.8 Basic System Diagram

A system diagram depicting the INDICE0101 chip being used in a simplified LED driver is presented in Figure 2.

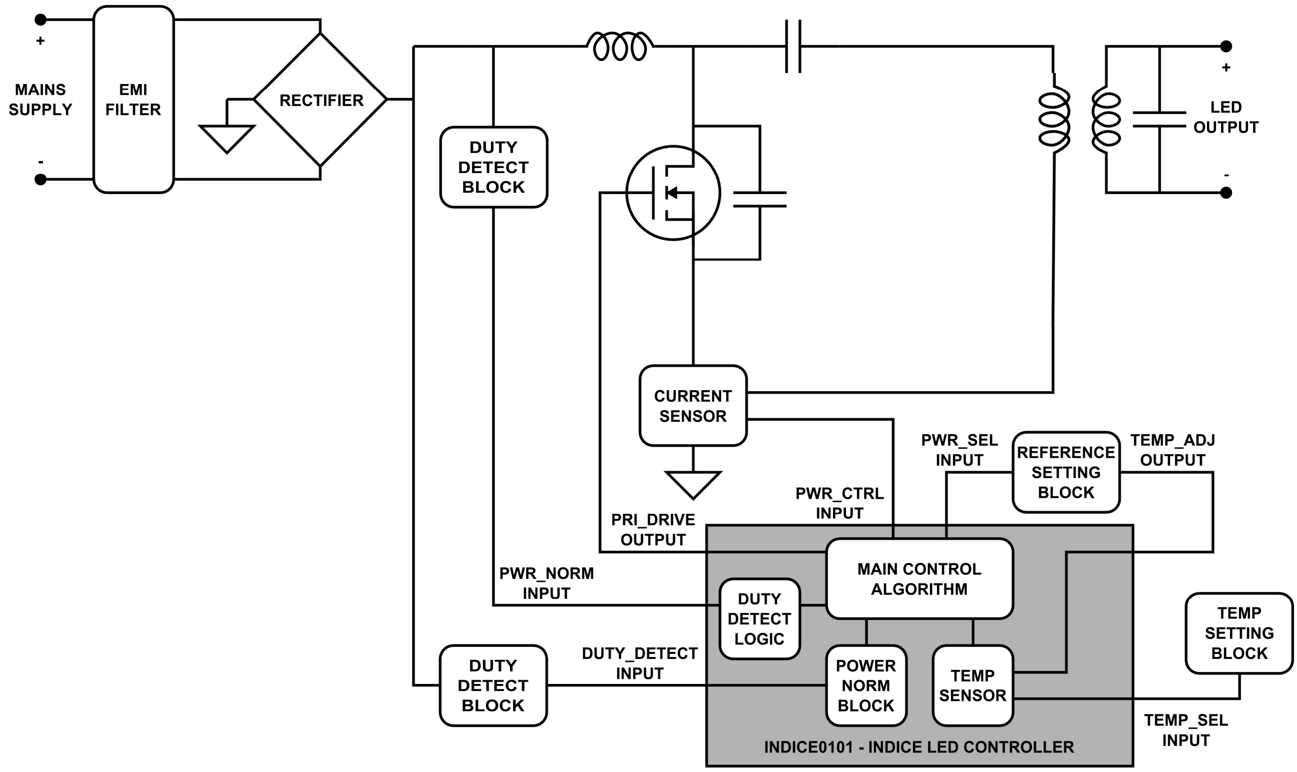

Figure 2: Simplified system diagram of INDICE0101 chip.

2 Operating Conditions

2.1 Absolute Maximum Ratings

Subjecting the Indice LED Driver chip to any conditions beyond those listed in this section may cause permanent damage to the device. These are maximum condition ratings only. Exposure to the absolute maximum rated conditions for long periods can adversely affect device reliability. Proper operation of the device under any conditions, other than those indicated in the “Recommended Operational Conditions” section, is not implied. Absolute maximum ratings of the Indice LED Driver Chip are included in Table 2.

GND pin to V_{CC} pin voltage.	-0.3 V to 4.1 V
Any other pin voltage. (Referenced to GND pin voltage.)	-0.3 V to V_{CC} + 0.3 V
Storage temperature range. $T_{STORAGE}$ (1).	-55 °C to 150 °C

(1) Higher temperatures can be applied during board soldering according to current JEDEC J-STD-020 standards specification. Peak reflow temperatures should not exceed those classified on the device packaging.

Table 2: Absolute maximum ratings of the Indice LED Driver Chip.

2.2 Recommended Operational Conditions

Recommended operational conditions for the Indice LED Driver Chip are given in Table 3.

GND pin voltage.	0 V
V_{CC} pin voltage. (Referenced to GND pin voltage.)	2.2 V to 3.6 V
Operating ambient free air temperature. T_A	-40 °C to 92 °C
Typical current draw	3mA

Table 3: Recommended operational conditions of the Indice LED Driver Chip.

2.3 Input Pin Operation

The measured operational characteristics of the Indice LED Driver Chip input pins are presented below, in Table 4. Leakage data on all high impedance input pins is given in Table 5. All of these values are measured over recommended supply voltages and operating ambient free air temperatures (unless otherwise stated.)

Parameter	Test Conditions	MIN	TYP	MAX	Unit
Rising edge input threshold voltage. V_{IT+}	V_{CC} = 3 V.	1.35		2.25	V
Falling edge input threshold voltage. V_{IT-}	V_{CC} = 3 V.	0.75		1.65	V
Input voltage hysteresis. $V_{HYS} = (V_{IT+} - V_{IT-)}$	V_{CC} = 3 V.	0.3		1	V
Input capacitance. C_{IN}	GND or V_{CC} applied to pin.		5		pF

Table 4: Input pin operation of the Indice LED Driver Chip.

Parameter	Test Conditions	MIN	TYP	MAX	Unit
Input leakage current. I_{LEAK}	V_{CC} = 3 V (1).			±50	nA

(1) Leakage current measured with pin attached to GND or VCC. Each pin measured individually.

Table 5: High impedance input pin leakage operation of the Indice LED Driver Chip.

2.4 Output Pin Operation

The measured operational characteristics of the Indice LED Driver Chip output pins are presented below, in Table 6. These values are measured over recommended supply voltages and operating ambient free air temperatures (unless otherwise stated.)

Parameter	Test Conditions	MIN TYP MAX	Unit
High output voltage V_{OH}	V_{CC} = 3 V, I_{MAX} = 6 mA delivered.	V_{CC} – 0.3	V
Low output voltage V_{OL}	V_{CC} = 3 V, I_{MAX} = 6 mA drawn.	GND + 0.3	V

Table 6: Output pin operation of the Indice LED Driver Chip.

3 Chip Functionality

3.1 Primary Drive

The primary drive signal, PRI_DRIVE_OUTPUT, is used in conjunction with the power select and power control inputs, PWR_SEL_INPUT and PWR_CTRL_INPUT respectively, to provide closed loop control of the output power.

In terms of the basic control system, shown below in Figure 3, the PRI_DRIVE_OUTPUT signal can be considered as the control logic output into the system. The control logic itself is implemented within the Indice LED Driver Chip, along with some conditioning of the reference and sensor signals before comparison.

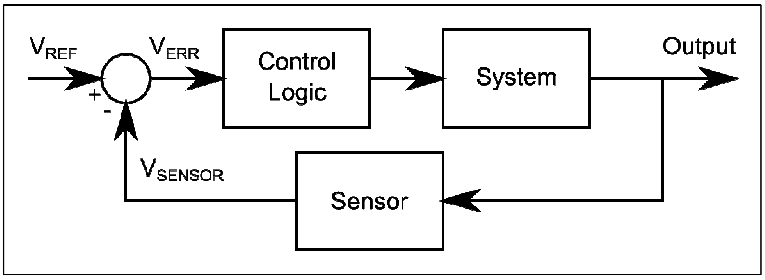

Figure 3: Basic closed loop control system. The figure shows the basic transfer blocks and the comparison of reference and sensor signals, V_{REF} and V_{SENSOR}, to produce the error signal, V_{ERR}.

The result of the conditioning, comparison and control logic is a digital drive line out of PRI_DRIVE_OUTPUT. This digital drive can be used to drive the primary switching element of an LED power converter circuit.

The controller assumes that this controller output is coupled to the output power though the system as shown in Figure 3, such that outputting a high level will increase the output power, while outputting a low level will decrease the output power. This relationship must hold in order to achieve closed loop control of the system.

3.2 Power Select Input

The power select input line, PWR_SEL_INPUT, is used to set the level that the control system is seeking to achieve on the power control input line, PWR_CTRL_INPUT. Control is then achieved by varying the primary drive signal, PRI_DRIVE_OUTPUT, in accordance with changes to both input signals.

With respect to the basic control system, shown previously in Figure 3, PWR_SEL_INPUT can be considered more generally as the reference signal used for the control comparison.

The signal undergoes some conditioning before comparison, so control system calculations should not be carried out based solely on raw signal comparisons.

3.3 Power Control Input

The power control input line, PWR_CTRL_INPUT, is used as an input point for output sensor information, closing the control loop and allowing for stable output power to the load LEDs.

PWR_CTRL_INPUT can be thought of as the sensor signal used in the basic control system shown above in Figure 3.

The signal undergoes some conditioning before comparison, so control system calculations should not be carried out based solely on raw signal comparisons.

3.4 Temperature Adjustment Output

The temperature adjustment output, TEMP_ADJ_OUTPUT, is a varying duty cycle output, at approximately 3.9 kHz. The duty cycle of this waveform adjusts according to internal temperature control logic operating based on an internal temperature sensor. This signal can be used as an adjustment to the overall system power in order to maintain a constant control chip temperature. This is particularly useful if the control module and chip have tight thermal coupling to the output LEDs, because the signal then allows for the output power to be varied in order to keep the output LEDs at a suitable running temperature.

TEMP_ADJ_OUTPUT starts at 100% duty cycle. Given a high enough system power draw this will begin to raise the system temperature towards the selected temperature level.

The system then implements a 2nd order z-transform to target the desired temperature level. As the temperature of the system nears the selected temperature setting TEMP_ADJ_OUTPUT will begin to reduce the duty cycle to control the temperature. Continued raising temperature above the selected temperature setting will result in TEMP_ADJ_OUTPUT dropping to a 0% duty cycle.

3.5 Temperature Level Select Input

The temperature level select input, TEMP_SEL_INPUT, is an analogue input used for setting the target temperature level for the temperature control system. The input takes an analogue signal from 0 V to 1.5V and quantises this into 16 V levels.

In order to set a particular temperature level it is best to input a voltage between the 0.1 V quantisation levels. The input signal will then be rounded down to the nearest quantisation level by the internal chip logic. Included in Table 7 below are the recommended voltage settings and their associated temperature set point.

Level	Recommended Voltage	Resulting Temperature
0	0.05 V	67 ℃
1	0.15 V	69 ℃
2	0.25 V	70 ℃
3	0.35 V	72 ℃
4	0.45 V	74 ℃
5	0.55 V	75 ℃
6	0.65 V	77 ℃
7	0.75 V	79 ℃
8	0.85 V	80 ℃
9	0.95 V	82 ℃
10	1.05 V	84 ℃
11	1.15 V	85 ℃
12	1.25 V	87 ℃
13	1.35 V	89 ℃
14	1.45 V	90 ℃
15	1.5 V	92 ℃

Table 7: Various target temperature settings. For each setting the recommended input voltage is given and the resulting target temperature.

3.6 Power Normalisation Input

The power normalisation input, PWR_NORM_INPUT, is used to interface with the Indice LED Driver Chip's power normalisation logic.

The power normalisation logic is designed to monitor a conditioned version of the rectified supply voltage and uses this information to normalise the LED power based on the input voltage.

The normalisation process is carried out by biasing the TEMP_ADJ_OUTPUT output. This biasing is undertaken at a slow rate of 2 Hz and can take up to 1 min to complete the adjustment process.

The power normalisation logic can be disabled by connecting the PWR_NORM_INPUT pin to GND with a 47 kΩ pull-down.

3.7 Duty Cycle Detect

This input is used in conjunction with power normalisation input to detect whether the lamp is connected to a phase cut dimmer circuit. The duty cycle detect provides close to same driver power for the LED when it is connected to AC mains or a dimmer set at full output power.

The normalisation process is carried out by biasing the TEMP_ADJ_OUTPUT output. This biasing is undertaken at a slow rate of 2 Hz and can take up to 1 min to complete the adjustment process.

The power normalisation logic can be disabled by connecting the PWR_NORM_INPUT pin to GND with a 47 kΩ pull-down.

3.8 Reset

The reset line, RESET, is an active low line that allows for the resetting of the Indice LED Driver Chip. This is useful for clearing and resetting the temperature level settings, as these settings are measured from the TEMP_SEL_INPUT and stored at system start-up.

It is advised that RESET be tied to VCC, by a 47 kΩ pull-up, during normal operation.

A voltage level of $<V_{IT-}$ on RESET will cause a reset event.

4 Chip Packaging

Below in Figure 4 are the dimensions of the QFN16 package used for the Indice LED Driver Chip.

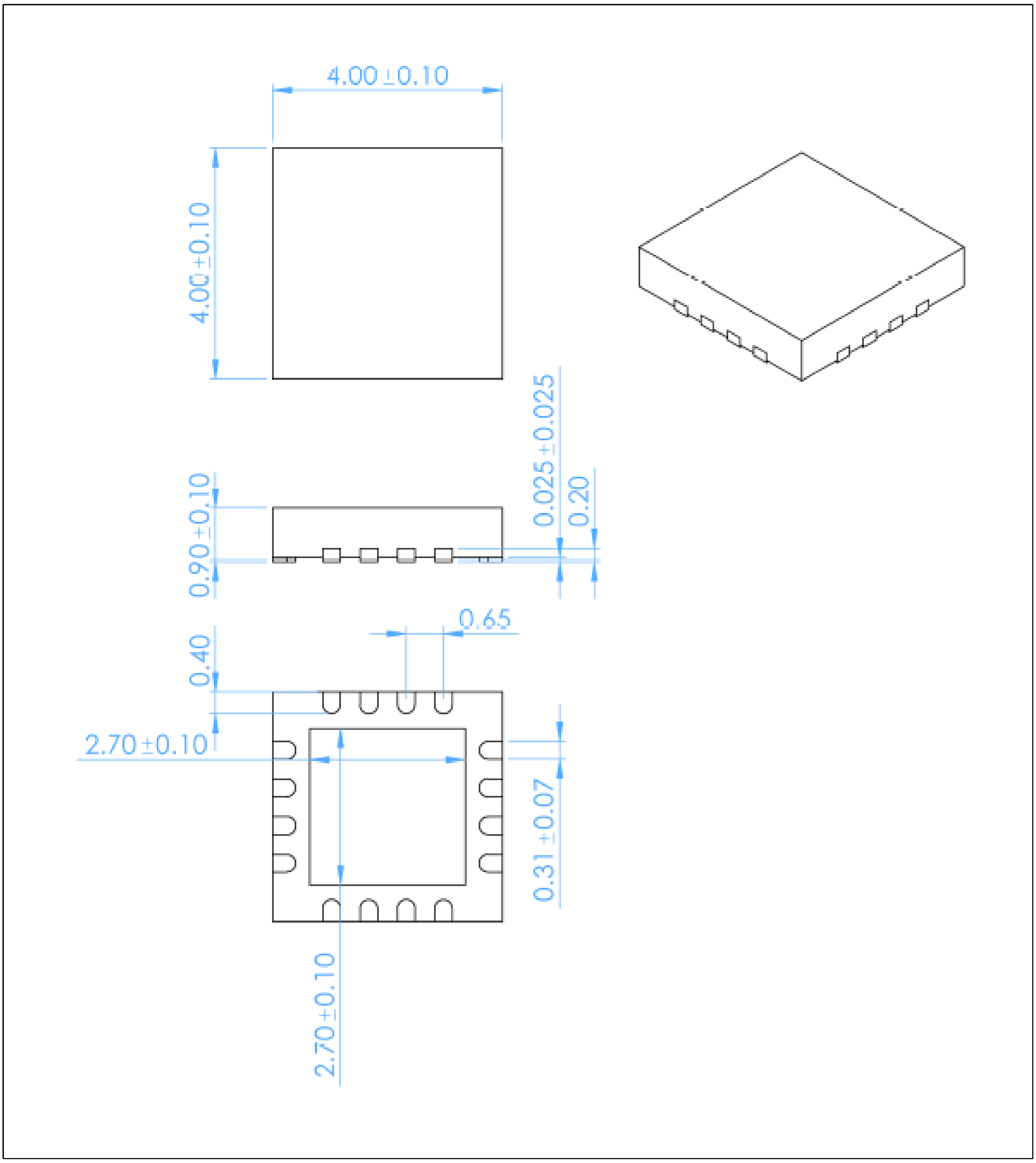

Figure 4: Package details. All noted dimensions in mm. Not to scale.

5 PCB Footprint

The suggested dimensions for PCB footprint and solder paste stencils are presented in Figure 5 and Figure 6 respectively.

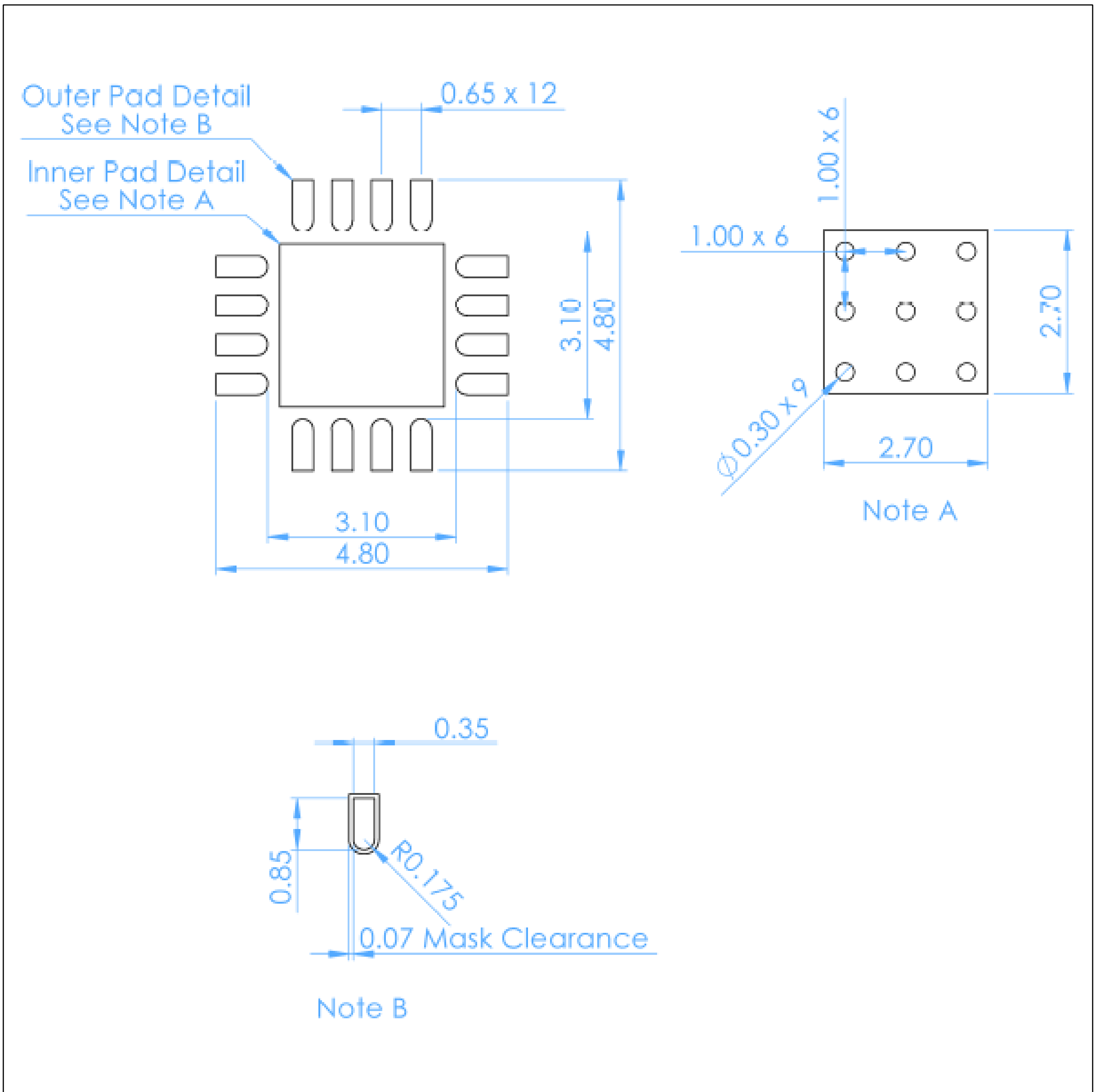

Figure 5: Suggested PCB footprint. All noted dimensions in mm. Not to scale.

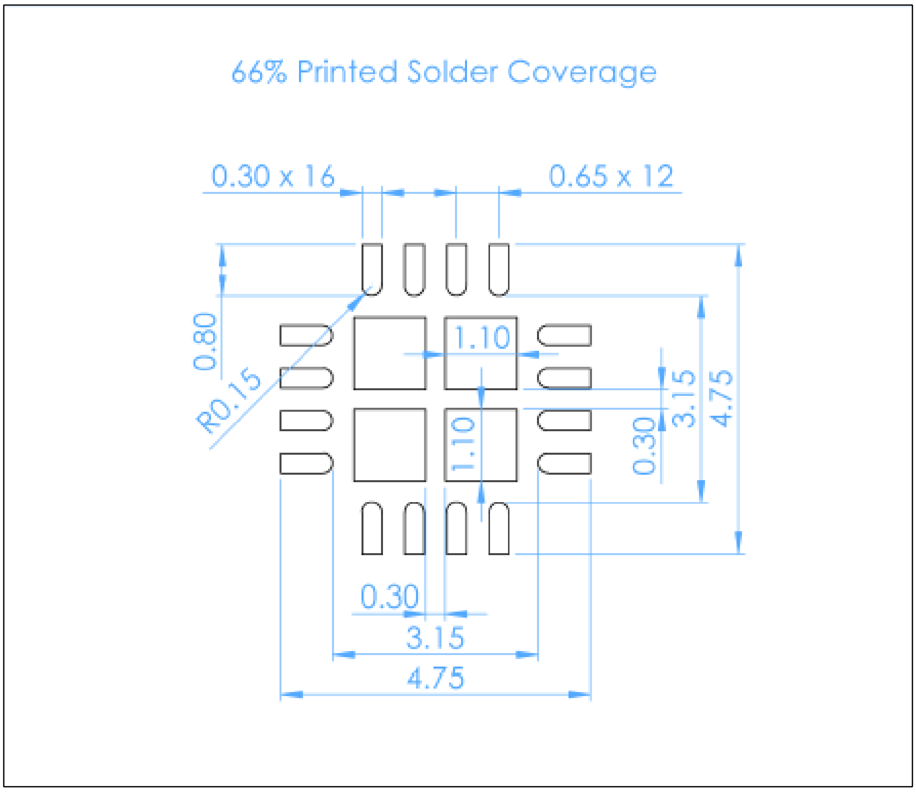

Figure 6: Suggested solder paste stencil. All noted dimensions in mm. Not to scale.

6 Revision Control

Version	Date	Details
0.1	07/03/2012	Document creation, from INDICE0101 datasheet.
0.2	17/04/2012	Amended introduction and document overview
0.3	27/06/2012	Fixed datasheet numbering on first page
0.4	05/06/2015	Updated sections under features, 1.2, 1.4, 1.5, 1.6, 1.8, 1.9 and 2.2