



## Evaluation Procedure (DEP-003)

### The IPM- C Series POL converters

The IPM Series, single output, non-isolated point of load DC/DC converters, are the latest offering from a world leader in power systems technology and manufacturing — Delta Electronics, Inc. They operate from a 3V~5.5V (IPM04C) or an 8V~14V (IPM12C) source and provide a programmable output voltage of 0.8V to 3.3V(IPM04C) or 0.8V to 5V(IPM12C). With creative design technology and optimization of component placement, these converters possess outstanding electrical and thermal performance, as well as offering extremely high reliability under highly stressful operating conditions. All models are protected against abnormal input/output voltage and current conditions.

This document guides the user through the evaluation procedure to qualify a POL module. The data shown in this Evaluation Procedure is for the SIP and SMT Package Type POL evaluation board. Please refer to the appropriate technical data sheet for detailed performance and technical information for the specific POL units.

### IPM Series



### 1.0 Purpose

This document guides the user in performing electronic measurements on an IPM POL (point of load) DC/DC converter using the Delta Evaluation Board.

### 2.0 Relevant Documentation

The documentation and background information listed below is relevant to this evaluation procedure:

- Applicative date sheets for IPM Series unit under evaluation.
- Power Module Evaluation Board Schematic.
- Power Module Evaluation Board Layout.
- General Test and Safety Procedures.



### 3.0 Equipment Required

- DC Power Supply 0 - 20 V @ 0 - 20A (Agilent 6574A 0 -60V/0 - 35A or equivalent).
- Oscilloscope (Tektronix TDS 460A or equivalent) 4 Channel 400 MHz, equipped with a x1 scope probe, a x10 scope probe, and two BNC cables (length less than 20 inches/500mm)
- Digital multimeters, one with 20A range and ideally all with 4 1/2 digit resolution (DVM1, DVM2 and DVM3) (Zentech 2041 or equivalent).
- Electronic load (Chroma 63030 or equivalent), 300W approx rating, or a suitable resistive load.
- DC power supply (GW GPC-3060D or equivalent).

### 4.0 Equipment Set-Up and Description

Please refer to the Power Module Evaluation Board Layout (see page 15) for reference designators cited in this document and Figure 1 is the Set-up Diagram.

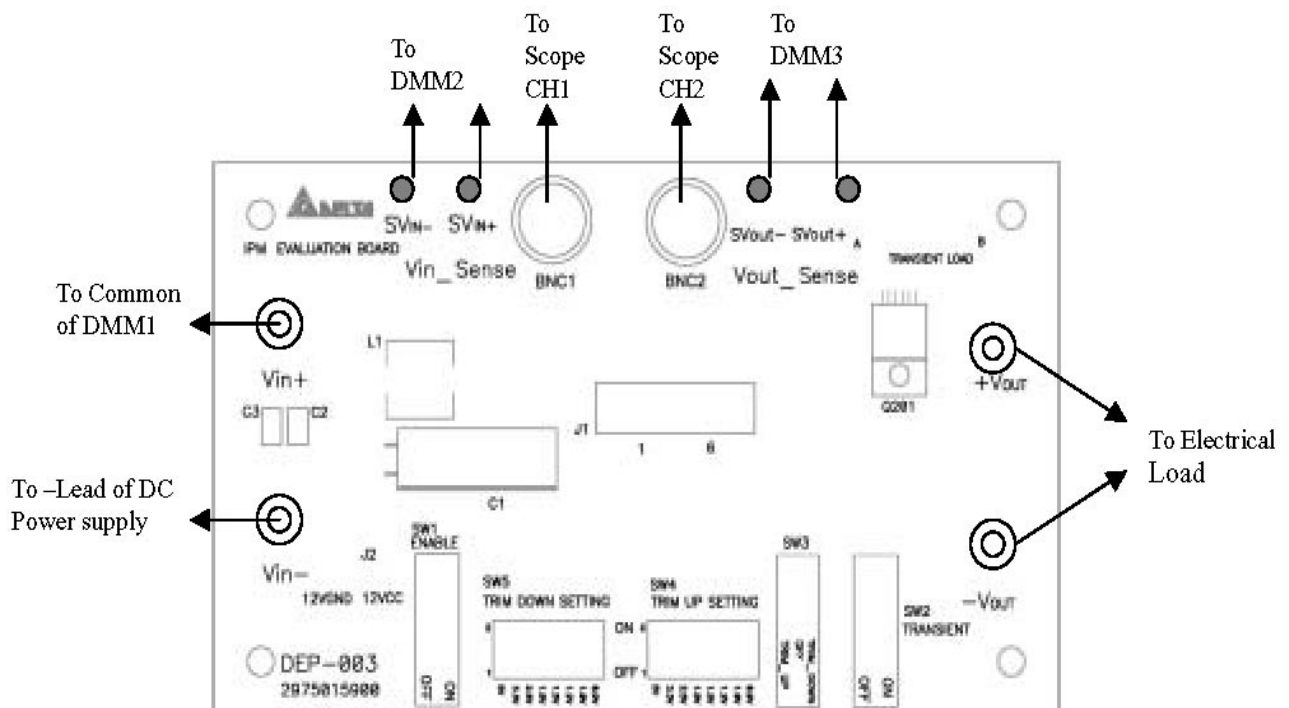


Figure 1. Set-up Diagram



- 4.1 Connect one lead from the “+” lead of the power supply to the “20A” terminal of the first multimeter DMM1. Then connect one lead from the “Common” of the DMM1 to the “Vin” pin of the Evaluation Board. Set function of DMM1 to DCA to measure the input current.
- 4.2 Connect one wire from the “-” lead of the power supply (Item 3.1) to the “Vin-” pin of the Evaluation Board. Note: Use stranded leads at least equivalent to 14 AWG for all connections in sections 4.1 and 4.2.
- 4.3 Connect the plus “+” and minus “-“ connection leads from a second multimeter to the “SVin+” and “SVin-” Pins on the Evaluation Board. This multimeter is designated DMM2 to measure the input voltage.
- 4.4 Connect the plus “+” and minus “-“ connection leads from the third multimeter to the “SVout+” and “SVout-” Pin on the Evaluation Board. The multimeter is designated DMM3. DMM3 is used to measure the output voltage.
- 4.5 Connect a BNC cable (length less than 20 inches/500mm) from BNC1 of the Evaluation Board to Channel 1 of the oscilloscope (item 3.2). This cable is used to measure the input voltage (between SVin+ and SVin-).
- 4.6 Connect a BNC cable (length less than 20 inches/500mm) from BNC2 of the Evaluation Board to Channel 2 of the oscilloscope. This cable is used to measure the output voltage (between SVout+ and SVout-).
- 4.7 Connect the positive and negative power leads of the electronic load (ensuring correct polarity), or an appropriate resistive load, to the Evaluation Board output terminal pin (“+Vout” for positive power lead and “-Vout” for the negative power lead).
- 4.8 For IPM04C series: Open J2 on the Evaluation Board. Connect one lead from the “+” lead of the power supply to the “12Vcc” on the Evaluation Board. Then connect one lead from the “-” of the power supply to the “12VGND” on the Evaluation Board. For IPM12C: short J2 on the Evaluation Board.

## 5.0 Thermal Management of the Converter

It is imperative that sufficient airflow should be provided to the converter at all times during all portions of testing. Please refer to the applicative data sheet for the proper cooling and derating necessary to achieve accurate results when testing the converter.



## 6.0 Tests Performed

The following tests are performed at room temperature (+25 C).

### 6.1 Input Characteristics

- ◆ Input Voltage Range.
- ◆ Under-Voltage Lockout.
- ◆ No Load Input Current.

### 6.2 Output Characteristics

- ◆ Line Regulation.
- ◆ Load Regulation.
- ◆ Output Regulation.
- ◆ Output Voltage Set-Point Adjustment Range.

### 6.3 Dynamic Characteristics

- ◆ Maximum Output Voltage Deviation (due to step change in load).
- ◆ Turn on Response time.

### 6.4 Thermal Characteristic

- ◆ Efficiency

## 7.0 Test Set-Up

### 7.1 Initial Set-Up

- 1) Examine the part number of the power module to determine that the correct module is being evaluated. Note: IPM12C0A0S04A and IPM04C0A0S06A would denote the SMT package, while IPM12C0A0R04A and IPM04C0A0R06A would denote the SIP package. This Evaluation Board can be used for both packages.
- 2) Set multimeter DMM1 to the DC current 20A range. Set multimeters DMM2 and DMM3 to DC voltage, auto ranging.
- 3) Electronic Load  
Turn on the Electronic Load (or resistive load) and adjust the current level. The maximum rated output current is 4A for the model IPM12C0A0R04A series and 6A for the model IPM04C0A0R06A series. Ensure the output load does not exceed the recommended maximum current.
- 4) SW1 is used to enable or disable the converter. Turn SW1 to the OFF position to enable the converter, and turn SW1 to the ON position to disable the converter.
- 5) SW2 is used for On/Off Transient function test. Turn SW2 to the OFF position if this function is not being used. Turn SW2 to the ON position if the Transient function test is required.



- 6) SW3 is used for the trim-down or trim-up setting of the Output Voltage. For IPM, if the converter requires a trim up, set SW3 to the Trim-up position. If the converter requires a trim down, set SW3 to the Trim-down position. For normal operating, turn off the SW3.
- 7) SW4 and SW5 are used for the Output Voltage Set-Point Adjustment by external resistors. For IPM12C0A0R04A, if the converter requires a trim-up to 5V, set the SW4\_1 to ON position and SW3 to trim-up position. If the converter requires a trim-down to 0.8V, set the SW5\_8 to ON position and SW3 to trim-down position.
- 8) For constant output voltage module, if the converter requires a trim-up, set the SW4\_2 to ON position and SW3 to trim-up position. If the converter requires a trim-down, set the SW5\_8 to ON position and SW3 to trim-down position. Please refer to the Function Tables below for the setting details.

#### SW4 Function Table

Subdivide switch NO.	For adjustable output module	For constant output module
SW4_1	5.0V setting	5.0V trim up
SW4_2	3.3V setting	3.3V trim up
SW4_3	2.5V setting	2.5V trim up
SW4_4	1.8V setting	1.8V trim up
SW4_5	1.5V setting	1.5V trim up
SW4_6	1.2V setting	1.2V trim up
SW4_7	1.0V setting	1.0V trim up
SW4_8	0.95V setting	0.9V trim up

Note: Settings of SW4\_1 and SW4\_7 are for IPM12C series only

#### SW5 Function Table

Subdivide switch NO.	For adjustable output module	For constant output module
SW5_1	-	5.0V trim down
SW5_2	-	3.3V trim down
SW5_3	-	2.5V trim down
SW5_4	-	1.8V trim down
SW5_5	-	1.5V trim down
SW5_6	-	1.2V trim down
SW5_7	-	1.0V trim down
SW5_8	0.80V setting	0.9V trim down



## 7.2 Initial Power Up

- 1) Turn the power supply ON, set the current limit on power supply (refer to specification of either converter) and increase the input voltage (use DMM2 to monitor the voltage) until it reaches the desired value.
- 2) Set the switch SW1 to “OFF” position to enable the power module.
- 3) The converter is now operating, which can be verified by observing the DMM3 (appropriate value for the nominal output voltage) and channel 2 of the oscilloscope (appropriate value for the nominal output voltage).
- 4) Set the switch SW1 to the “ON” position after performing each test.

## 8.0 Tests and Evaluation

### 8.1 Input Characteristics

#### 8.1.1 Input Voltage Range and Under-Voltage Lockout

The IPM04C Series of DC/DC converters will operate at full load from 3.0V<sub>in</sub> to 5.5V<sub>in</sub>. For the output of 3.3V, the input voltage range is from 4.0V<sub>in</sub> to 5.5V<sub>in</sub>. The IPM12C Series DC/DC converters will operate at full load from 8V<sub>in</sub> to 14V<sub>in</sub> for 12V<sub>in</sub> (nominal) types. The converters feature input under-voltage protection, which will not allow the converter to start up unless the input voltage exceeds the turn-on voltage threshold.

#### Test

- 1) Turn on the fan.
- 2) Set the input voltage to the desired operating point while monitoring DMM2.
- 3) Set the switch SW1 to the “OFF” position to enable the converter.
- 4) Test the input under voltage function while observing DMM2, DMM3 and channel 1 of the oscilloscope. Increase the input voltage until the output of the converter reaches the appropriate value. This will occur between 2.40 and 2.70 volts for IPM04C modules and between 7.6 to 8.0 volts for IPM12C modules. Please refer to the appropriate converter data sheet for the detailed specification.

#### 8.1.2 No Load Input Current Test

- 1) Turn on the fan.
- 2) Set the input voltage to the desired operating point while monitoring DMM2.
- 3) Set the switch SW1 to the “OFF” position to enable the converter.
- 4) Remove/disable the output electronic load or resistive load.
- 5) Note the input current from DMM1.
- 6) The result is the No-Load Input current of the DC/DC converter.  
The No-Load Input Current will be around 20 to 85mA for the IPM12C series and around 20 to 70mA for the IPM04C series depending on the model under evaluation. (Please refer to the data sheet for the detailed specification).



## 8.2 Output Characteristics

### 8.2.1 Line Regulation

Line Regulation Deviation is defined as the change in output voltage caused by varying the input voltage over a specified range while the output load and temperature remain constant.

#### Test

- 1) Turn on the fan.
- 2) Set the output power to the desired operating point.
- 3) Set the switch SW1 to the "OFF" position to enable the converter.
- 4) Adjust the input voltage across the converter's input range (refer to specified range) while monitoring DMM2.
- 5) Note the maximum +/- deviation of the output voltage over the full range of the input operating voltage (please refer to the data sheet for the detailed specification).

### 8.2.2 Load Regulation

Load Regulation Deviation is defined as the changes in output voltage caused by varying the output load current over the specified range (no load to full load) while the input voltage and temperature remain constant.

#### Test

- 1) Turn on the fan.
- 2) Set the input voltage to the desired operating level while monitoring DMM2.
- 3) Set the switch SW1 to the "OFF" position to enable the converter.
- 4) Adjust the output load across the converter's operating load range.
- 5) Note the maximum +/- deviation of the output voltage over the full range of the operating load range (please refer to the data sheet for the detailed specification).

### 8.2.3 Output Ripple

Output Ripple is defined as the periodic AC component on the DC/DC converter's output voltage. The output ripple is measured in terms of peak to peak and RMS values, both done with a specific bandwidth.

#### Test

- 1) Turn on the fan.
- 2) Set the switch SW1 to the "OFF" position to enable the converter.
- 3) Adjust the input voltage while monitoring DMM2 and set the output load to the full rated load current.
- 4) Adjust channel 2 on the oscilloscope to be AC coupled at  $1\mu\text{S}/\text{Div}$  and  $10\text{mV}/\text{Div}$  using the 20 MHz bandwidth-limit option on the scope.
- 5) The output ripple of the DC/DC converter is measured at full load operating power.



## 8.2.4 Output Voltage Set-Point Adjustment Range (Trim)

Output Voltage Set-Point Adjustment can be carried out by using an external resistor or external voltage source to increase or decrease the output voltage set-point (please refer to the data sheet for the detailed specification). Refer all trim voltage requirements to Item 7.1-6, 7.1-7, 7.1.8, and refer all the design numbers to Evaluation Board Schematic.

### (1) Output Voltage Set-Point Adjustment by using an external resistor

#### For IPM12C series

To implement Trim-up by using an external resistor,  $R_{trim-up}$  must be connected between the TRIM pin and ground. For IPM12C0A0R04A, Please refer to the IPMR table for the desired  $V_{out}$ . The value of  $R_{trim-up}$  can be calculated by the following equation and the datasheet can also be referred for further information.

$$R_{trim-up} = \frac{3.752}{|V_{out} - 0.9|} - 0.261 \quad k\Omega$$

To implement Trim-down by using an external resistor,  $R_{trim-down}$  must be connected between the TRIM pin and  $V_{out}$ . For IPM12C0A0R04A, Please refer to the IPMR table for the desired  $V_{out}$ . The value of  $R_{trim-down}$  can be calculated by the following equation and the datasheet can also be referred for further information.

$$R_{trim-down} = \frac{1.072}{|0.9 - V_{out}|} - 5.621 \quad k\Omega$$

**IPMR:** Rtrim values versus some commonly used  $V_{out}$  for IPM12C0A0R04A.

Vout	Rtrim ( $\Omega$ )
0.800	5.09K
0.900	Open
1.0	37.2K
1.2	12.2K
1.5	5.98K
1.8	3.90K
2.5	2.08K
3.3	1.30K
5.0	653





### For IPM04C series

To implement Trim-up by using an external resistor,  $R_{trim-up}$  must be connected between the TRIM pin and ground. For IPM04C0A0R06A, Please refer to the IPMR table for the desired  $V_{out}$ . The value of  $R_{trim-up}$  can be calculated by the following equation and the datasheet can also be referred for further information.

$$R_{trim-up} = \frac{7.0}{|V_{out} - 0.9|} - 0.187 \quad k\Omega$$

To implement Trim-down by using an external resistor,  $R_{trim-down}$  must be connected between the TRIM pin and  $V_{out}$ . For IPM04C0A0R06A, Please refer to the IPMR table for the desired  $V_{out}$ . The value of  $R_{trim-down}$  can be calculated by the following equation and the datasheet can also be referred for further information.

$$R_{trim-down} = \frac{2.0}{|0.9 - V_{out}|} - 10.187 \quad k\Omega$$

**IPMR:** Rtrim values versus some commonly used  $V_{out}$  for IPM04C0A0R06A.

Vout	Rtrim ( $\Omega$ )
0.8	9.813K
0.9	Open
1.2	23.146K
1.5	11.479K
1.8	7.590K
2.5	4.188K
3.3	2.729K

### Test

- 1) Turn on the fan.
- 2) Adjust the input voltage while monitoring DMM2 and with output load set to the desired operating point.
- 3) Set the enable switch SW1 to the "OFF" position to enable converter.
- 4) Use SW3, SW4 and SW5 (refer to Item 7.1\_7) for Trim setup.
- 5) Note the voltage by observing DMM3.
- 6) Test the Load Regulation (refer to Item 8.2.2).



## (2) Output Voltage Set-Point Adjustment by using an external voltage source

### For IPM12C series

Output voltage of IPM12C is programmable while applying a voltage between the TRIM and GND pins. The following equation can be used to determine the value of  $V_{trim}$  needed for a desired output voltage  $V_o$ :

$$V_{trim} = 0.7439 - 0.0488V_o$$

$V_{trim}$  is the external voltage in V  
 $V_o$  is the desired output voltage

For example, to program the output voltage of a IPM module to 3.3 Vdc,  $V_{trim}$  is calculated as follows:

$$\begin{aligned} V_{trim} &= 0.7439 - 0.0488 \times 3.3 \\ &= 0.5829V \end{aligned}$$

### For IPM04C series

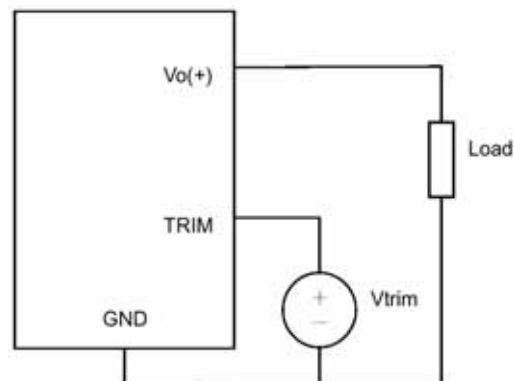
Output voltage of IPM04C is programmable while applying a voltage between the TRIM and GND pins. The following equation can be used to determine the value of  $V_{trim}$  needed for a desired output voltage  $V_o$ :

$$V_{trim} = 0.7168 - 0.0187V_o$$

$V_{trim}$  is the external voltage in V  
 $V_o$  is the desired output voltage

For example, to program the output voltage of a IPM module to 3.3 Vdc,  $V_{trim}$  is calculated as follows:

$$\begin{aligned} V_{trim} &= 0.7168 - 0.0187 \times 3.3 \\ &= 0.655V \end{aligned}$$



**Figure 2.** Configuration for programming output voltage using an external voltage source



## 8.3 Dynamic Characteristics

### 8.3.1 Output Voltage Deviation

Output Voltage Deviation is defined as the response of the converter to a sudden step change in the output load current. The output voltage deviation is characterized by two parameters: Maximum Output Voltage Deviation and Response Time (please refer to the data sheet for the detailed specification). The value of dynamic resistance for a defined step current is defined as:

$$R_{dynamic} = \frac{V_{out}}{0.5 * I_{max}}$$

#### Test

- 1) Turn on the fan.
- 2) Adjust the input voltage to the desired operating point.
- 3) Set the electronic or resistive load at 50% of maximum load.
- 4) Change channel 1 to scope probe and measure across the  $R_{dynamic}$ .
- 5) Set the switch SW1 to the "OFF" position to enable the converter.
- 6) Set channel 2 on the oscilloscope to be AC coupled and to 50mV/Div and for 50uS/Div. Set the trigger to auto and adjust the trigger point at a negative going pulse for step load change from 50% to 100% of  $I_o$  or adjust the trigger point at positive going pulse for step load change from 100% to 50% (Please refer to data sheet)
- 7) Measure the Peak deviation and capture the waveform as required.

### 8.3.2 Turn-On Transient Time

Turn-On Response Time is defined as the time it takes for the output to rise to within 90% of its final value from the time when the converter is enabled. The rise time is deliberately made slower to reduce the inrush current and to eliminate any overshoot in the output voltage. These test functions have two categories.

- 1) Turn on the module by using the External switch to control input voltage.
- 2) Turn on module by using the Enable on/off.

**Note:** There is a difference in performance in each mode - please refer to the data sheet for the detailed specification.

**Test (Turn on the module by using the external switch)**

- 1) Turn on the fan.
- 2) Turn on the input power supply and set it to the desired operating point.
- 3) Set channel 1 on the oscilloscope to be DC coupled and to the appropriate range for the input voltage.
- 4) Connect a coaxial cable from channel 1 to BNC1 on the Evaluation Board.
- 5) Set channel 2 on the oscilloscope to be DC coupled and to the appropriate range for the output voltage.
- 6) Connect a coaxial cable from channel 2 to BNC2 on the Evaluation Board.
- 7) Set the Time base to 5mS/Div
- 8) Set the Trigger mode to normal trigger and set the Trigger level at approximately 2V (rising) or suitable trigger point (referring to data sheet) on channel 2.
- 9) Turn on the external switch to supply power source to module and use the cursor V Bars of Scope to measure the delay time, and then record the waveform on the oscilloscope.

**Test (Turn on the module by using the Enable on/off)**

- 1) Turn on the fan.
- 2) Turn on the input power supply and set it to the desired operating point.
- 3) Set channel 1 on the oscilloscope to be DC coupled and to 1V/division. (Refer to data sheet).
- 4) Connect a scope probe from channel 1 between the on/off control pin and reference ground (SGND) on the Evaluation Board.
- 5) Set channel 2 on the oscilloscope to be DC coupled and to the appropriate range for the output voltage.
- 6) Connect a coaxial cable from channel 2 to BNC2 on the Evaluation Board.
- 7) Set the Time base to 5mS/Div
- 8) Set the Trigger mode to normal trigger and set the Trigger level at approximately 2V (rising) or suitable trigger point (referring to data sheet) on channel 2.
- 9) Turn on-off Enable switch (SW1) and use the cursor V Bars of Scope to measure the delay time, and then record the waveform on the oscilloscope.

## 8.4. Thermal Characteristic

### 8.4.1 Efficiency

Efficiency is the ratio of total output power to the input power. It is typically measured at full load and nominal input voltage.

**Test**

- 1) Turn on the fan.
- 2) Set the enable switch SW1 to the "OFF" position to enable the converter.
- 3) Adjust the input voltage to the desired operating point.
- 4) Set the electronic or resistive Load to the desired operating point.
- 5) Read and note the output voltage (DMM3) and input voltage (DMM2).
- 6) Read and note the input and output currents from the DMM1 and the electronic load.



7) Use the following formulas to calculate the efficiency:

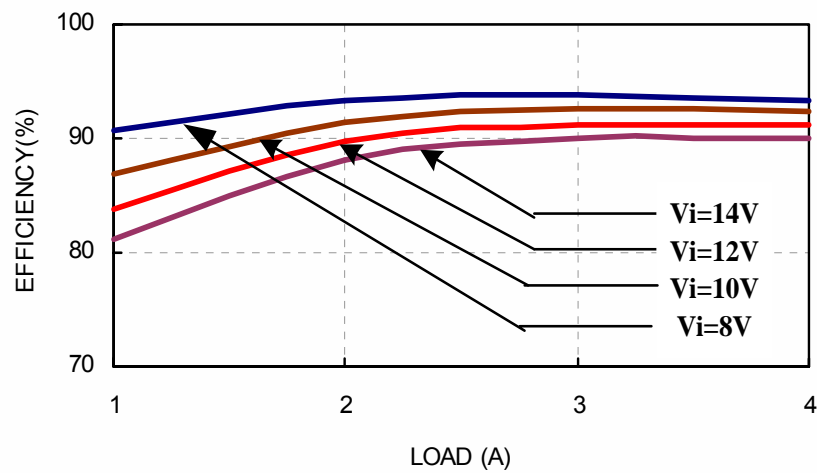
$$\text{Efficiency} = (\text{Pout} / \text{Pin}) \times 100(\%)$$

$$\text{Pin} = \text{Iin} \times \text{Vin}$$

$$\text{Pout} = \text{Iout} \times \text{Vout}$$

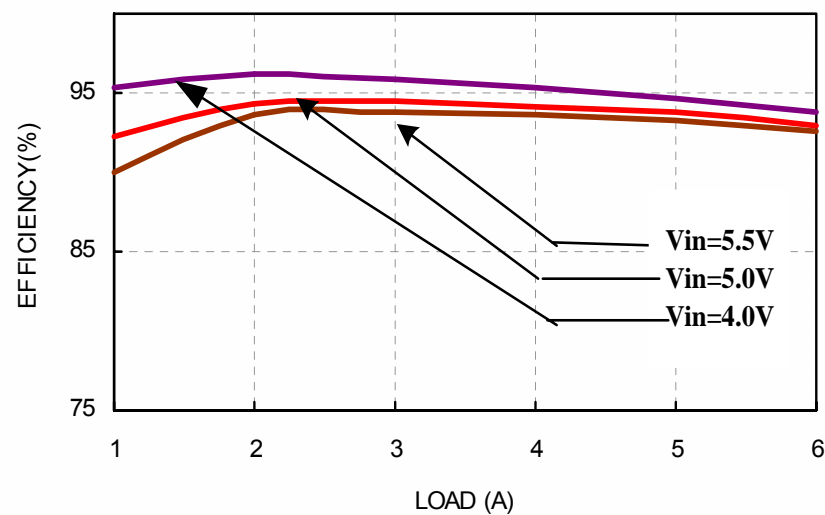
**For IPM12C series**

The following graph shows the efficiency results of the IPM12C0A0R04A converter measured at different operating points, the output voltage was set at 5V.

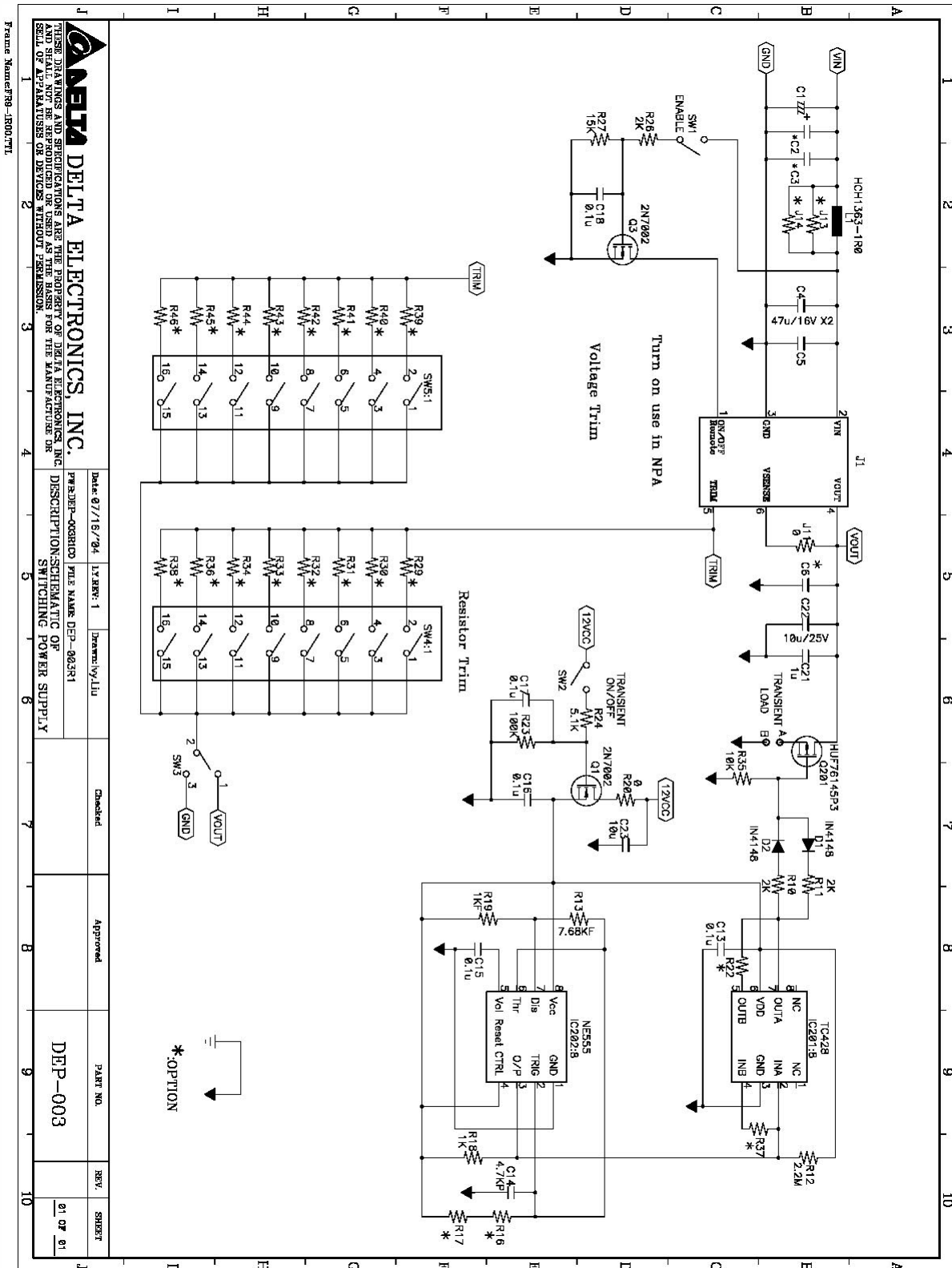


**For IPM04C series**

The following graph shows the efficiency results of the IPM04C0A0R06A converter measured at different operating points, the output voltage was set at 3.3V.



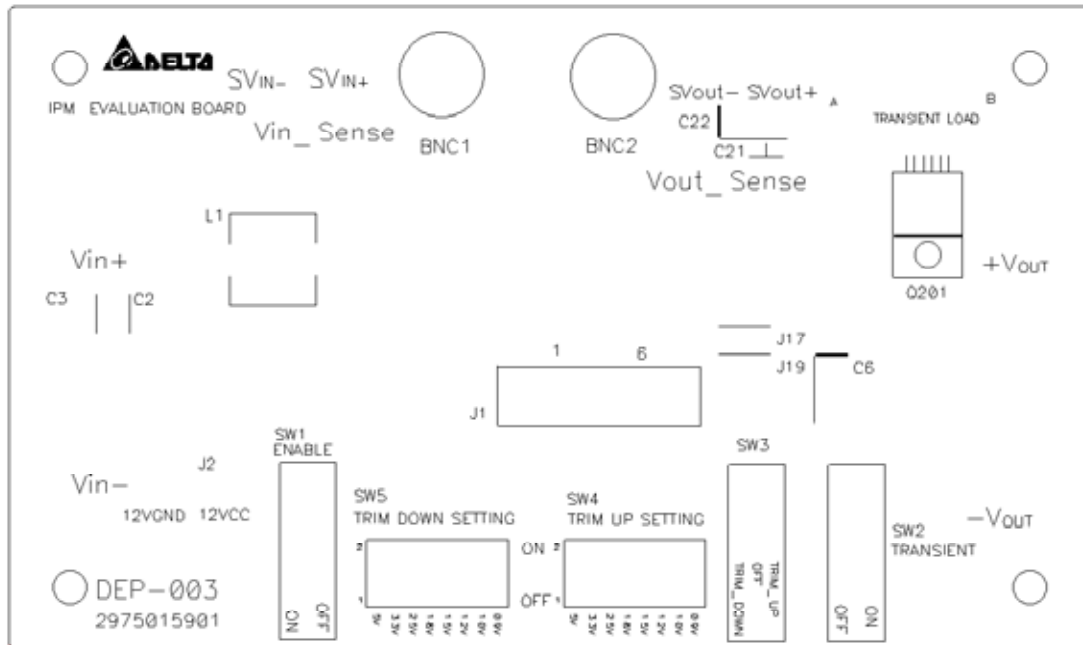
# Appendix A- Evaluation Board Schematic



		THESE DRAWINGS AND SPECIFICATIONS ARE THE PROPERTY OF DELTA ELECTRONICS, INC. AND SHALL NOT BE REPRODUCED OR USED AS THE BASIS FOR THE MANUFACTURE OR REPAIR OF APPARATUS OR DEVICES WITHOUT PERMISSION.	
Frame Name: DEP-1800.TTL	Date: 07/16/'94	I.X.REF: 1	Drawn by: JLu
PRJ: DEP-003	FILE NAME: DEP-003.R1	DESCRIPTION: SCHEMATIC OF SWITCHING POWER SUPPLY	Checked
PART NO.	DEP-003	Approved	Approved
REV.	01 OF 01	SHEET	01 OF 01

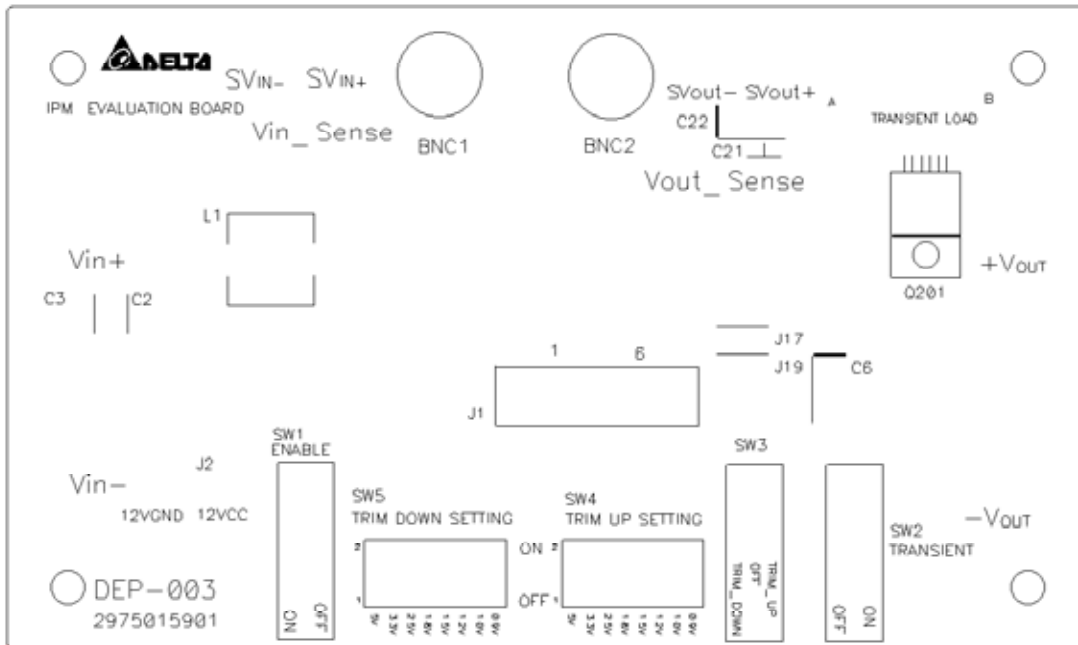


## Appendix B - Evaluation Board Layout (Top View)





## Appendix C - Evaluation Board Layout (Bottom View)



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