

Application Guide for the EPC7C023/024 Eval/Demo Board

EPC Space

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ESD Precaution



Proper ESD precautions should be employed when handling the EPC7C023/024 Eval/Demo Board to prevent damage to the components installed on the board.

Introduction

This document describes the recommended connection of the EPC7C023/024 (EPC7019G or EPC7014B pass element, respectively) to power supplies and monitoring instruments for proper operation for the evaluation of these HEMTs utilized as the pass elements of a linear regulator. The analog control IC used is the TI TL1431 (reference designation U1).

This document also provides the regulation performance for both line and load regulation performance, the transient performance for load current deviations, the schematic of the evaluation board, the Bill of Materials (BOM) and the layout of the board in the form of layer-by-layer Gerber rendering of the evaluation printed circuit board.

Demo/Evaluation PCB Photograph

Figure 1a shows the top view of the EPC7C023/024 Eval/Demo Board. Figure 1b shows the bottom view of the Demo Board. These pictures illustrate the component placements, power and input signal connections and the numerous test points available for monitoring by the end-user:

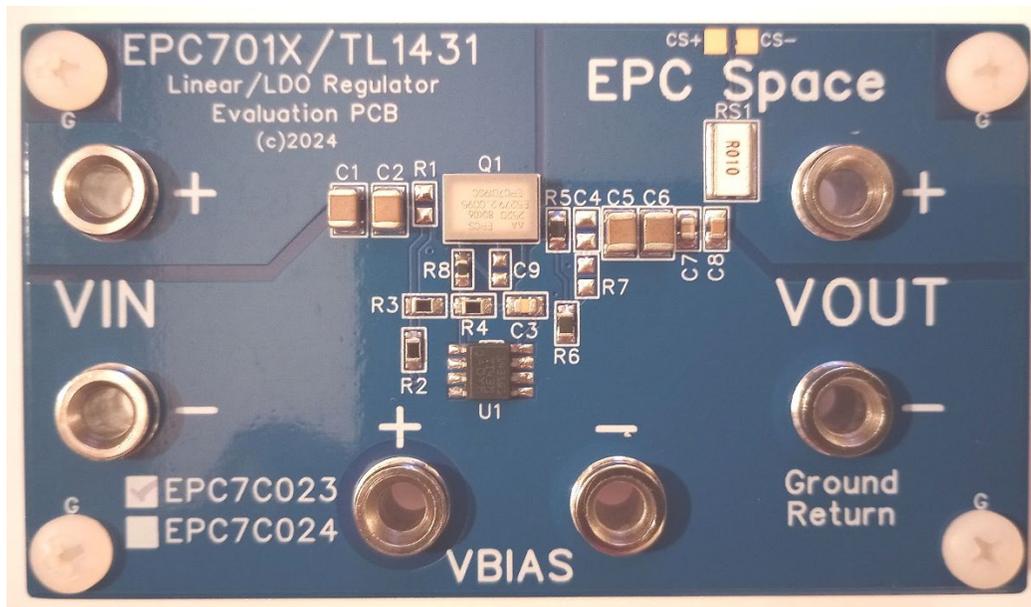


Figure 1a. EPC7C023/024 Eval/Demo Board (Top View Showing Q1 Installed).



Figure 1b. EPC7C023/024 Eval/Demo Board (Bottom View Showing Q2 Installed).

Evaluation Board Functional Schematic

The EPC7C023/024 evaluation board functional schematic is shown in Figure 2:

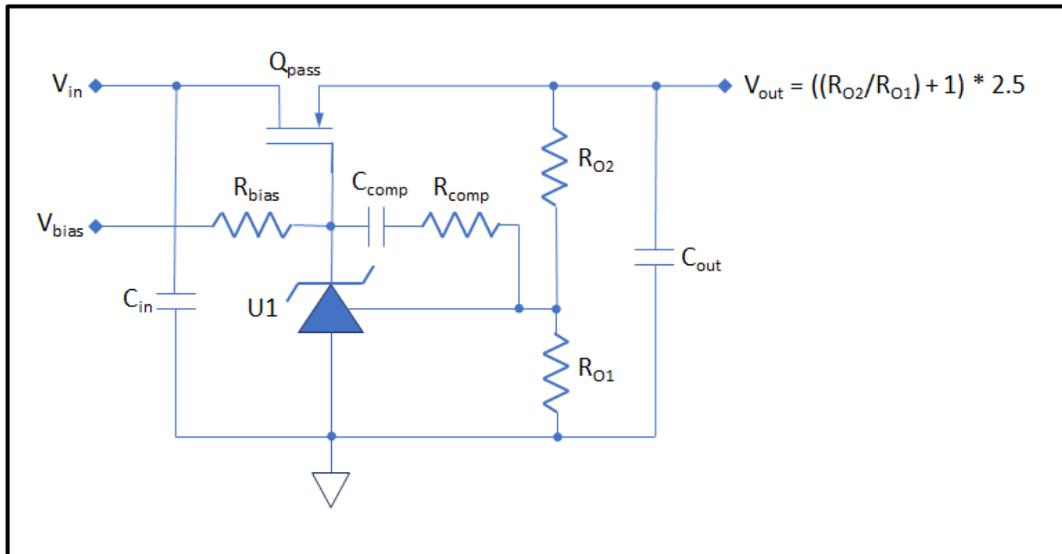


Figure 2. EPC7C023/024 Functional Schematic.

Evaluation Board Schematic

The EPC7C023/024 evaluation board detailed schematic is shown in Figure 3:

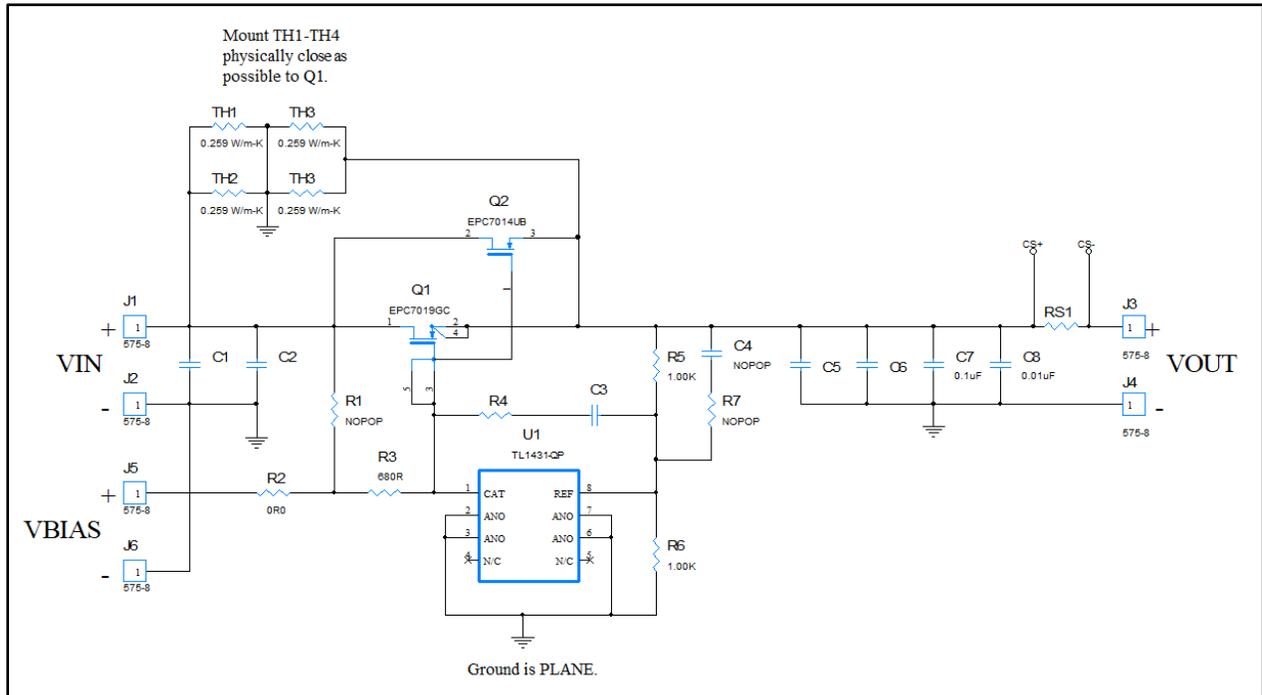


Figure 3. EPC7C023/024 Schematic.

Evaluation Board Implementation

The EPC7C023/024 Eval/Demo Board was designed to showcase the performance of the EPC7019G (EPC7C023) or EPC7014UB (EPC7C024) HEMTs when these devices are connected as the pass elements in a linear regulator configuration. This evaluation board is configured as a high current regulator (up to 5A/dc/7C023/Q1) or a low current regulator (up to 0.5A/7C024/Q2) – either HEMT Q1 or Q2 will be included on the board, but not both transistors. The high-current pass transistor, Q1, is located on the top side of the board and the low-current pass transistor, Q2, is located on the bottom side.

There was no attempt made to optimize the performance of each variant of the regulator (high/low current). The eval boards are populated with biasing and compensation components to capture typical performance data during in-house electrical testing. Because of the many applications possible, the end-user is encouraged to frequency compensate the control loop of the regulator, which uses the TI TL1431 regulator IC as the feedback element, to their specific system requirements.

An output current sense resistor, RS1, is provisioned on the board with two uncommitted Kelvin connections (CS+ and CS-) to facilitate easier integration into end-user test-bench set-ups that require current limiting.

To provide for improved thermal performance of the high-current (and thus higher power) pass transistor Q1, four thermal “helper” elements TH1-TH4 are provided on the bottom side of the board. These elements are Vishay ThermoWick SMT thermal jumpers in EIA 0612 packages.

Component Values vs Evaluation Board Identity

The evaluation boards as-shipped have the following critical component values placed in the various reference designations shown in Figure 3, as shown in Tables I and II:

Table I. EPC7C023 Linear Regulator Evaluation Board Simplified BOM.

Eval. Board	Ref. Des.	Component Description	Value
EPC7C023	C1,C2	Input Capacitors	10uF
	Q1	Pass Element	EPC7019G
	Q2		NOPOP
	R4	Frequency Compensation	1.50K
	C3		1500pF
	R1	Jumper	NOPOP
	R2		0R0Ω
	R5,R6	Output Set	10KΩ
	C5,C6	Output Capacitors	20uF
	C9	Pass Element Equalization	NOPOP

Table II. EPC7C024 Linear Regulator Evaluation Board Simplified BOM.

Eval. Board	Ref. Des.	Component Description	Value
EPC7C024	C1,C2	Input Capacitors	22uF
	Q1	Pass Element	NOPOP
	Q2		EPC7014UA
	R4	Frequency Compensation	4.02K
	C3		390pF
	R1	Jumper	NOPOP
	R2		0R0Ω
	R5,R6	Output Set	10KΩ
	C5,C6	Output Capacitors	2.2uF
	C9	Pass Element Equalization	1000pF

Regulator Configuration

There are two possible configurations for the demo/eval board the board: standard linear regulator or low-dropout (LDO) linear regulator.

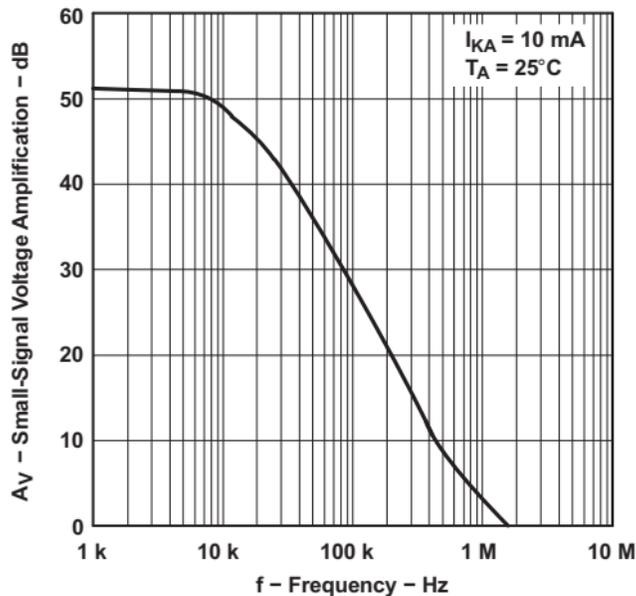
The standard regulator configuration is enabled by populating resistor R1 with a zero Ohm (0R0) jumper and depopulating (NOPOP) resistor R2. The input power supply is provided to the Vin terminals. The VBIAS terminals are unused. In this configuration VIN must be at least 3.5V greater than the output voltage, VOUT, to maintain regulation (although the following test results use lower values).

The LDO regulator configuration is the as-shipped configuration. It is enabled by depopulating (NOPOP) resistor R1 and populating resistor R2 with a zero Ohm (0R0) jumper. The input power supply is provided to the VIN terminals. The VBIAS terminals are used, and in this configuration VBIAS must be at least 3.5V greater than the output voltage, VOUT, to maintain regulation.

Regulation Loop Frequency Compensation

The regulation loop frequency compensation is performed by R4 and C3. This application note is not intended to be a primer on compensating the control loop of a linear voltage regulator. This regulator configuration is comprised of three stages that determine the loop frequency response: the LM1431 regulator/amplifier, the voltage divider that sets the output voltage and the pass transistor/output capacitors/load. However, if the end-user is inclined to determine the frequency response of the loop and then optimize the transient response, the following information should help the designer in that effort.

The voltage gain versus frequency of the LT1431 is found in its data sheet, as shown in Figure 4:



Small-Signal Voltage Amplification vs Frequency

Figure 4. TL1431 (U1) Voltage Gain vs. Frequency.

With regards to accurately simulating the regulator circuit, many of the SPICE models available for the TL1431 on the internet yield disappointing results in reproducing the performance of the IC. The following model is an accurate representation of the TL1431, particularly with regards to the gain/phase performance of the IC, particularly in LTSPICE:

```
.SUBCKT TL1431 CAT ANO REF
D1 REF CAT Dc
G1 ANO N003 REF N001 1
D2 N001 REF Dc
R1 REF ANO 1Meg
C1 N003 ANO 1n Rpar=1k
R2 N002 N003 700k
D3 ANO N002 Di
G2 CAT N001 N002 ANO 90m
D4 ANO N001 2V5
C2 CAT N002 40p
D5 ANO CAT Dc
.model Di D(Ron=10m)
.model Dc D(Ron=7 Vfwd=0.6 Vrev=36V)
.model 2V5 D(Ron=0.13 Vfwd=0.6 Vrev=2.5V Roff=7k)
.ENDS TL1431
```

The gain of the resistive voltage divider, A_{VD} , comprised of R_{O1} and R_{O2} , as identified in Figure 2, is:

$$A_{VD} = R_{O2} / (R_{O1} + R_{O2})$$

For equal valued resistors as utilized on the eval/demo boards, the gain in dB is $20 * \log(0.5) = -6\text{dB}$. For the pass element and load components, it is instructive to note that the pass transistor is connected as a common drain, source-follower configuration. This makes determining the loop gain-phase characteristics an easier effort as the voltage gain of this stage is:

$$A_{VF}(s) = (g_m * Z_F) / ((g_m * Z_F) + 1);$$

whose value is ~ 1 for most loads and output capacitances in the range of interest.

The quantity g_m in the previous equation is the transconductance ($\Delta I_d / \Delta V_{gs}$, in Siemens) of the HEMT and Z_F is the output impedance between the HEMT's source (i.e. VOUT) and ground:

$$Z_F(s) = (R_{LOAD} * (1 + s(ESR * C_o))) / (1 + s((ESR + R_{LOAD}) * C_o));$$

where ESR is the equivalent series resistance of the output capacitor(s), C_o is the total output capacitance and R_{LOAD} is the DC load resistance.

With the three gain stages identified, it is now possible to determine the gain/phase of the regulation loop versus frequency for the minimum and maximum load values in the end application, given the circuit component values chosen and identified:

$$A_{VLOOP}(s) = A_V(U1) * A_{VD} * A_{VF}$$

For those wanting to avoid doing this exercise by hand, it is similarly possible to construct a SPICE model, for example using LTSPICE, and compensate the circuit using a compensation network RCOMP and CCOMP (a feedback zero), and then iteratively tune the resulting output deviation (for an output current deviation) for the smallest peak value, while displaying critically-damped behavior.

Recommended Test Equipment Connections

Figure 5 shows the recommended test equipment connections to/from the EPC7C023 Eval/Demo Board.

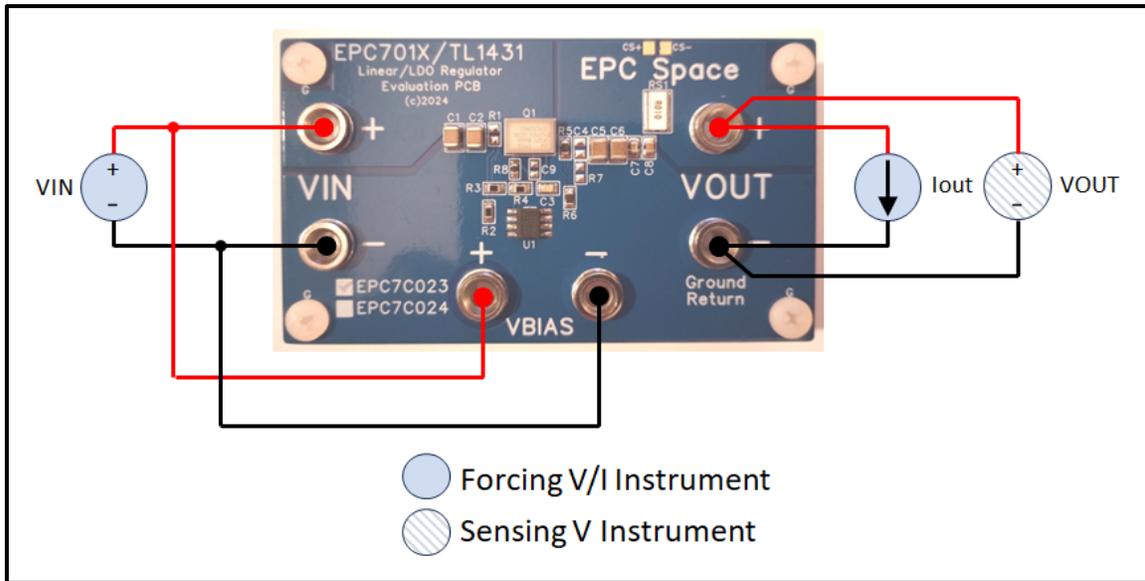


Figure 5. EPC7C023/EPC7C024 DC Test Standard Regulator Configuration.

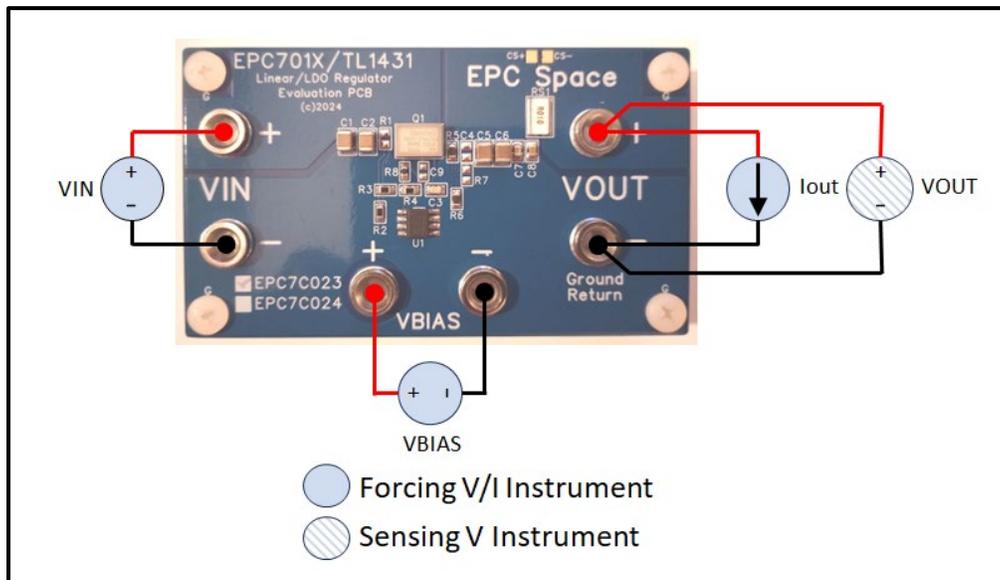


Figure 6. EPC7C023/EPC7C024 DC Test LDO Regulator Configuration.

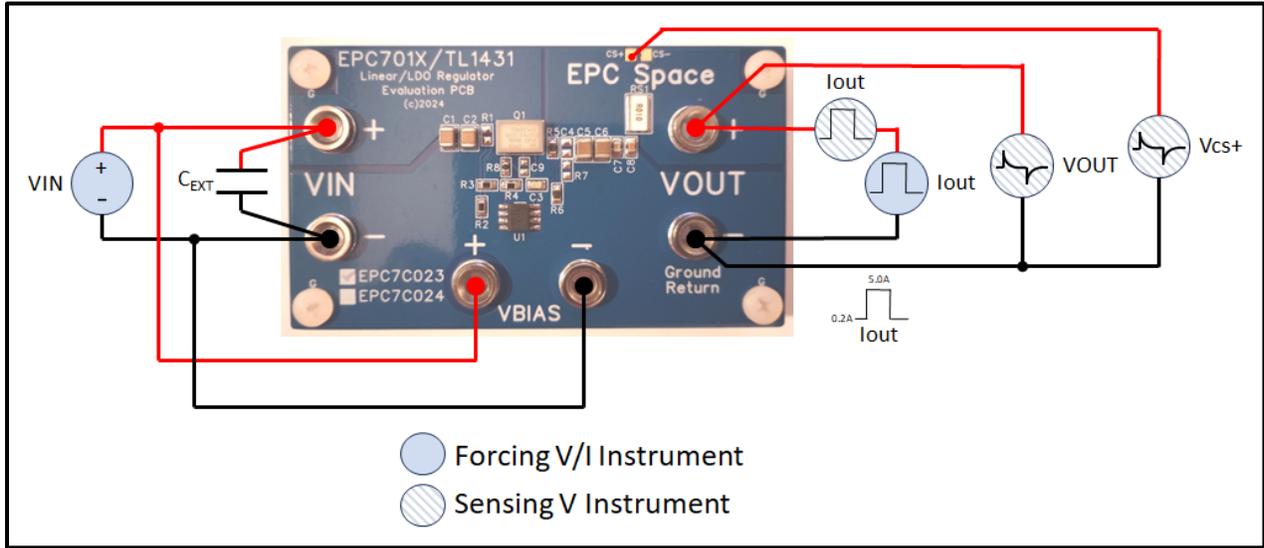


Figure 7. EPC7C023 AC Test Standard Regulator Configuration.

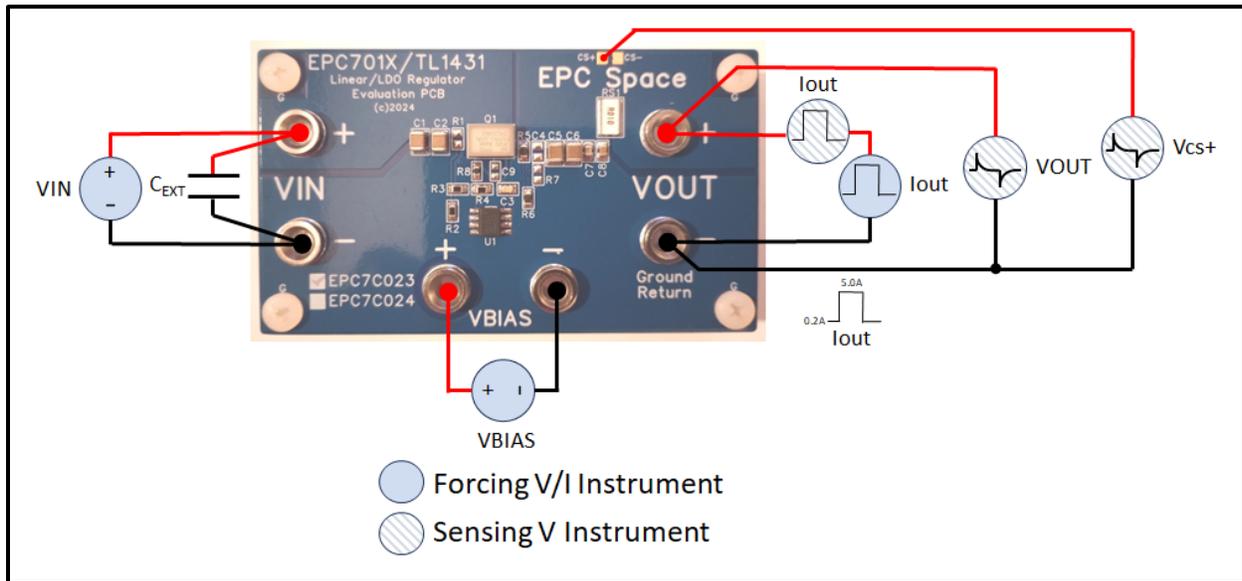


Figure 8. EPC7C023 AC Test LDO Regulator Configuration.

In Figures 7 and 8, C_{EXT} is a minimum 470uF/16V aluminum electrolytic capacitor to compensate for the inductance of the cables from the power supply to the evaluation board(s).

The same connection arrangement applies to the EPC7C024 board, with the exception of the pulsed load current is switching from 0.05A to 0.5A.

Recommended Test Equipment

The following test equipment is recommended to properly evaluate the EPC7C015 Eval/Demo Board:

- 0-10V, 10A adjustable DC power supply for VIN (EPC7C023).
- 0-10V, 2A adjustable DC power supply for VIN (EPC7C024).
- 0-10V, 100mA adjustable lab power supply set to 8.50Vdc for VBIAS (either version).
- 10A maximum adjustable/pulsed electronic load.
- 200MHz two channel oscilloscope.
- One 10:1 passive oscilloscope probe (to monitor CS+).
- Dual banana jack-to-BNC adapter.
- BNC to probe tip adapter (to monitor VOUT).

Typical DC Regulation/Drop-Out Performance

The following typical regulation and drop-out performance was obtained for each HEMT version of the EPC7C023 and EPC7C024 demo board. For the standard regulation tests, the regulation performance versus input voltage (VIN) and load current ILOAD for the EPC7C023 board is shown in Table III.

Table III. Typical EPC7C023 Standard Configuration Regulation Performance.

Iout (Adc)	Vin = VBIAS (Vdc)				Δ_{h-l}	Line Regulation (Vdc)
	7	7.5	8	8.5		
0.01	4.9906	4.9909	4.9912	4.9916	0.001	
0.02	4.9904	4.9908	4.9911	4.9913	0.0009	
0.05	4.9901	4.9908	4.991	4.9909	0.0008	
0.1	4.9896	4.9904	4.9907	4.9908	0.0012	
0.2	4.9888	4.9878	4.9901	4.9901	0.0013	
0.5	4.9866	4.9882	4.9882	4.9883	0.0017	
1	4.9829	4.9852	4.985	4.9851	0.0022	
2	4.973	4.9798	4.9792	4.9788	0.0058	
5	4.9502	4.9625	4.9619	4.9622	0.012	
Δ_{h-l}	0.0404	0.0284	0.0293	0.0294		

Load Regulation (Vdc)

With regards to the standard regulation tests, the regulation performance versus input voltage (VIN) and load current ILOAD for the EPC7C024 board is shown in Table IV.

Table IV. Typical EPC7C024 Standard Configuration Regulation Performance.

I _{out} (Adc)	V _{in} = VBIAS (Vdc)				Δ _{h-l}	Line Regulation (Vdc)
	7.75	8.00	8.25	8.5		
0.01	5.0021	5.0024	5.0027	5.0030	0.0009	
0.02	5.0019	5.0021	5.0025	5.0028	0.0009	
0.05	5.0012	5.0015	5.0021	5.0023	0.0011	
0.1	4.9798	5.0008	5.0011	5.0018	0.022	
0.2	4.8953	4.9997	5.0000	5.0010	0.1057	
0.5	4.7048	4.9091	4.9976	4.9987	0.2939	
D _{h-l}	0.2973	0.0933	0.0051	0.0043		

Load Regulation (Vdc)

For both the EPC7C023 and EPC7C024 the regulation accuracy is better than 1%, with the exception of three data points for the EPC7C024 board where ILOAD was greater than 0.2A and where VBIAS was less than 8.25Vdc. In fact, for all currents for both evaluation boards where VBIAS is greater than 8.00Vdc, the regulator accuracy is better than 0.5%!

For the LDO configuration, the regulation performance versus input voltage (VIN) and load current ILOAD for the EPC7C023 board is shown in Table V and for the EPC7C024 in Table VI.

Table V. Typical EPC7C023 LDO Configuration Regulation Performance.

I _{out} (Adc)	VBIAS (Vdc)						Δ _{h-l}	Line Regulation (Vdc)
	8.500							
	V _{in} (Vdc)							
5.5	6	6.25	6.5	7	7.5			
0.01	4.9908	4.9901	4.9907	4.9912	4.9914	4.9914	0.0006	
0.02	4.9907	4.9901	4.9906	4.991	4.9911	4.9911	0.0004	
0.05	4.9903	4.9899	4.9905	4.9906	4.9907	4.9907	0.0004	
0.1	4.9898	4.9895	4.9901	4.9901	4.9902	4.9902	0.0004	
0.2	4.9891	4.9888	4.9891	4.9885	4.9883	4.9811	-0.008	
0.5	4.9869	4.9866	4.9867	4.9862	4.9863	4.9858	-0.0011	
1	4.9834	4.9831	4.9828	4.9822	4.9822	4.9821	-0.0013	
2	4.9769	4.9761	4.9752	4.9733	4.9738	4.9737	-0.0032	
5	4.9575	4.9550	4.9515	4.9492	4.9488	4.9480	-0.0095	
Δ _{h-l}	0.0333	0.0351	0.0392	0.0420	0.0426	0.0434		

Load Regulation (Vdc)

 Fails 1%, Passes 1.5%

Table VI. Typical EPC7C024 LDO Configuration Regulation Performance.

		VBIAS (Vdc)						Line Regulation (Vdc)
		8.500						
		Vin (Vdc)						
I _{out} (A _{dc})		5.5	6	6.25	6.5	7	7.5	Δ _{h-I}
0.01		5.0022	5.0023	5.0024	5.0027	5.0028	5.0029	0.0007
0.02		5.0019	5.0020	5.0022	5.0025	5.0026	5.0027	0.0008
0.05		5.0014	5.0015	5.0017	5.0020	5.0021	5.0021	0.0007
0.1		5.0008	5.0009	5.0011	5.0014	5.0016	5.0016	0.0008
0.2		5.0003	5.0004	5.0006	5.0006	5.0006	5.0008	0.0005
0.5		4.9976	4.9983	4.9982	4.9982	4.9982	4.9982	0.0006
Δ _{h-I}		0.0046	0.0040	0.0042	0.0045	0.0046	0.0047	

Load Regulation (Vdc)

For both the EPC7C023 and EPC7C024 configured as an LDO the regulation accuracy is better than 1.5%, except for three data points for the EPC7C023 board where ILOAD was 5A and where VIN was greater than 6.50Vdc. In fact, for all currents for both evaluation boards where VIN is less than 6.50Vdc, the regulator accuracy is better than 0.5%!

The typical dropout voltage performance obtained for the EPC7C023 board is shown in Table VII and in Table VIII for the EPC7C024. For all the following readings, the dropout voltage is obtained by adjusting the input voltage until the output voltage is 4.950Vdc (~ -1%).

Table VII. Typical EPC7C023 Dropout Voltage Performance.

I _{out} (A _{dc})	VDO (Vdc)	Dropout Voltage (Vdc)
0.01	0.0003	
0.02	0.0004	
0.05	0.0006	
0.1	0.0021	
0.2	0.0047	
0.5	0.0118	
1	0.04742	
2	0.0488	
5	0.152	

Table VII. Typical EPC7C024 Dropout Voltage Performance.

I_{out} (A_{dc})	VDO (V_{dc})	Dropout Voltage (V_{dc})
0.01	0.0056	
0.02	0.0115	
0.05	0.029	
0.1	0.059	
0.2	0.1232	
0.5	0.3684	

The results obtained in Tables VI and VII are very respectable for any pass element, and obviously noteworthy for an eGaN HEMT, a technology which is not necessarily associated with linear regulators! Decidedly from here on out, eGaN HEMTs should be of serious consideration in linear regulator designs.

Typical Dynamic Performance

The typical dynamic performance obtained for the two evaluation boards – the output deviation of the output voltage for a deviation in the output current, shown for two output current deviations -- half to full load deviation (2.5A to 5A, EPC7C023 or 0.25A to 0.5A, EPC7C024) and almost full load deviation (0.2A to 5A, EPC7C023 or 0.02A to 0.5A, EPC7C024) – are shown in Figures 9 and 10 for the EPC7C023 board. In Figures 9 and 10 the blue waveforms are displayed at 2A/division:



Figure 9. EPC7C023 AC Output Deviation: ½ to Full Load Current Deviation.

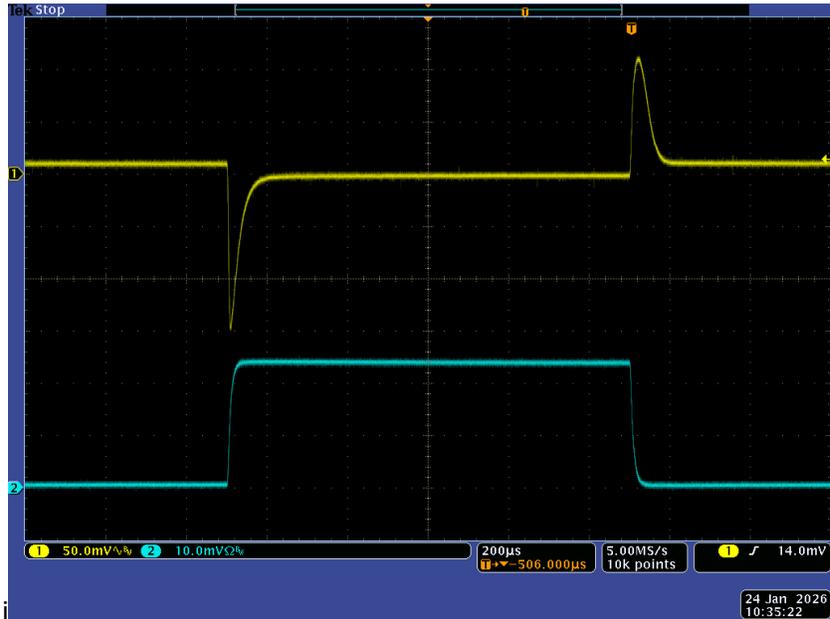


Figure 10. EPC7C023 AC Output Deviation: Minimum to Full Load Current Deviation.

In Figures 11 and 12, following, the blue waveforms are displayed at 0.2A/division:

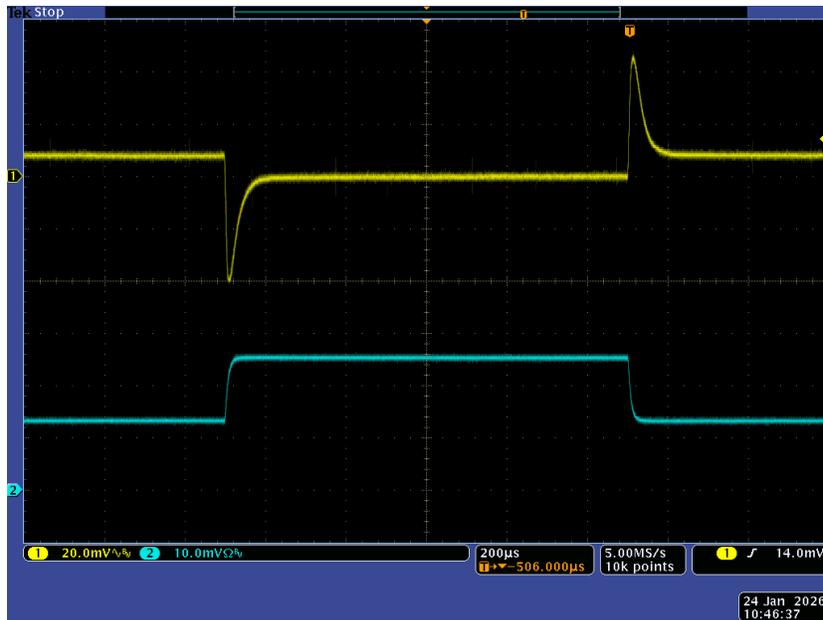


Figure 11. EPC7C024 AC Output Deviation: 1/2 to Full Load Current Deviation.



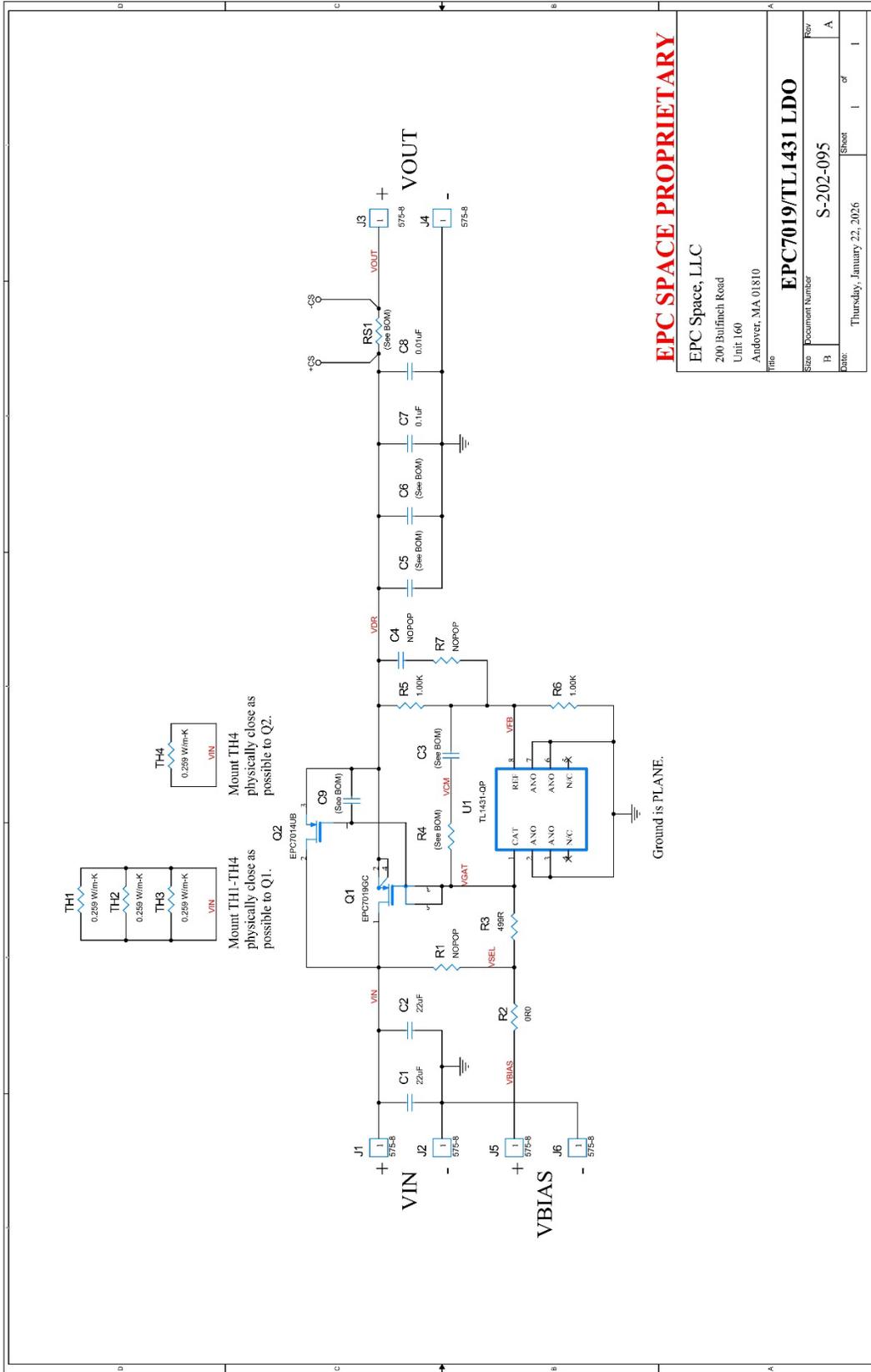
Figure 12. *EPC7C024 AC Output Deviation: Minimum to Full Load.*

Figures 9 to 12 indicate excellent load transient performance, which is solely controlled by the TL1431 IC and the compensation network R4 and C3. Due to the presence of the current sense resistor, RS, which is outside the regulator’s feedback loop, the output voltage deviations shown in yellow in Figs. 9 to 12 are measured at the +CS terminal on the board. The signal CS+ is the regulated output of voltage regulator.

What Figures 9 through 12 further show is the ability of eGaN HEMTs to be excellent pass transistors for linear voltage regulators!

EPC7C023/024 Demo Board Schematic

Figure 13. EPC7C023/024 Eval/Demo Board Schematic Diagram.



EPC7C023/024 Demo Board BOMs

The BOMs for EPC7C023 and EPC7C024 Eval/Demo Boards are shown in Tables VIII and IX, respectively. All passive components used are qualified to AEC-QXXX standards, where possible.

Table VIII. EPC7C023 BOM.

Master BOM						
Item	Quantity	Ref. Des.	Description/Value	Mfr.	Mfr. P/N	
1	6	BJ1,BJ2,BJ3,BJ4,BJ5,BJ6	Staking Banana Jack, Uninsulated	Keystone	575-8	
2	2	C1,C2	10uF/25V/X7R/10%/1210/AEC Ceramic Capacitor	Taiyo Yuden	C1210C106K3RACAUTO	
3	1	C3	1500pF/50V/X7R/10%/0805/AEC Ceramic Capacitor	Kemet	C0805C152J5GACAUTO	
4	NOPOP	C4	NOPOP			
5	2	C5,C6	22uF/25V/X7R/10%/1210/AEC Ceramic Capacitor	Taiyo Yuden	TMK325B7226KMHP	
6	1	C7	0.1uF/50V/X7R/10%/0805/AEC Ceramic Capacitor	AVX	08055C104K4T4A	
7	1	C8	0.01uF/50V/X7R/10%/0805 Ceramic Capacitor	Kemet	C0805C103K5RACAUTO	
8	NOPOP	C9	NOPOP			
9	1	Q1	40V/90A HEMT FSMD-G Package	EPC Space	EPC7019G	
10	NOPOP	Q2	NOPOP			
11	NOPOP	R1	NOPOP			
12	1	R2	Zero Ohm Jumper/1%/0805 Thick Film Chip Resistor	Vishay	CRCW08050000Z0EA	
13	1	R3	499R/1%/0805/500mW Thick Film Chip Resistor	Vishay	CRCW0805499RFKEAHP	
14	1	R4	1.50K/1%/0805 Thick Film Chip Resistor	Vishay	CRCW08051K500FKEA	
15	2	R5,R6	10.0K/1%/0805 Thick Film Chip Resistor	Vishay	CRCW080510K0FKEC	
16	NOPOP	R7	NOPOP			
17	1	R8	Zero Ohm Jumper/1%/0603 Thick Film Chip Resistor	Vishay	CRCW06030000Z0EA	
18	1	RS1	0R.01/1%/2W/1225 Thick Film Chip Resistor	Susumu	KRL6432E-M-R010-F-T1	
19	4	TH1,TH2,TH3,TH4	ThermaWick Thermal Jumper/0612/0.259W/K	Vishay	THJP0612AST1	
20	1	U1	Shunt Precision Voltage Reference/2.5V Reference/SOIC-8	TI	TL1431QDRQ1	
21	4	N/A	0.5" Length/0.25" Width/#6-32 Threaded Standoff/Nylon 6-6	Keystone	1903C	
22	4	N/A	0.25" Length/#6-32 Philips Head Screw/Nylon	Essentra	010632PW025	
23	1	PCB	3.50" x 2.00" x 0.063"/FSMD-G LDO Evaluation PCB	Fab9/Speedy	47-121-A	

Table IX. EPC7C024 BOM.

Master BOM						
Item	Quantity	Ref. Des.	Description/Value	Mfr.	Mfr. P/N	
1	6	BJ1,BJ2,BJ3,BJ4,BJ5,BJ6	Staking Banana Jack, Uninsulated	Keystone	575-8	
2	2	C1,C2	22uF/25V/X7R/10%/1210/AEC Ceramic Capacitor	Taiyo Yuden	CGA6P3X7R1E226M250AB	
3	1	C3	390pF/50V/COG/10%/0805/AEC Ceramic Capacitor	Kemet	C0805C391K5GACTU	
4	NOPOP	C4	NOPOP			
5	2	C5,C6	1.0uF/50V/X7R/10%/1210/AEC Ceramic Capacitor	Taiyo Yuden	CGA6L2X7R1H105K160AA	
6	1	C7	0.1uF/50V/X7R/10%/0805/AEC Ceramic Capacitor	AVX	08055C104K4T4A	
7	1	C8	0.01uF/50V/X7R/10%/0805 Ceramic Capacitor	Kemet	C0805C103K5RACAUTO	
8	1	C9	1000pF/50V/X7R/10%/0603 Ceramic Capacitor	Kemet	C0603C102K5RACAUTO	
9	1	Q1	NOPOP			
10	1	Q2	60V/1A HEMTUB Package	EPC Space	EPC7014UB	
11	NOPOP	R1	NOPOP			
12	1	R2	Zero Ohm Jumper/1%/0805 Thick Film Chip Resistor	Vishay	CRCW08050000Z0EA	
13	1	R3	499R/1%/0805/500mW Thick Film Chip Resistor	Vishay	CRCW0805499RFKEAHP	
14	1	R4	4.02K/1%/0805 Thick Film Chip Resistor	Vishay	CRCW08054K02FKEA	
15	2	R5,R6	10.0K/1%/0805 Thick Film Chip Resistor	Vishay	CRCW080510K0FKEC	
16	NOPOP	R7	NOPOP			
17	1	R8	Zero Ohm Jumper/1%/0603 Thick Film Chip Resistor		CRCW06030000Z0EA	
18	1	RS1	0R.05/1%/2W/1225 Thick Film Chip Resistor	Susumu	PRL3264-R050-F-T1	
19	NOPOP	TH1,TH2,TH3,TH4	ThermaWick Thermal Jumper/0612/0.259W/K		THJP0612AST1	
20	1	U1	Shunt Precision Voltage Reference/2.5V Reference/SOIC-8	TI	TL1431QDRQ1	
21	4	N/A	0.5" Length/0.25" Width/#6-32 Threaded Standoff/Nylon 6-6	Keystone	1903C	
22	4	N/A	0.25" Length/#6-32 Philips Head Screw/Nylon	Essentra	010632PW025	
23	1	PCB	3.50" x 2.00" x 0.063"/FSMD-G LDO Evaluation PCB	Fab9	47-121	

Printed Circuit Board (47-120) and Layout Details.

The printed circuit board (47-120) for the EPC7C023/024 Eval/Demo Board is constructed with four layers. The PCB is 3.50" x 2.00" and is 0.063" thick. The outer layers are 2 oz/in² and the inner layers are 1 oz/in² copper etch. All electronic components with the exception of CB10 are SMT-packaged and all connectors are through-hole.

The individual Gerber layers for the PCB are shown in Figures 14 to 22, following:

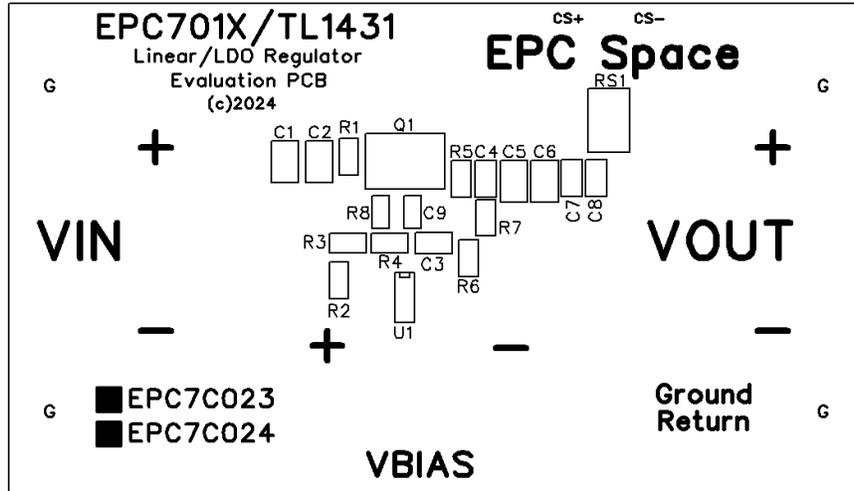


Figure 14. EPC7C023/024 Demo/Eval Board Top Silkscreen.

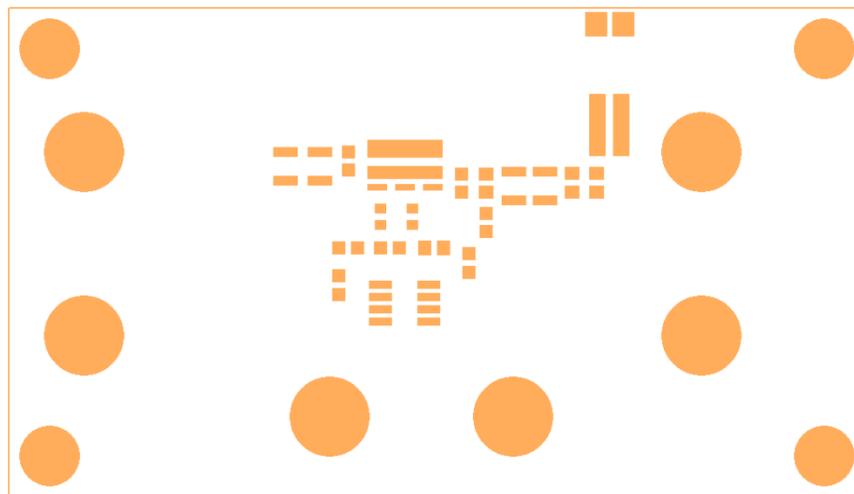


Figure 15. EPC7C023/024 Demo/Eval Board Top Solder Mask.

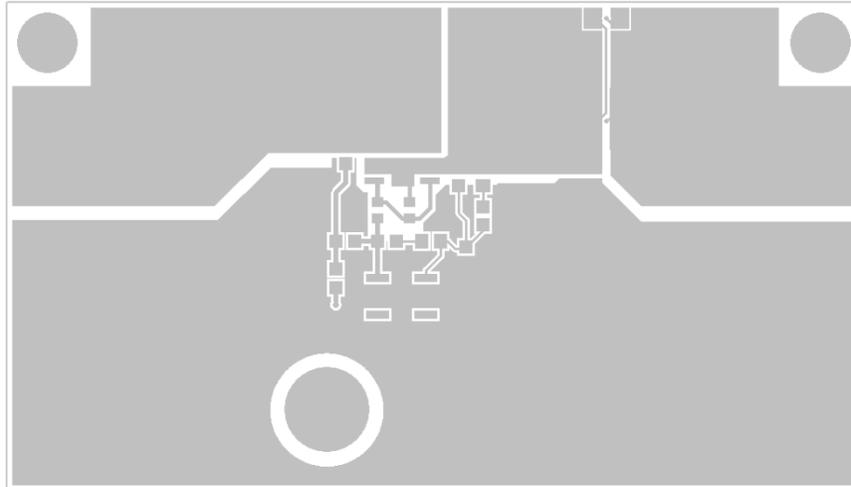


Figure 16. *EPC7C023/024 Demo/Eval Board Top Copper Etch (2oz.).*

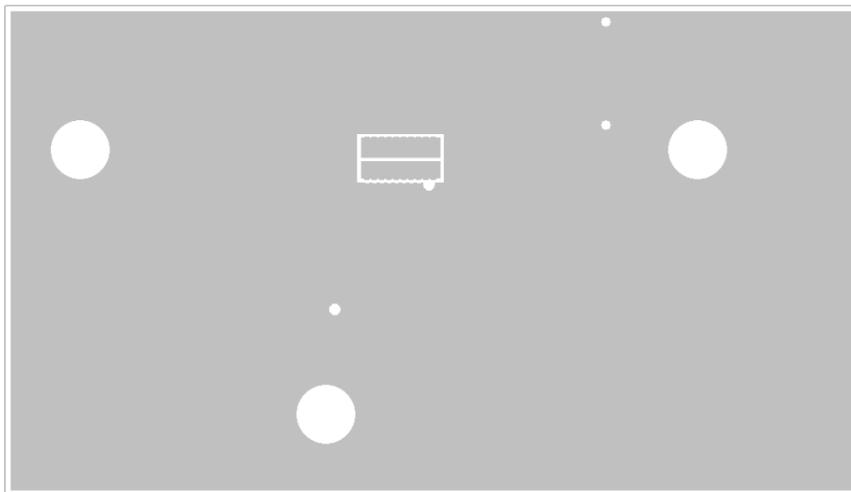


Figure 17. *EPC7C023/024 Demo/Eval Board Inner Layer #1 Copper Etch (1oz.).*

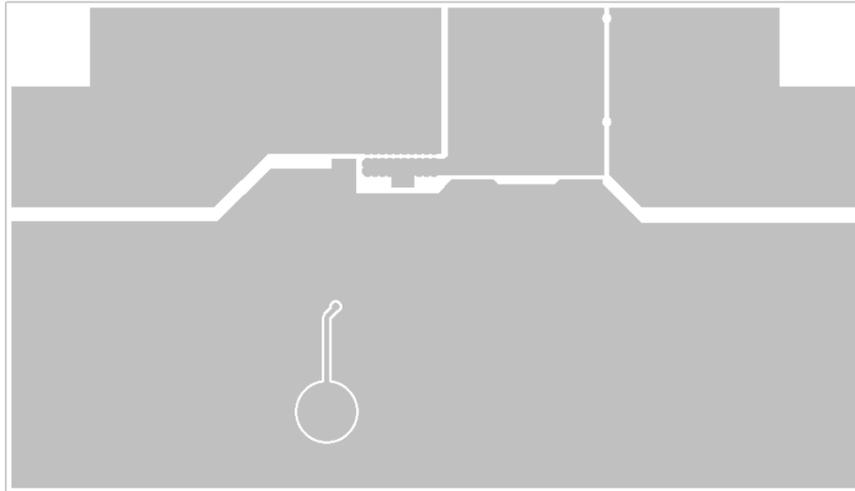


Figure 18. EPC7C023/024 Demo/Eval Board Inner Layer #2 Copper Etch (1oz.).

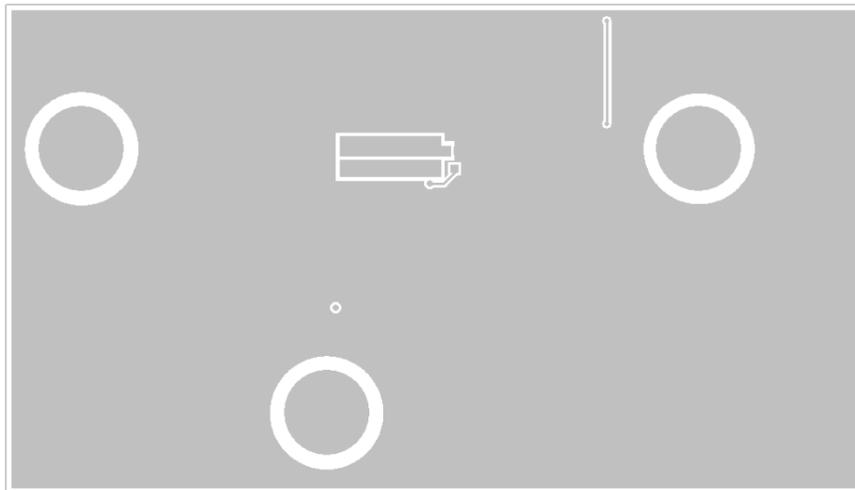


Figure 19. EPC7C023/024 Demo/Eval Board Bottom Copper Etch (2oz.).

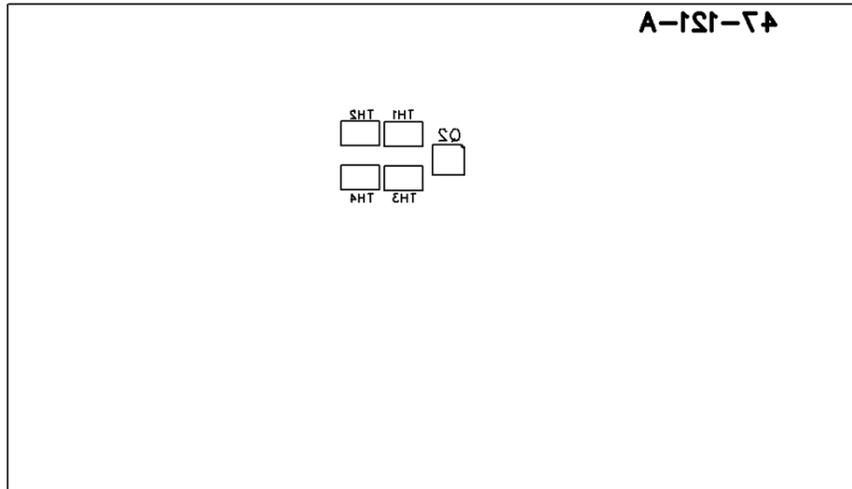


Figure 20. EPC7C023/024 Demo/Eval Board Bottom Silk Screen.

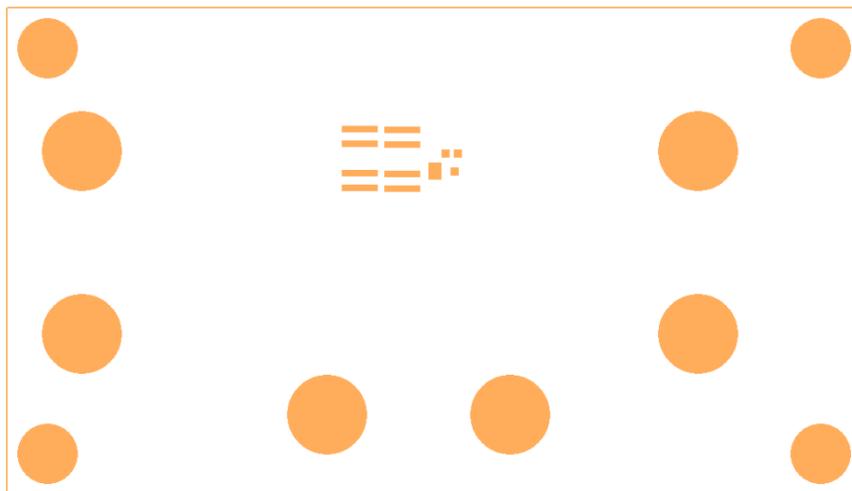


Figure 21. EPC7C023/024 Demo/Eval Board Bottom Solder Mask.

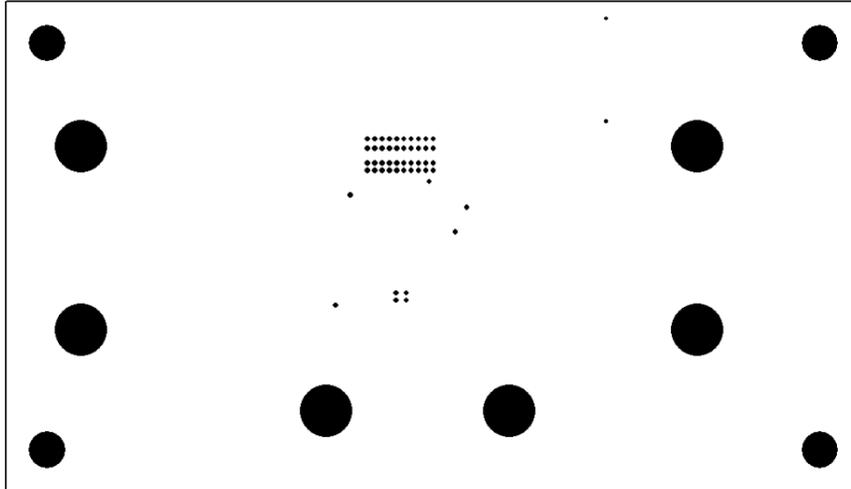


Figure 22. *EPC7C023/024 Demo/Eval Board Drill Pattern.*

NOTES:

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Revisions:

Revision	Date	Status
PR	2/11/2026	Pre-Release
--		Release
A		Revision A