QPA2811PCK01
Reference Design User's Guide

DESCRIPTION

The QPA2811 is a packaged, high-power X-band amplifier fabricated on Qorvo's GaN on SiC process (QGaN15). Covering 8.5 – 10.55 GHz, the QPA2811 provides 48.9 dBm of saturated output power and 27.9 dB of large-signal gain while achieving 48.5 % power-added efficiency.

The ACT43750 provides several functions designed to optimize performance of GaN RF power amplifiers. It provides the RF PA negative gate voltage using an ultra-low noise inverting buck dc-to-dc regulator with integrated FETs. The gate voltage can be automatically calibrated to achieve the target drain current (I_{DQ}). The ACT43750 provides the required GaN power up and power down sequencing between the drain and gate voltages. It also enables drain switching in pulsed radar applications.

APPLICATIONS

QPA2811 is ideal for military radar systems. The ACT43750 can be used to bias many different Qorvo RF power amplifiers. This reference design is specifically intended to bias the QPA2811.

FEATURES

The QPA2811PCK01 reference design combines two boards which allows for easy evaluation of both the QPA2811 and ACT43750 ICs. The two assemblies mate together to provide a secure and low-impedance path for the V_{DRAIN}, V_{GATE}, and GND connections between the two devices. The ACT43750 is pre-configured to calibrate I_{DQ} to the target value (1.24A). Both assemblies are 2" x 1" in size to allow for mechanical compatibility.

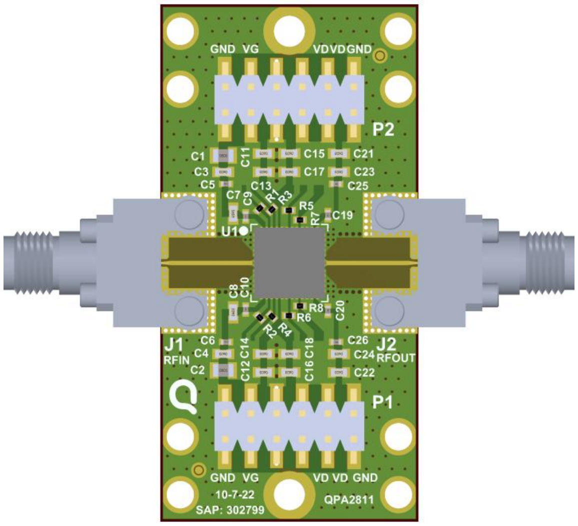


Figure 1 - QPA2811EVBPK01

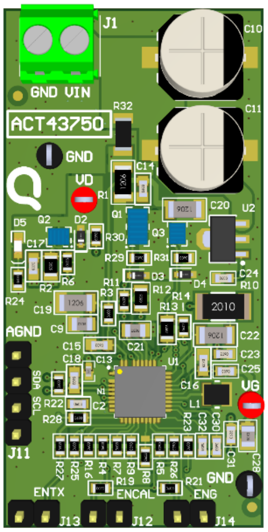


Figure 2 - ACT43750EVBP2

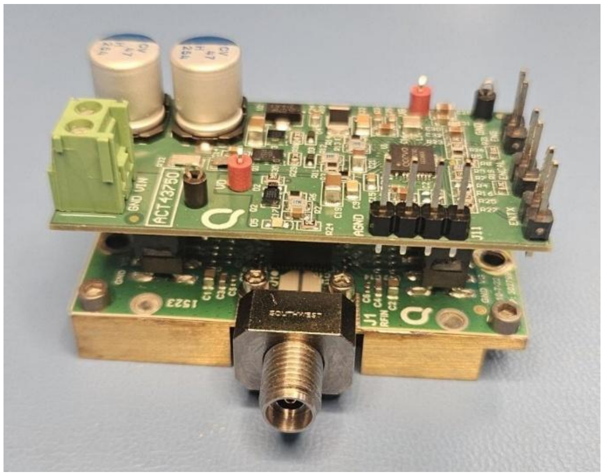


Figure 3 – Mated Boards

REFERENCE DESIGN CONTENTS

- ACT43750EVBP2 optimized for QPA2811
- QPA2811EVBPK01
- USB-TO-I2C Dongle and Cable

RECOMMENDED TEST EQUIPMENT

- DC Power Supply (24V, up to 8A)
- Function Generator (for drain switching)
- Windows PC with USB port for I2C Dongle
- RF Input Signal
- Load for RF Output

HARDWARE SETUP

- The ACT43750 EVB will be mounted on top of the QPA2811 EVB.
- Connect the 24V DC supply to J1 on the ACT43750 EVB.
- Connect the USB-to-I2C Dongle to J11 on the ACT43750 EVB. Make sure the black wire is connected to AGND.
- Plug the USB Dongle into the PC.
- If V_{DRAIN} switching is desired, connect a function generator to J13 on the ACT43750 EVB. ENTX supports 1.8V, 3.3V, 5V logic.
- Connect RF input to J1 of the QPA2811 EVB.
- Connect RF output to J2 of the QPA2811 EVB.
- Ensure that the QPA2811 EVB is oriented in the correct direction. If it is accidentally rotated 180°, then V_{DRAIN} and V_{GATE} will be flipped, and the device may be damaged.

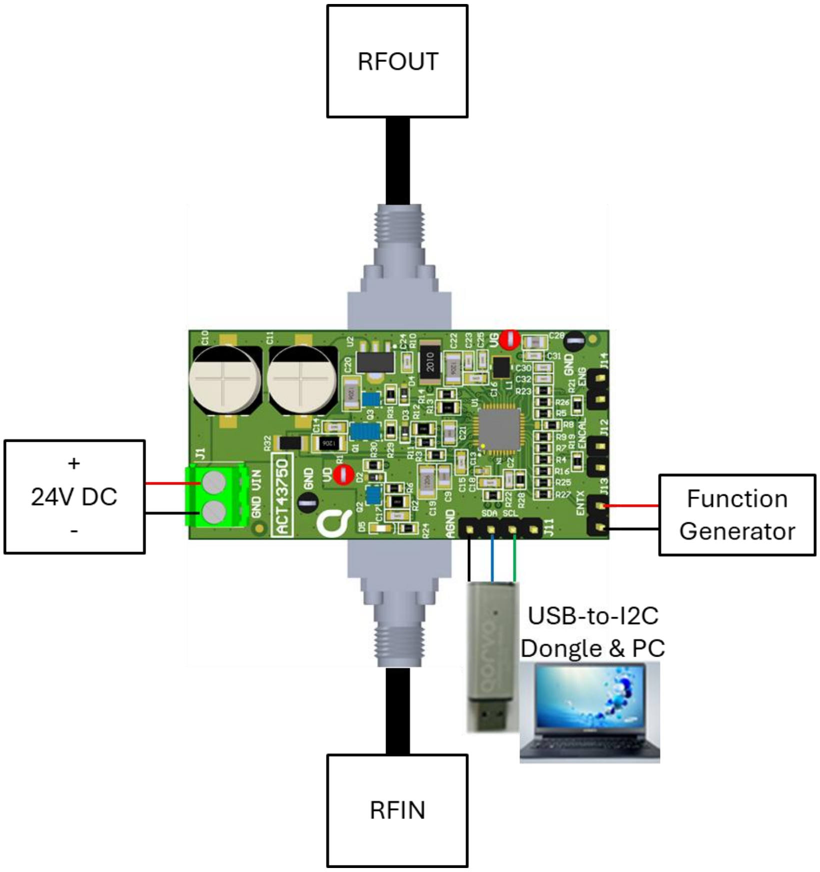


Figure 4 - Hardware Setup

OPERATING CONDITIONS

Parameter	Min	Typ	Max	Unit
V_{DRAIN}	20	24	28	V
I_{DRAIN}			7.6	A
ENTX On-Time	12	100	-	µs
ENTX Off-Time	40	900	-	µs

ACT43750 GUI INSTALLATION

1) Download the ACT43750 GUI installer from the Qorvo website
2) Plug the Qorvo USB Dongle into a free USB port
3) Install the GUI by opening the installer
4) Open ACT43750 Customer GUI Rev0.6.exe

POWER UP (WITH I2C)

1) Apply 24V to J1 of the ACT43750 EVB.
2) Open the GUI. Press "Read" button and confirm readback success.
3) Press "Enable V_{GATE}" button. V_{GATE} will default to -4V.
4) Press "Autocalibration" button.
    a. V_{GATE} will slowly ramp up to achieve the target I_{DQ} of 1.24A
5) Apply drain switching signal to ENTX.
    a. The pulse width on-time should be greater than 12µs according to the ACT43750 specification.
    b. To limit power dissipation in QPA2811, consider using a low duty cycle.
6) Apply RF signal.

POWER UP (WITHOUT I2C)

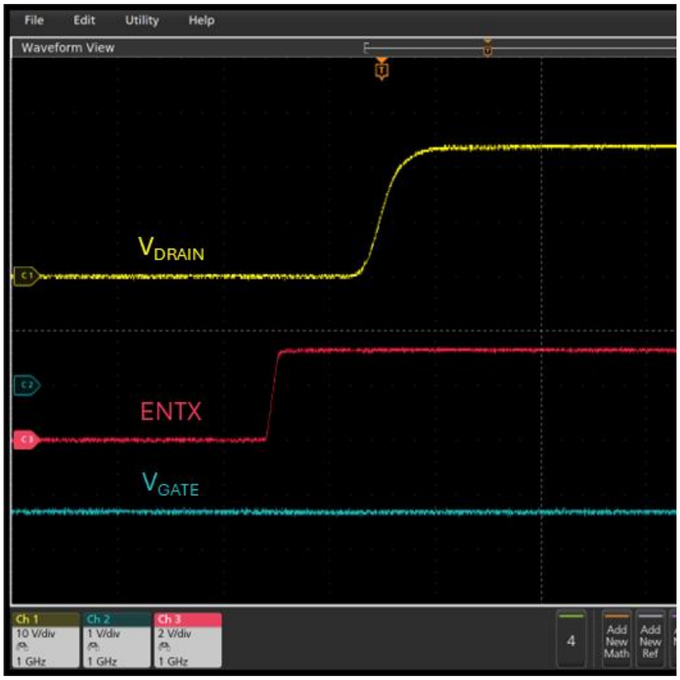
1) Apply 24V to J1 of the ACT43750 EVB.
2) Enable V_{GATE} with the ENG pin (place jumper on J14 and leave in place)
3) Perform Autocalibration with the ENCAL pin (place jumper on J12 for 1-second; then remove the jumper)
    a. V_{GATE} will slowly ramp up to achieve the target I_{DQ} of 1.24A
4) Apply drain switching signal to ENTX (connect a function generator to J13).
    a. The pulse width on-time should be greater than 12µs according to the ACT43750 specification.
    b. To limit power dissipation in QPA2811, consider using a low duty cycle.
5) Apply RF signal.

POWER DOWN

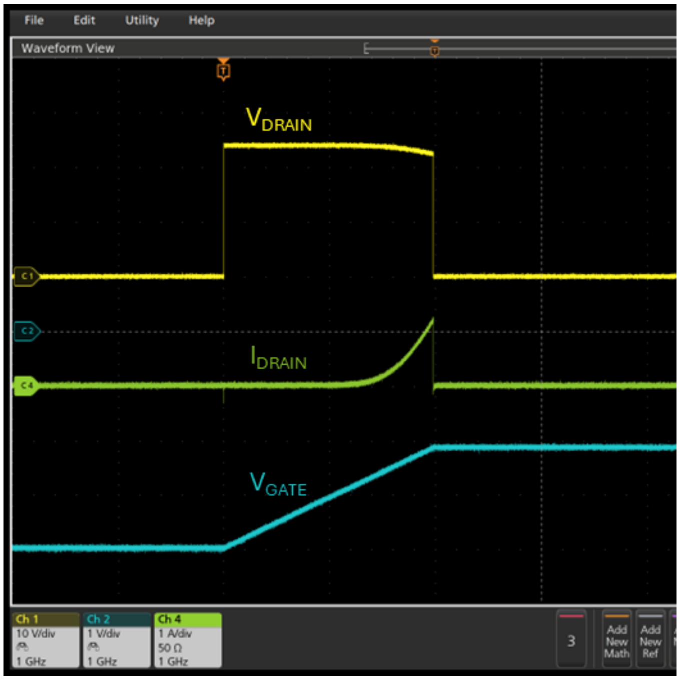
1) Turn off RF signal.
2) Turn off drain switching function generator
3) Verify V_{DRAIN} is discharged to 0V.
4) Turn off the 24V DC supply

TEST RESULTS

1 ms/div
V_{DRAIN} = 24V I_{DQ} = 1.24A
V_{DRAIN} Switching w/ ENTX



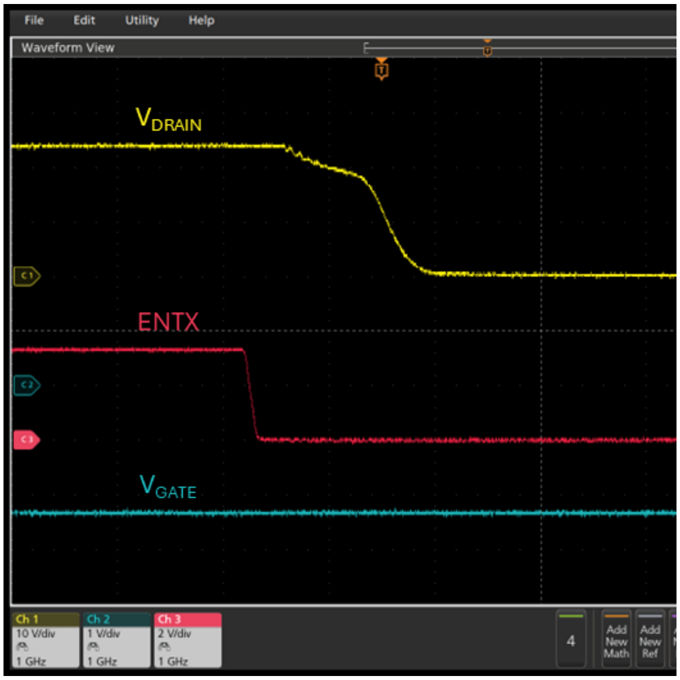
200 ns/div
V_{DRAIN} = 24V I_{DQ} = 1.24A HSGU = 150Ω
V_{DRAIN} Rise Time w/ ENTX



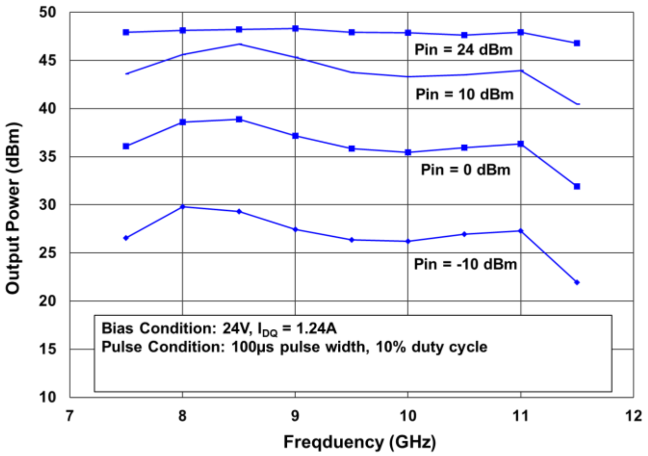
40 ms/div
V_{DRAIN} = 24V I_{DQ} = 1.24A
I_{DQ} Calibration

400 ns/div
V_{DRAIN} = 24V I_{DQ} = 1.24A C_{DRAIN} = 20nF
V_{DRAIN} Rise Time w/ Inrush Current

TEST RESULTS, CONTINUED

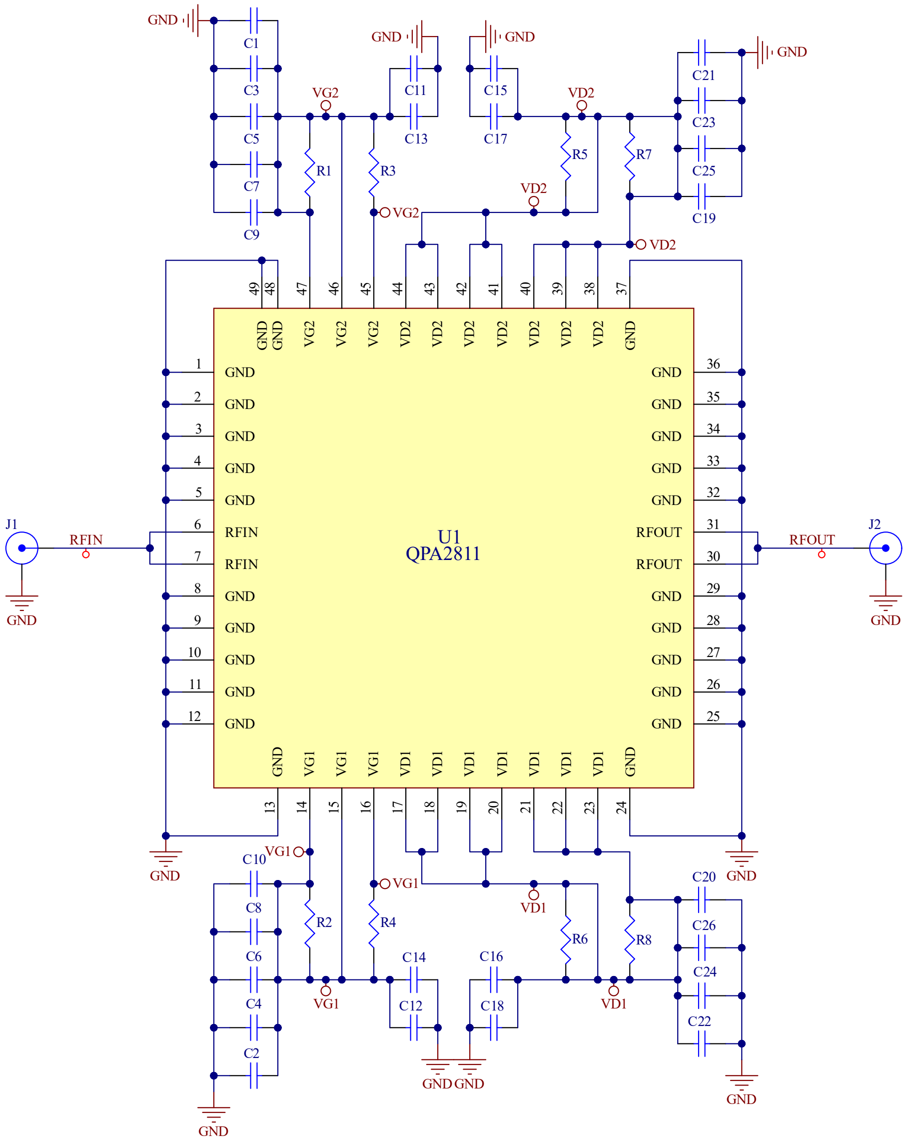


200 ns/div
V_{DRAIN} = 24V I_{DQ} 1.24A DTDSW50 = 1110
V_{DRAIN} Fall Time w/ ENTX



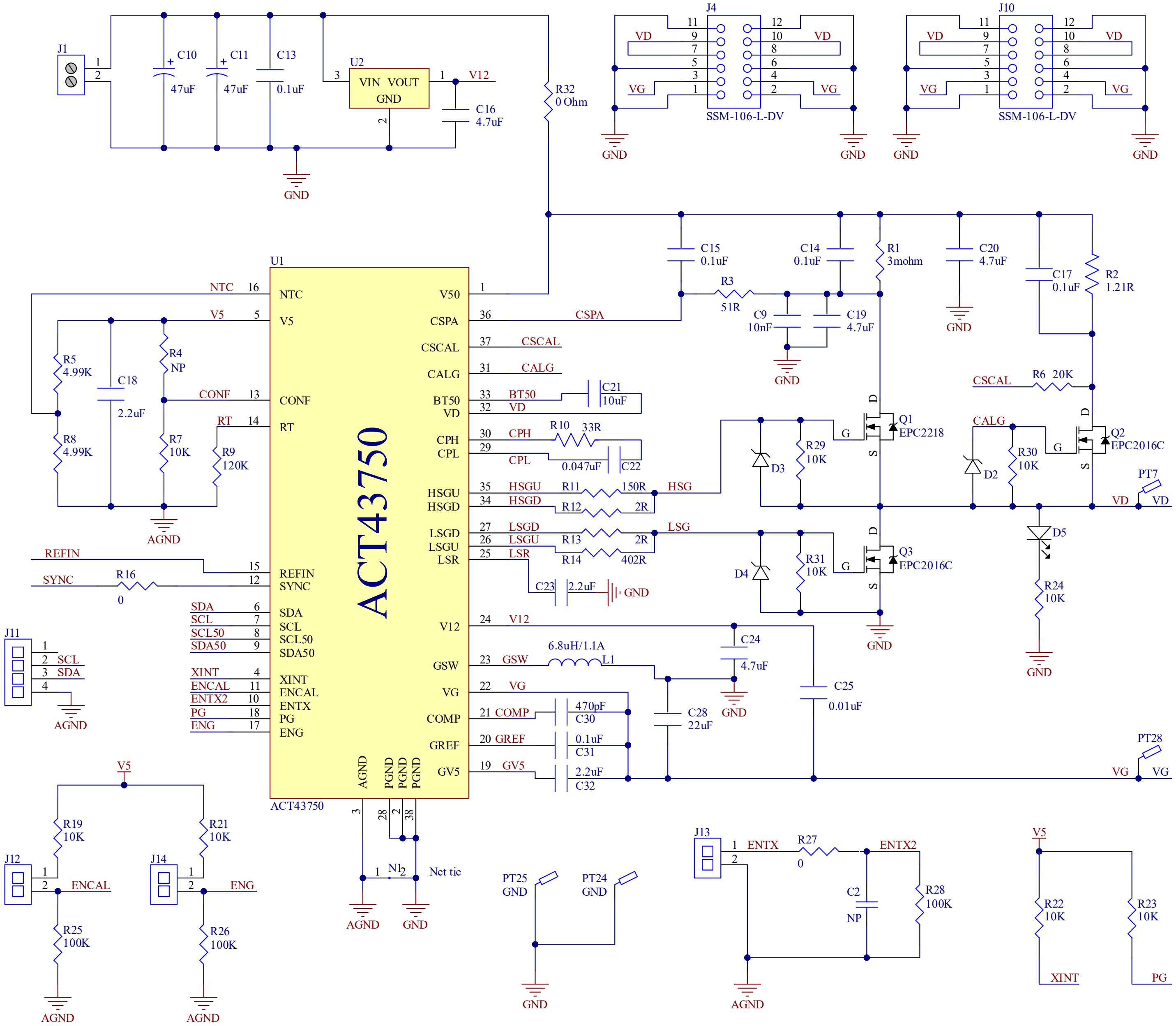
QPA2811 Output Power with ACT43750EVBP2

QPA2811EVBPK01 SCHEMATIC AND BOM



Ref Des	Value	Description	Part Number
C1, C2	10 uF	CAP, 10uF, ±10%, 16V, X7R, 0805	Various
C3, C4, C7, C8	1 uF	CAP, 1uF, 10%, 50V, X5R, 0603	Various
C5, C6, C9, C10	0.1 uF	CAP, 0.1uF,10%, 50V, X7R, 0402	Various
C25, C26	10nF	CAP, 10nF,10%, 50V, X7R, 0402	Various
R1, R2, R3, R4, R5, R6, R7, R8	0 Ohm	RES, 0 OHM, 1/10W, 0402	Various
J1, J2	2.92 mm	Female End Launch Connector	Southwest Microwave 1092-01A-12

ACT43750EVBP2 SCHEMATIC



ACT43750EVBP2 BOM

Qty	Designator	Description	Part Number
2	C10, C11	CAP, 47uF, 20%, 50V, ALUM POLY, RADIAL	Nichicon PCV1H470MCL7GS
1	L1	IND, 6.8uH, 20%, 1.1A, SHLD, W/W, 1008	MURATA DFE252010F-6R8M=P2
1	Q1	TRSTR, GaNFET, N-CH, 100V, 60A	EPC EPC2218
2	Q2, Q3	TRSTR, GaNFET, N-CH, 100V, 18A	EPC EPC2016C
1	R1	RES, 3mOhm, 1%, 1W, 1206	KOA Speer TLR2BWDTD3L00F75
1	R10	RES, 33 OHM, 1%, 1W, 2010	Vishay CRCW201033R0FKEFHP
1	R2	RES, 1.21 OHM, 1%, 1/4W, 0805	KOA Speer RK73H2ATTD1R21F
1	R32	RES, 0 OHM, JMPR, 1206	KOA Speer TLRZ2B
1	U1	ACT43750-103.E1	Qorvo ACT43750-103.E1
3	D2, D3, D4	DIO, ZENER, 5.1V, 200mW, SOD523	MCC BZT52C5V1T-TP
1	D5	LED, GREEN, DIFF, 527nM, 3V, 0603	ROHM SMLD12EN1WT86
1	U2	IC, VOLT REG, LINEAR, 12V, 100mA, SOT89-3	Diodes, Inc. AS78L12RTR-G1
1	J1	CONN, TERM BLK, 2-POS, 3.5mm, T/H	Wurth 691214110002S
1	J11	CONN, HDR, VERT, 4-POS, 0.100", T/H	Wurth 61300411121
3	J12, J13, J14	CONN, HDR, ST, 2-POS, 0.100", T/H	Wurth 61300211121
2	J4, J10	CONN, HDR, RCPT, VERT, 2x6, 0.100", SMD	SAMTEC SSM-106-L-DV
2	PT24, PT25	TEST POINT, BLACK, 0.040", T/H	KEYSTONE 5001
2	PT7, PT28	TEST POINT, RED, 0.040", T/H	KEYSTONE 5000

ACT43750EVBP2 BOM, CONTINUED

Qty	Designator	Value	Tolerance	Rating	Size	Part Number
1	C13	0.1uF	10%	50V	0402	Standard
4	C14, C15, C17, C31	0.1uF	10%	100V	0603	Standard
2	C16, C24	4.7uF	10%	25V	0603	Standard
3	C18, C23, C32	2.2uF	10%	25V	0603	Standard
2	C19, C20	4.7uF	10%	50V	1206	Standard
1	C21	10uF	10%	25V	0805	Standard
1	C22	47nF	10%	100V	1206	Standard
1	C25	10nF	10%	50V	0603	Standard
1	C28	22uF	10%	16V	0805	Standard
1	C30	470pF	5%	50V	0603	Standard
1	C9	10nF	10%	100V	0805	Standard
1	R11	150 OHM	1%	1/10W	0603	Standard
2	R12, R13	2 OHM	1%	1/4W	0805	Standard
1	R14	402 OHM	1%	1/10W	0603	Standard
2	R16, R27	0R	--	1/10W	0603	Standard
9	R24, R19, R21, R22, R7, R23, R29, R30, R31	10K	1%	1/10W	0603	Standard
3	R25, R26, R28	100K OHM	1%	1/10W	0603	Standard
1	R3	51 OHM	1%	1/10W	0603	Standard
2	R5, R8	4.99K OHM	1%	1/10W	0603	Standard
1	R6	20K OHM	1%	1/10W	0603	Standard
1	R9	120K OHM	1%	1/10W	0603	Standard

ACT43750EVBP2 BOM NOTES

Gate Resistors: R11, R12, R13, R14

R11	HSGU	150Ω	High resistor value to slowly turn-on FET. Reduces inrush current into capacitance on RFPA Drain.
R12	HSGD	2Ω	Low resistor value to quickly turn-off FET
R13	LSGD	2Ω	Low resistor value to quickly turn-off FET
R14	LSGU	402Ω	High resistor value to slowly turn-on FET. Reduces inrush current from capacitance on RFPA Drain.

The QPA2811EVBPK01 includes 2 x 10nF of capacitance on V_{DRAIN}. This capacitor must be charged/discharged each time the drain voltage is turned on/off. To minimize inrush current, we have selected high resistor values for HSGU and LSGU.

Reduced HSGU and LSGU values will allow for faster rise and fall time of V_{DRAIN}. The rise and fall times are a function of the gate resistance and the Q_G of the MOSFET (Q1 and Q3). Inrush current is calculated as follows:

$$I = C\ x\ dV/dt$$

C: Capacitance on V_{DRAIN} (2 x 10nF)
dV: V_{DRAIN} (24V for QPA2811)
dt: Rise Time or Fall Time of V_{DRAIN} (typically ns)

I_{DQ} Calibration Resistor: R2

The ACT43750 can automatically calibrate the RFPA gate voltage to achieve the target I_{DQ} of 1.24A. This target is set with the R2 calibration resistor.

$$R_{SCAL} = \frac{1.5V}{I_{DQ}}$$

I_{DQ}: Defined as 1.24A in the QPA2811 Datasheet
R_{SCAL}: Calibration Resistor

Optional Current Probe: R32

R32 is a 0-Ohm resistor in series with the high-side drain switch. If desired, the user may remove this resistor and insert a loop for current measurement.

Charge Pump: C21, C22, R10

The Charge Pump generates the gate drive voltage for the high-side N-channel MOSFETs (Q1, Q2).

C21 stores the gate drive voltage. Use an 0805 10uF capacitor between BT50 and VD.

C22 is 47nF. This value is chosen for optimal charge pump performance.

R10 is 33Ω. Power dissipation in R10 is calculated as follows:

$$P = 0.5 * C * V^2 * F$$

Example Calculation:

$$P = 0.5 * 47nF * 24^2 * 1kHz = 0.014W$$

C: C22 (47nF)
V: V_{DRAIN} (24V for QPA2811)
F: Drain Switching Frequency (application dependent)

Power dissipation is negligible in this example calculation. However, if operating at higher voltage or higher frequency, a high-power resistor may be necessary for R10.

Overcurrent Protection: R1, R3, C15

R1 sets the overcurrent protection threshold:

$$R_{SPA} = \frac{35mV}{OCP\ Threshold}$$

R3 and C15 form a low-pass RC filter. It is designed to filter short-duration current spikes and prevent nuisance trips of the OCP threshold.

Bulk Input Capacitors: C10, C11

C10 and C11 are 50V 47µF bulk capacitors. QPA2811 has V_{DRAIN} of 24V; hence, 50V capacitors are adequate for this application. For higher voltage RFPA, C10 and C11 can be adjusted accordingly.

ACT43750-103.E1: U1

CMI103 is in development for this reference design. The user may notice a white dot on top of the IC to indicate prototype status.