APPLICATION NOTE

High Voltage Driver Circuit for High-Power PIN Diode Switches

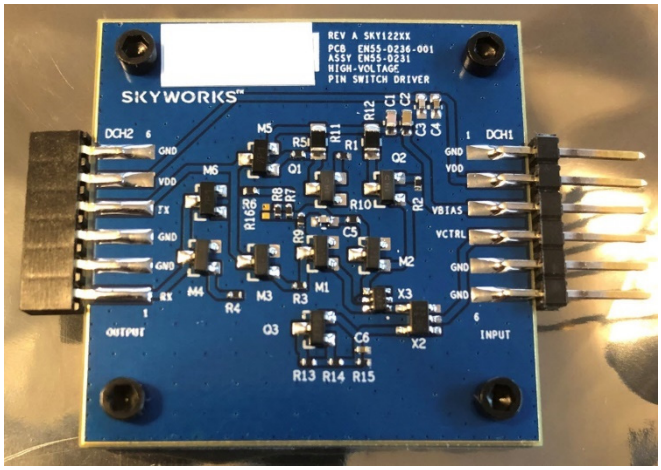
Introduction

The Skyworks High Voltage Driver Circuit for High-Power PIN Diode Switches is a CMOS/TTL compatible, DC coupled, high-speed PIN diode bias controller. The part number is EN55-D231.

This driver reference design operates with the Skyworks series of high-power SPDT PIN diode switches. These include:

- SKY12248-478LF
- SKY12255-708LF

This driver is designed to provide forward currents up to 200 mA for each diode, and 48 V reverse bias. It is designed for SPDT switches operating with a CW input a power up to 160 W. The driver utilizes fast switching NPN/MOSFET transistors. The driver is designed to utilize a VDD of 5 V and a VBIAS up to +48 V.



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Features

- High drive current capability of 200 mA
- Up to 48 V back bias for switch off state condition
- Fast turn on/turn off switching speed of <403 nS with 48 V
- CMOS logic input
- Single TTL logic input

Table 1. Absolute Maximum Ratings[1]

Parameter	Conditions
VDD	–0.5 V to 7 V
VBIAS	–0.5 V to 60 V
VCTRL	–0.5 V to 5 V
RX drive current	200 mA
TX drive current	200 mA
Operational temperature	–40 to +85°C
Storage temperature	–55 to +125°C

1 Exposure to maximum rating conditions for extended periods may reduce device reliability. There is no damage to device with only one parameter set at the limit and all other parameters set at or below their nominal value. Exceeding any of the limits listed here may result in permanent damage to the device.

Table 2. Pin Description (INPUT CONNECTOR)[1]

PIN	Conditions	Value
GND	Ground	GROUND
VDD	5 V	INPUT
VBIAS	48 V	INPUT
VCTRL	Logic Control 0/3 V	INPUT
GND	Ground	GROUND
GND	Ground	GROUND

[1]Only 1 board GND pin needs to be connected.

Table 3. Pin Description (OUTPUT CONNECTOR)[1]

PIN	Conditions	Value
GND	Ground	GROUND
VDD	5 V	OUTPUT
TX	0 V or up to +48 V	OUTPUT
GND	Ground	GROUND
GND	Ground	GROUND
RX	0 V or up to +48 V	OUTPUT

[1]Only 1 board GND pin needs to be connected.

Table 4. Truth Table (Switch)

Logic Control	State	State
VCTRL	TX Mode	RX MODE
0	OFF	ON
1	ON	OFF

Table 5. Electrical Specifications T = +25 °C, VDD = 5 V, VBIAS = +48 V[1]

Parameter	Conditions	Min	Typ	Max	Unit
DC output current TX or RX Mode			150	200	mA
Reverse bias voltage TX or RX Mode	1 V drop on PIN diode		47		V
Switching speed ANT-RX	TRISE: RF 10% to 90%		78		ns
Switching speed ANT-RX	TFALL: RF 90% to 10%		182		ns
Switching speed ANT-RX	TON: DC 50% to RF 90%		536		ns
Switching speed ANT-RX	TOFF: RF 90% to DC 50%		382		ns
Switching speed ANT-TX	TRISE: RF 10% to 90%		252		ns
Switching speed ANT-TX	TFALL: RF 90% to 10%		305		ns
Switching speed ANT-TX	TON: DC 50% to RF 90%		554		ns
Switching speed ANT-TX	TOFF: RF 90% to DC 50%		583		ns
Settling time ANT-TX	0.3 dB from settled RF value		637		ns
Settling time ANT-RX	0.3 dB from settled RF value		612		ns
Pulse repetition freq. PRF	50% duty cycle	DC		100	kHz
Logic levels	Logic “0” Logic “1”	0 1.17	0.3 1.8	0.63 3.3	V V

[1] Measured when driving the SKY12248-492LF SPDT switch.

Table 6. Recommended Operating Conditions

Parameter	Conditions	Min	Typ	Max	Unit
VDD voltage	ANT and driver voltage	4.5	5	5.5	V
VDD current	ANT and driver current		150		mA
VBIAS	Bias voltage	5		48	V
VCTRL (LOW)	RX Mode	0.0	0.3	0.63	V
VCTRL (HIGH)	TX Mode	1.17	1.8	3.3	V

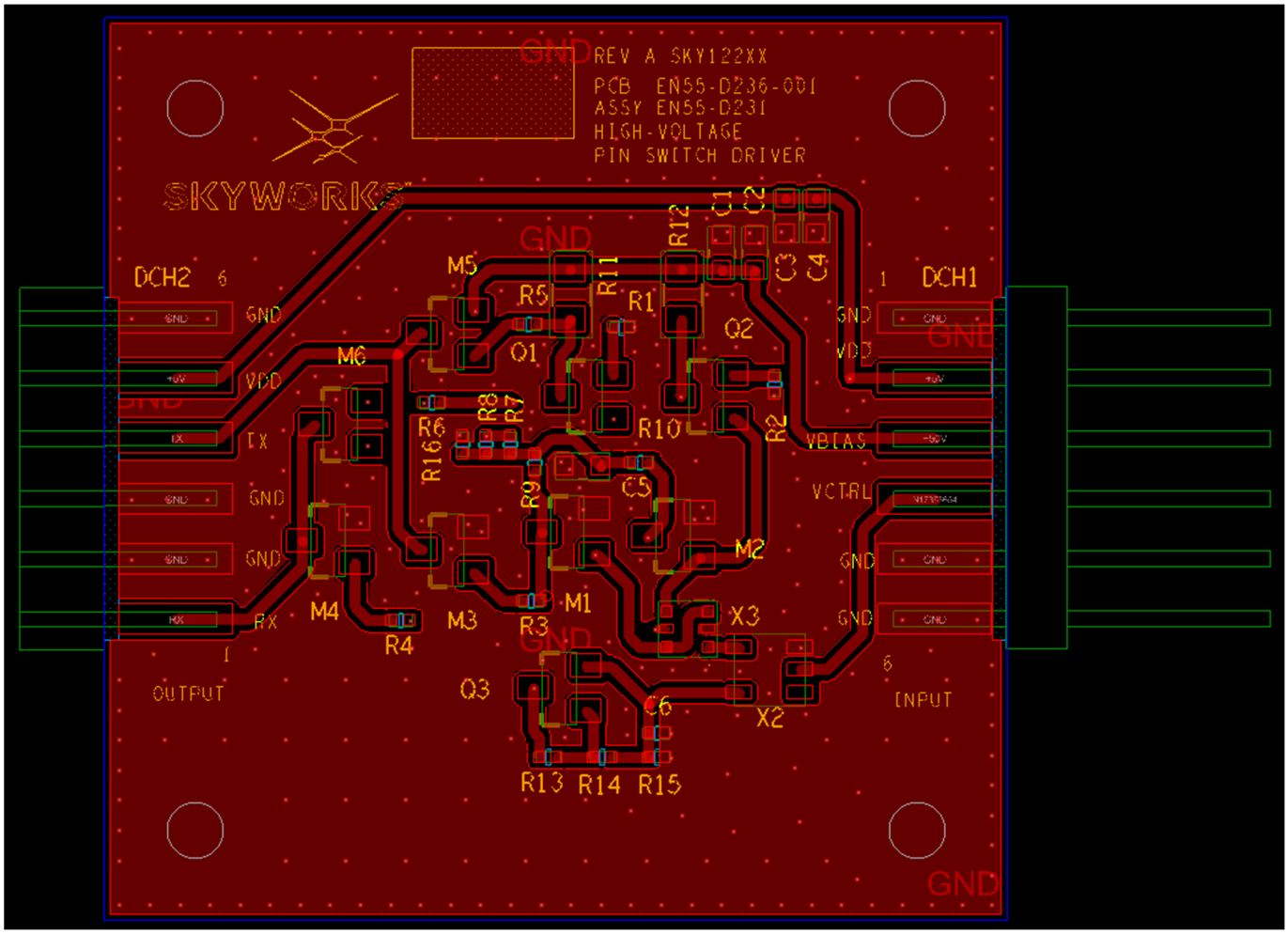


Figure 1. Circuit Board 1.5-in x 1.5-in

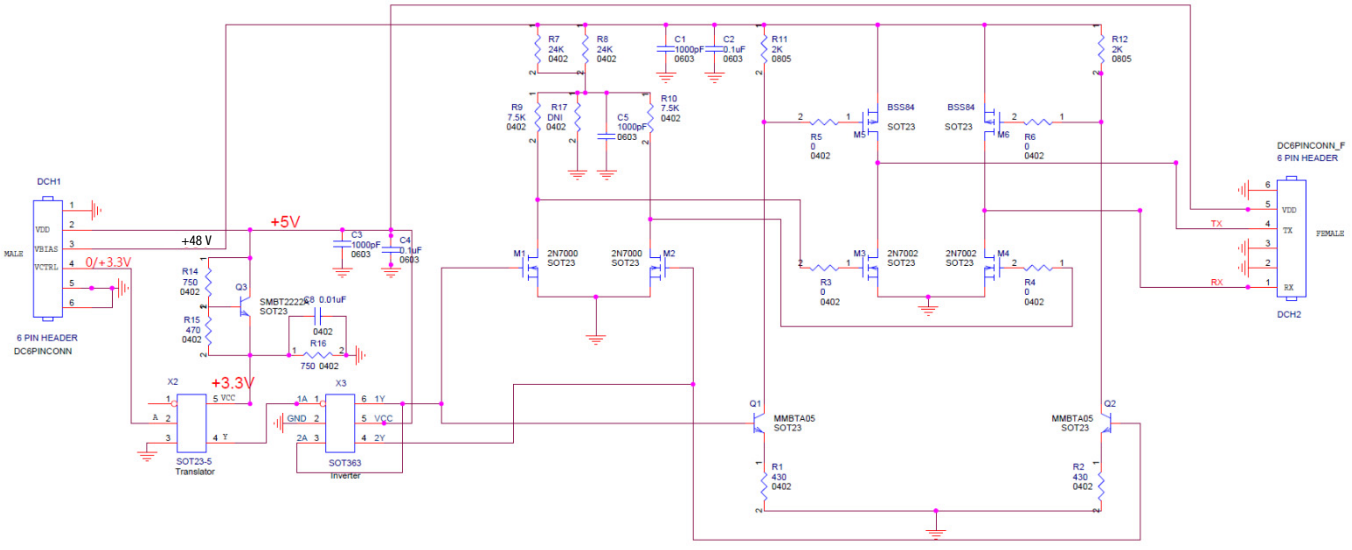


Figure 2. Application Circuit Schematic

Table 7. Driver Board EN55-D236-001 Bill of Materials

Item Number	Quantity	Part Reference	Value	Units	Size	MFG	Part Number	Description
1	1	C1	1000	pF	0603	TDK Corp	C1608C0G1H102J080AA	CAP CER 1000 PF 50 V +/-5%
2	1	C2	0.1	uF	0603	Murata	GRM188R72A104KA35J	CAP CER 0.1 uF 100 V +/-10%
3	2	C3, C5	1000	pF	0402	Murata	GRM1555C1H102JA01J	CAP CER 1000 PF 50 V C0G 0402 +/-5%
4	1	C4	0.1	uF	0402	Murata	GRM155R71H104KE14J	CAP CER 0.1 UF 50V X7R 0402 +/-10%
5	1	C6	0.01	uF	0402	Murata	GRM155B31H103KA88D	CAP CER 0.01 UF 50 V 0402 +/-10%
6	2	R1, R2	430	Ohms	0402	Panasonic	ERJ-2RKF4300X	RES SMD 430 OHM 1/10 W +/1%
7	4	R3, R4, R5, R6	0	Ohms	0402	Panasonic	ERJ-2GE0R00X	RES SMD 0 OHM JUMPER 1/10 W
8	2	R7, R8	47K	Ohms	0402	Panasonic	ERJ-2RKF4702X	RES SMD 47K OHM 1/10 W +/1%
9	2	R9, R10	7.5K	Ohms	0402	Panasonic	ERJ-PA2F7501X	RES SMD 7.5 KOHM 1/5 W +/-1%
10	2	R11, R12	499	Ohms	0805	Vishay Dale	RCS0805499RFKEA	RES SMD 499 OHM 0.4 W +/1%
11	2	R13, R15	750	Ohms	0402	Panasonic	ERJ-2GEJ751X	RES SMD 750 OHM 0.1 W +/5%
12	1	R14	470	Ohms	0402	Panasonic		
13	1	R16	DNI					
14	1	X2			SOT23-5	Texas Instruments	SN74LV1T34DBVR	IC BUFFER NON-INVERT 5.5 V SOT23-5
15	1	X3			SOT363	Nexperia	74LVC2G14GW,125	IC INVERTER SCHMITT 2CH SC88
16	4	M1, M2, M3, M4			SOT-23	Diodes Inc.	NDS7002A	MOSFET N-CH 60 V 280 MA SOT-23
17	2	M5, M6			SOT-23	Diodes Inc.	ZXMP10A13FQTA	P-Channel 100 V 600 mA (Ta) 625 mW (Ta) Surface Mount SOT-23
18	2	Q1, Q2			SOT-23	On Semiconductor	NSVMMBTA05LT1G	NPN General Purpose Amplifier
19	1	Q3			SOT-23	On Semiconductor	SMBT2222A	NPN General Purpose Amplifier
20	1	DCH1 (M)	6 Pin Header			Samtec	TSW-106-25-S-S	Male 6-pin, .100 Ctrs., .025" square pins
21	1	DCH2 (F)	6 Pin Header			Samtec	SSQ-106-03-G-S	Female 6-pin, .100 Ctrs., .025" square pins
22	1	Heat Sink	1.5 x 1.5”			Skyworks	ENG031312RMP1	Aluminum: 0.25” thick
23	4	Screws	2-56					Hex Socket Head, Length = 0.25”

Driver Performance Data VDD = 5 V, VBIAS = +48 V, T = +25 °C

Figures 3 and 4 show the no load voltage vs. time response of the driver circuit operating with a 0 to 3.3 V VCTRL signal and 0 to +48 V on VBIAS. The PRF is set to 100 kHz. The red trace is the TX bias output pulse with a max voltage output of +48 V. The blue trace is RX bias output pulse and with a max voltage output of +48 V. The gold trace is VCTRL pulse of 0 to 3.3 V.

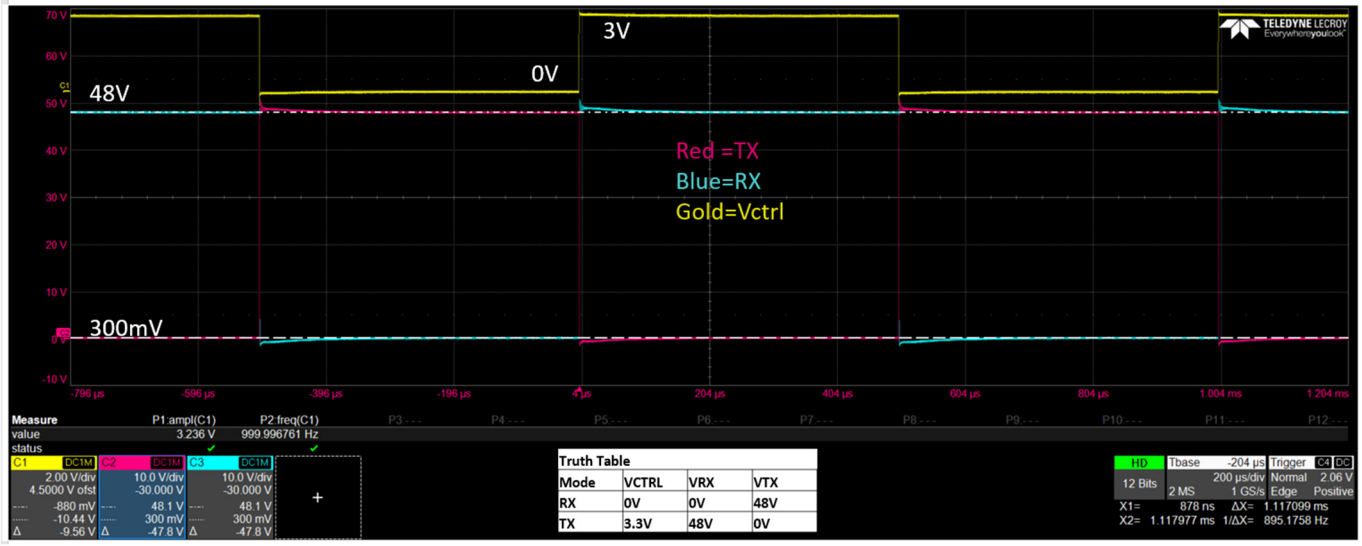


Figure 3. VCTRL to RX/TX Rise/Fall Time with SKY12248-492LF Connected: Vdd = 5 V, Vctrl 0/3.3 V, RX/TX = 0/48 V (No RF): 200 uS/Div

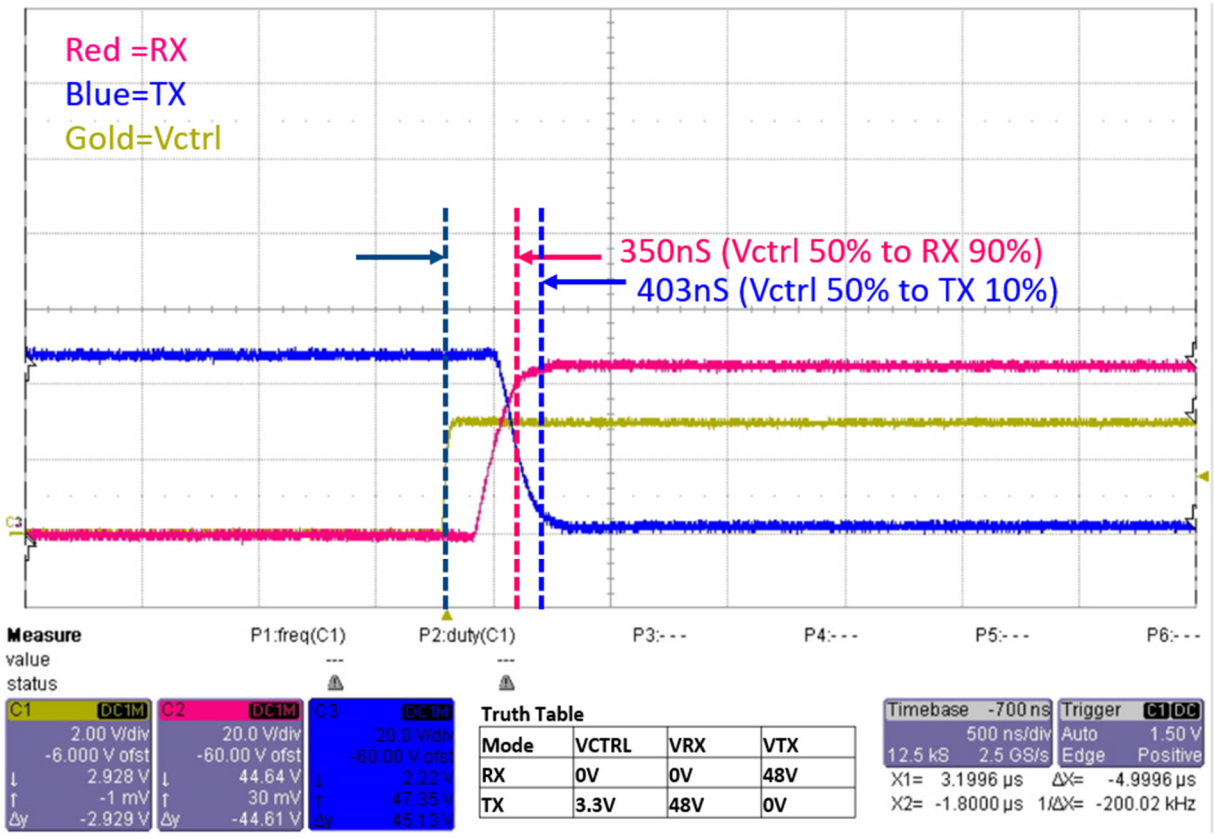


Figure 4. VCTRL to RX/TX Rise/Fall Time with SKY12248-492LF Connected: Vdd = 5 V, Vctrl 0/3.3 V, RX/TX = 0/48 V (No RF): 500 nS/Div

Driver + Switch Performance Data, VDD = 5 V, VBIAS = +48 V, T = +25 °C

The Skyworks driver circuit is designed to work with the Skyworks family of high-power PIN switches and mates directly to the Skyworks PIN switch evaluation board EN55-D236-001, as shown in Figure 5. The standard bill of materials for the SKY12248-478LF evaluation board is shown in Table 8 and represented in the schematic in Figure 6.

The exact bill of materials will vary from switch type and frequency of operation. See switch data sheets for specific bill of materials. The total bill of materials for the switch RF evaluation board and driver circuit board is the sum of the components listed in Tables 7 and 8.

Table 8. SKY12248-478LF Evaluation Board Bill of Materials Without Driver

Component	Size	Manufacturer	Mfr Part Number	Description
C1, C3	0603	MuRata	GQM1875C2E101GB12D	Ceramic capacitor, 12 pF, 250 V C0G, ±5%
C2	0402	MuRata	GQM1875C2E4R6WB12D	Ceramic capacitor, 4.6 pF, 250 V, C0G, ±0.05 pF
C4	0402	MuRata	GRM1555C18102JA01	Ceramic capacitor, 1000 pF, 50V, C0G, ±5%
C6, C7	0603	MuRata	G CM1885C2A101JA16D	Ceramic capacitor, 100 pF, 100 V, C0G, ±5%
C8	0402	MuRata	G RM1555C2A101JA01D	Ceramic capacitor, 100 pF, 100 V, C0G, ±5%
L1, L6	0603	CoilCraft	06038C-6N8XJE	Inductor, 6.8 nH, 2.1 A, ±5%
L2	0603	MuRata	LQW18AN8N7D00	Inductor, 8.7 nH, 650 mA, ± 0.5 nH
L3	0603	CoilCraft	0603HC-10NXGE	Inductor, 10 nH, 2.0 A, ±2%
L4	0402	MuRata	LQG15HN18NJ02D	Inductor, 18 nH, 350 mA, ±5%
R1, R6	0805	Rohm	ESR10EZPF56R0	Resistor, 56 Ω, 0.4 W, ± 1%
R3, R4	0805	ROhm	ERJ-P06F1001V	Resistor, 1K Ω, 0.5 W, ± 1%, for Off Bias = 16 V, R2, R5 = DNI
R2, R3, R4, R5	0805	Vishay Dale	CRCW08056K20FKYAHP	Resistor, 6.2 K Ω, 0.5 W, ± 1% for Off Bias = 48 V
C5, L5	DNI			

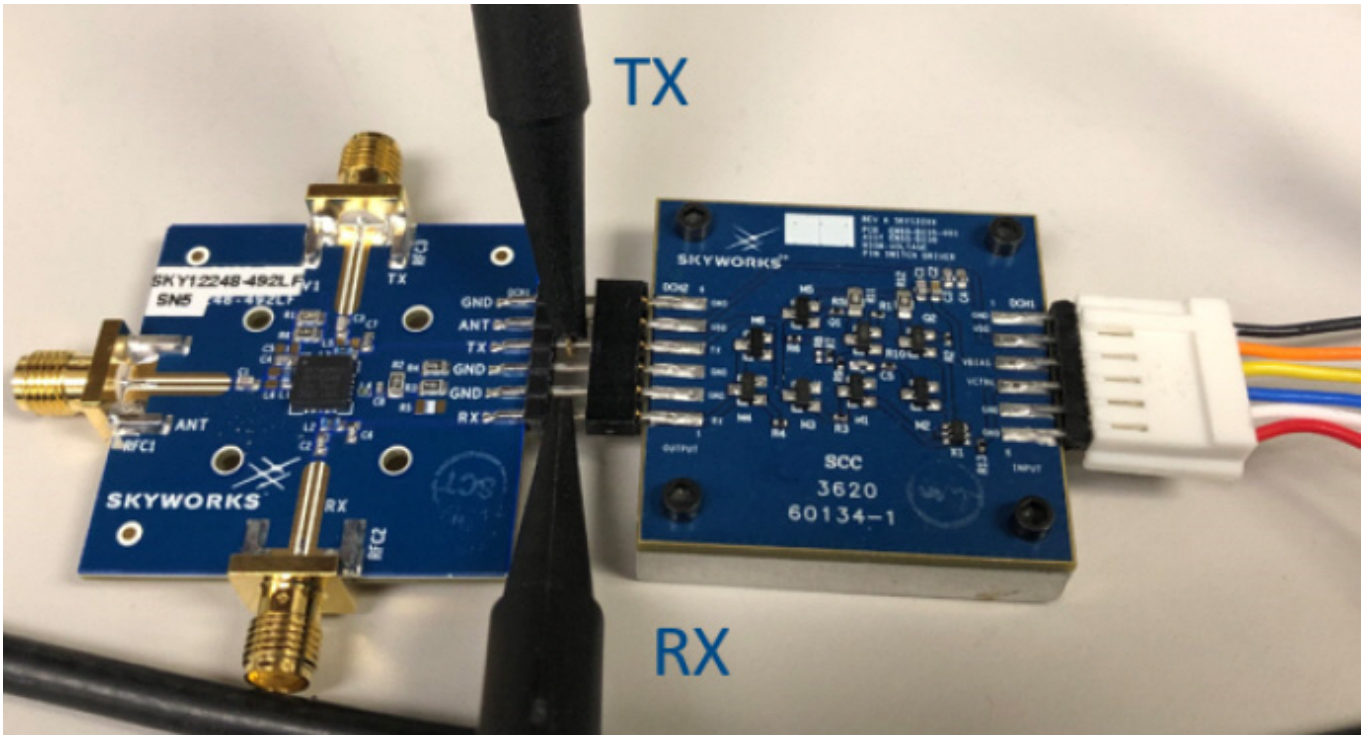


Figure 5. Skyworks High-Power PIN Switch Evaluation Board + Driver Circuit

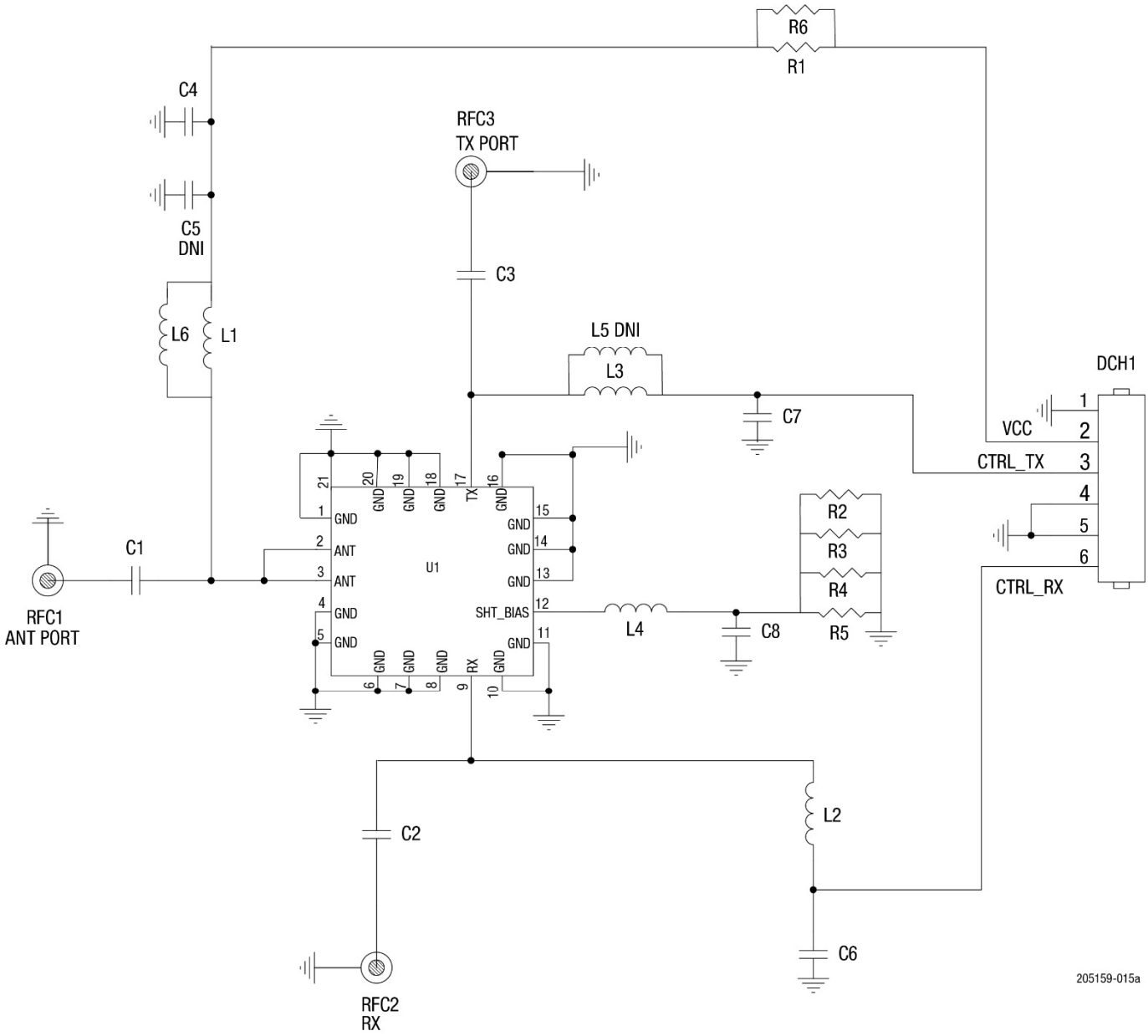


Figure 6. Skyworks High Power PIN switch Evaluation Board Circuit EN55-D677-001

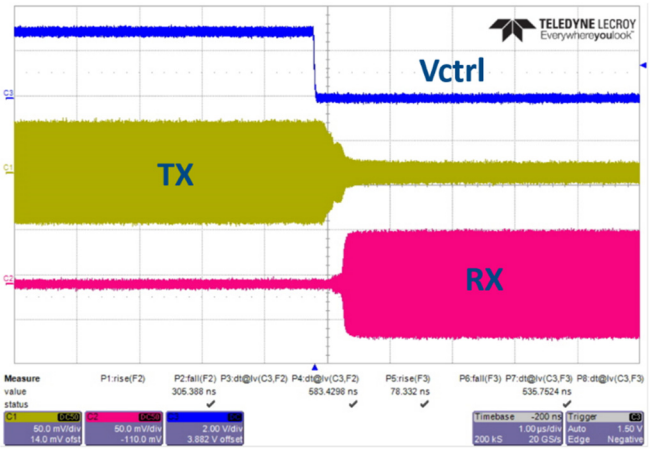
Figures 7 and 8 show the RF pulse measurement performance of the driver circuit connected to the SKY12248-478LF 120 W High Power PIN Diode T/R switch.

Figure 7 illustrates the RF rise and fall time of the RF pulse and the relationship of the VCTRL DC pulse to the RF turn on and off.

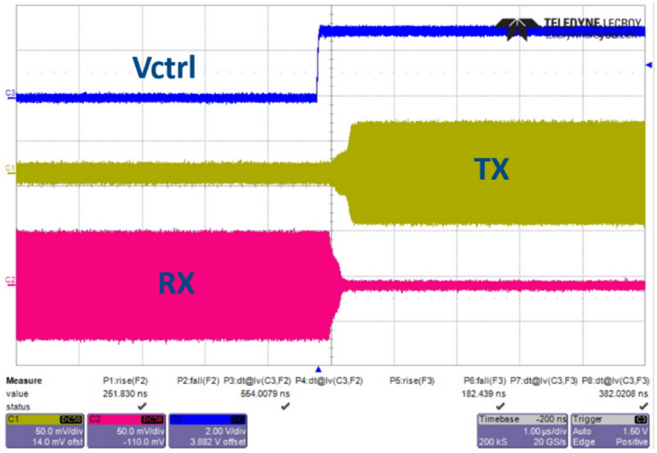
Figure 8 shows the RF signal settling time. This is the time delta from the VCTRL trigger until the RF signal is 0.3 dB below its settled value of the RF switch low loss state.

The VCTRL is switched 0 to 3.3 V, which switches RX/TX bias voltage from 0 to 48 V. The RF frequency is 2.6 GHz with an input power of -10 dBm. The PRF (pulse rate frequency) is 1 kHz and the duty cycle is 50%. Measurements are made with 2 to 3 GHz SMA band pass filters on the TX and RX RF ports.

Table 9 summarizes the test results.

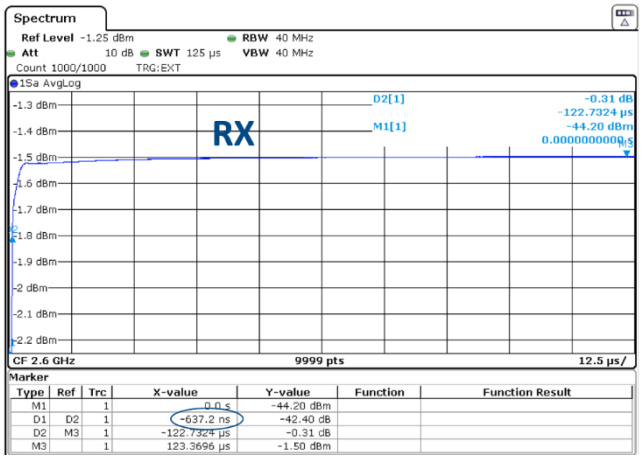


RF = 2.6 GHz, Pin = -10 dBm, F = 1 kHz,
DC = 50% (inc. HPF) Negative Trigger



RF = 2.6 GHz, Pin = -10 dBm, F = 1 kHz,
DC = 50% (inc. HPF) Positive Trigger

Figure 7. Skyworks High Power PIN Switch Evaluation Board + Driver Circuit
RX Fall/TX Rise Time with HV Driver



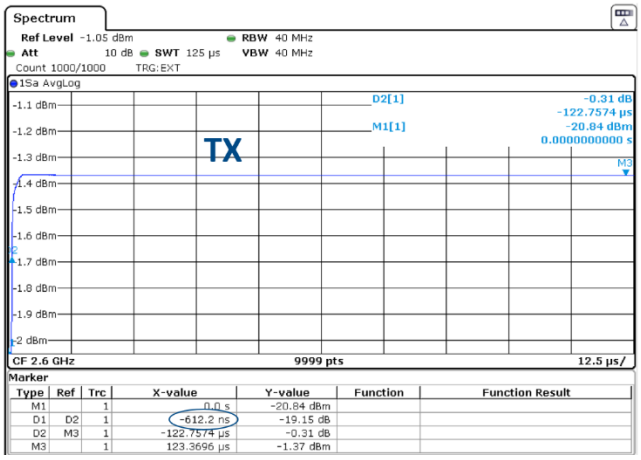


Figure 8. Skyworks High Power PIN Switch Evaluation Board + Driver Circuit
RX and TX 0.3 dB Settling Time with HV Driver

Table 9. Skyworks High Power PIN Switch Evaluation Board + Driver Circuit Switching Speed Test Summary

	RX	TX	Units
Rise Time 10 to 90%	78	252	nS
Fall Time 90 to 10%	182	305	nS
DC 50% to RF ON 90%	536	554	nS
DC 50% to RF OFF 10%	382	583	nS
Settling time (0.3 dB)	637	612	nS

Summary

The Skyworks high-power PIN diode switch driver reference design circuit is a CMOS/TTL compatible, DC coupled, high-speed PIN diode bias controller. It is designed to operate with the Skyworks series of high-power SPDT PIN diode switches. Samples of the PIN diode driver and switch EVBs are available from Skyworks.

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