TEXAS INSTRUMENTS

48-V to 3.3-V RCD Forward with UCC35705 Voltage-Mode Control and Self-Driven Synchronous Rectification

User's Guide

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Applying loads outside of the specified output range may result in unintended operation and/or possible permanent damage to the EVM. Please consult the EVM User's Guide prior to connecting any load to the EVM output. If there is uncertainty as to the load specification, please contact a TI field representative.

During normal operation, some circuit components may have case temperatures greater than 50°C. The EVM is designed to operate properly with certain components above 50°C as long as the input and output ranges are maintained. These components include but are not limited to linear regulators, switching transistors, pass transistors, and current sense resistors. These types of devices can be identified using the EVM schematic located in the EVM User's Guide. When placing measurement probes near these devices during operation, please be aware that these devices may be very warm to the touch.

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1 Introduction

The UCC35705 voltage mode controller with voltage feed-forward provides the control of this telecom (36 V_{DC} to 72 V_{DC}) to 3.3-V_{DC} converter with synchronous rectification. Capable of supplying 10 A of output current at 3.3 V_{DC} with up to 85% efficiency, UCC35705EVM uses self-driven, high-speed, very low $R_{DS(on)}$ MOSFETs for improved efficiency and high-speed operation.

WARNING:
Failure to exercise proper safety precautions or misuse of the module may result in damage to the module and/or injury to the operator.

2 Features

- Full range telecom input 36 V_{DC} to 72 V_{DC}
- 3.3 V_{DC} at 10 A_{DC} for 33-W output
- 1500-V isolation
- Business card sized 2.0" x 3.5" single component side board
- Optically isolated voltage mode control with voltage feed-forward
- 500-kHz high-speed oscillator frequency
- Peak 85% efficiency
- Peak-by-peak current limit protection
- Low input voltage protection
- RCD transformer reset clamp
- Externally programmable soft-start circuit

3 Description

UCC35705EVM uses the Texas Instruments UCC35705 high-speed, single-ended PWM with voltage feed-forward in a forward configuration with RCD reset clamp and synchronous rectifier output. This evaluation module highlights the high-speed capabilities of the UCC35705 PWM, operating at 500 kHz. The UCC35705 is designed to use an external switch driver, allowing the user to select a driver, based on the switching frequency and switching MOSFET. This also allows the UCC35705 and its sensitive feedback signals to be located in a lower noise environment further from the high current power devices without lengthening the high-current gate drive path. UCC35705EVM uses a single TPS2829 ±2-A driver in a 5-pin SOT–23 package to provide the high drive currents necessary for high-speed operation. Constantly improving MOSFET technology and higher-current MOSFET drivers such as the UCC27324 or UCC27322 would allow for even higher speed operation.

The self-driving synchronous rectification output stage of the converter dramatically improves efficiency by reducing the voltage drop through the rectifier stage without additional timing and driver circuitry by using the transformer's secondary to drive the gates of both synchronous devices.

4   Schematic

UCC35705EVM is built around the UCC35705 high speed voltage mode controller in a forward converter configuration. J1 provides the 48-V_{DC} nominal, 36-V_{DC} to 72-V_{DC} supply to the power transformer (T1) and primary switch (Q1). The output stage uses synchronous recitifers (Q2 and Q3) to rectify the transformer voltage, which is then smoothed by the output filter made from the output inductor (L1) and output capacitors (C17, C18 and C19).

The UCC35705 is configured with a unity gain buffer feedback pin designed to use a secondary side compensation network and optoisolator (U3).

The secondary side compensation network is a type three network with two zeros to cancel the voltage mode control double pole from the output L/C tank filter and two high-frequency poles to increase the control bandwidth and improve the supplies transient response. The feedback network uses a TL431 adjustable shunt regulator (U4) for low cost and high noise immunity while the soft-start network (C16, R23 and D5) forces the feedback network to come up slowly and minimizes overshoot during powerup.

A secondary dc input (J2) provides a V_{CC} bias voltage for the UCC35705 PWM (U2) and the TPS2829 MOSFET driver (U1). UCC35705EVM does not have self-biasing circuitry and will not operate without this secondary dc input.

UCC35705EVM is designed with a 50-Ω feedback resistor (R24) and two test points (TP1 and TP2) to allow for non-invasive analysis of the converters loop response with a network analyzer.
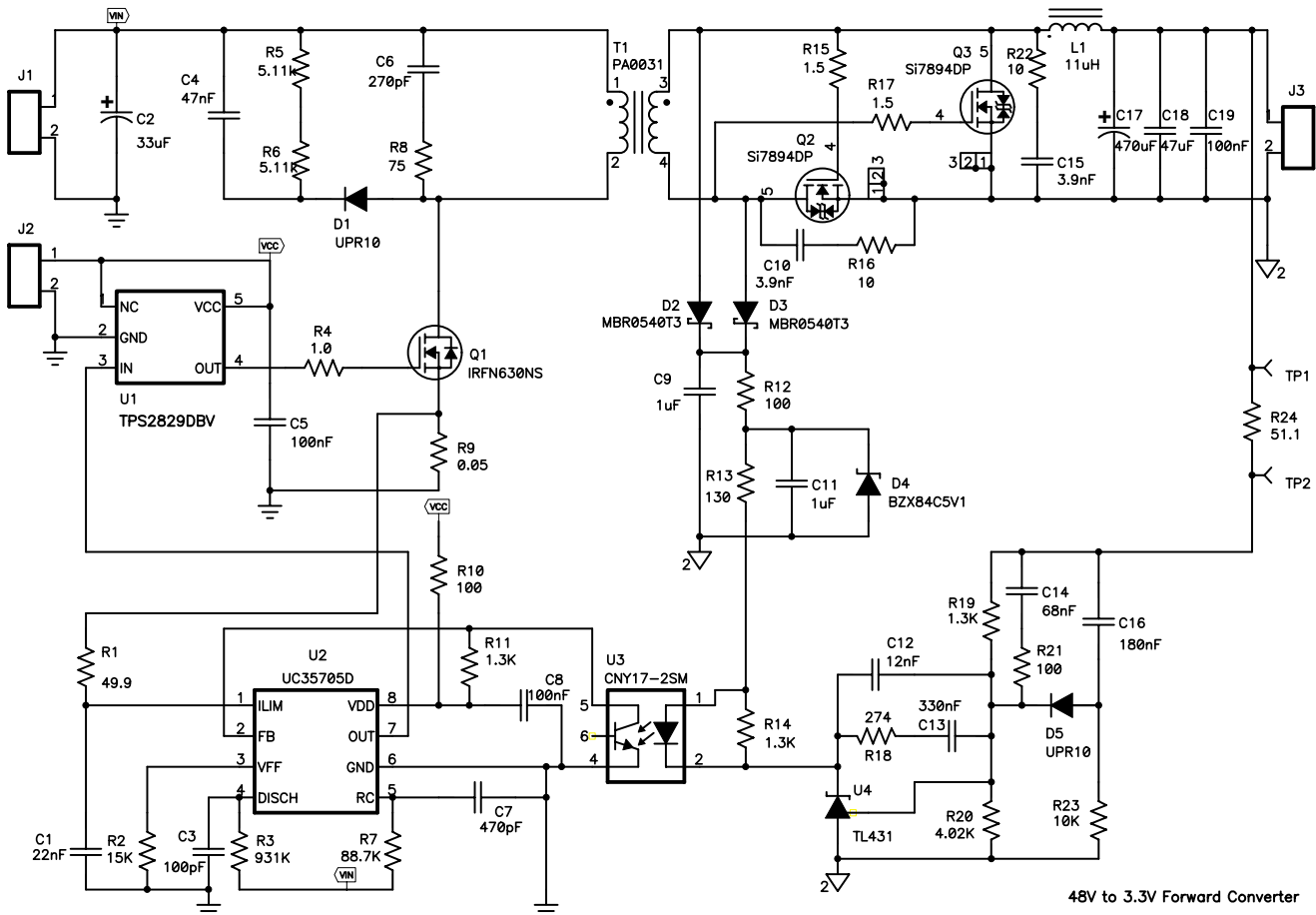

Figure 1. UCC35705EVM Board Schematic

5 Test Set Up

Testing and evaluation of UCC35705EVM requires two dc voltage supplies (V_{IN} and V_{CC}) and an output load (LOAD1) as shown in Figure 2. Note that the primary side ground J1 and J2 is isolated from the secondary side ground (J3) and J3 has the opposite polarity of J1 and J2. Loop test points TP1 (V_{OUT}) and TP2 (Feedback) are connected by a 50-Ω resistor and allow the user to connect a network analyzer for loop response evaluation.
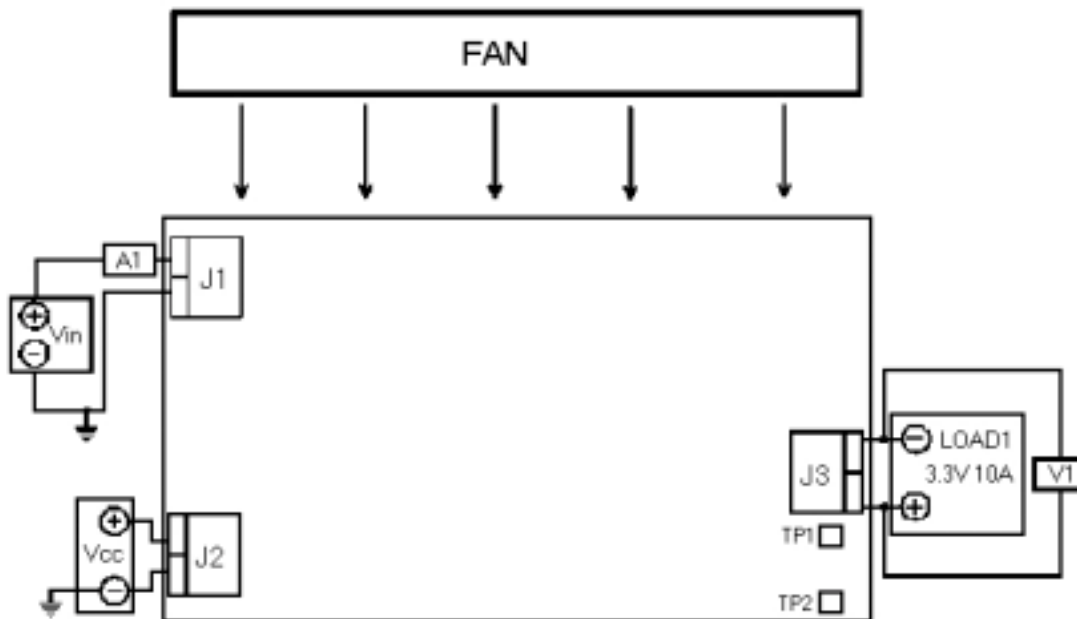

Figure 2. Recommended EVM Test Configuration

6 Output Load (LOAD1)

For the output load to VOUT, a programmable electonic load set to constant current mode and capable of sinking up to 10 A_{DC} is used. UCC35705EVM uses isolated grounds between input and output. V_{IN} and V_{CC} (J1 and J2) are referenced to the primary side, electrically isolated from V_{OUT} (J3), which is secondary side referenced.

The dc voltage meter V1 is connected directly to the output terminals (J3) to minimize voltage error from drops between the output terminals (J3) and output load (LOAD1)

7 V_{CC} dc Bias Supply (V_{CC})

UCC35705EVM is not designed with self-biasing circuitry and requires an external bias supply to provide power to the PWM and driver circuitry. V_{CC} is a variable dc voltage source capable of supplying between 0 V_{DC} and 12 V_{DC} at no less than 300 mA. V_{CC} is connected to J2 as shown in Figure 2.

8 dc Input Source (V_{IN})

The input voltage source is a variable dc source capable of supplying between 0 V_{DC} and 72 V_{DC} at no less than 1.5 A_{DC}, and connected to the input terminals (J1) as shown in Figure 2. For fault protection to the EVM, it is good common practice to current limit the source to no more than 2 A_{DC}. A dc ammeter (A1) inserted between the input source (V_{IN}) and input terminals (J1) ensures accurate input current readings.

9   Fan

Components in the UCC35705EVM reach temperatures exceeding 60°C during operation. Because UCC35705EVM is not enclosed to facilitate probing and circuit evaluation, it is recommended that a small fan capable of at least 20 cfm is placed near the module, blowing across the evaluation board to reduce component surface temperature and the risk of operator injury.

10   Power Up and Down Test Procedure

The following procedure is recommended for powering up and shutting down the EVM. Whenever the EVM is running the fan should be turned on. For safety reasons the EVM should never be left running unattended.

1. Working at an ESD workstation, make sure that any wrist straps, boot straps or mats are connected referencing the user to earth ground before power is applied to the EVM. Electrostatic smock and safety glasses should also be worn.

2. Set V_{CC} supply to 0 V and connect V_{CC} to J1 as shown in Figure 2.

3. Prior to connecting the dc input source, V_{IN}, set it to 0 V. It is advisable to also limit the source current from V_{IN} to 1 A maximum. Connect the ammeter A1 (0-A to 1-A range) between VIN and J2 as shown in Figure 9. Make sure V_{IN} is initially set to 0 V.

4. Connect LOAD1 and the voltmeter, V1 to J1 as shown in Figure 2. Set LOAD1 to constant current mode to sink 0 A_{DC} before V_{IN} and V_{CC} are applied.

5. Increase V_{CC} from 0 V to 12 V_{DC} and then set to 10.5 V_{DC}. Even with V_{CC} applied, the control and switching circuitry should not generate an output. The voltage feed forward function of the UCC35705 inhibits any output.

6. Increase V_{IN} from 0 V to 48 V_{DC}, while monitoring the output voltage on V1. V1 should not start to rise before 30 V_{DC} and should be in regulation (3.3 V) by 36 V_{DC}.

7. Vary LOAD1 anywhere between 0 A to 10 A_{DC}, making sure to turn on the fan blowing air directly on the EVM when running the EVM with a load.

8. Vary the input voltage between 36 V_{DC} and 72 V_{DC}.

9. Set the electronic load to 0 A then shut off.

10. Set VIN to 0 V then shut off.

11. Set V_{CC} to 0 V then shut off.

WARNING:
The voltage at the switch node between T1, Q1, D1 and R8 and the reset node C4, R6 and D1 can exceed 75 V and pose a shock hazard during operation. Use proper precautions when working around this switch node.

11   EVM Assembly Drawing and Layout

Figure 3, shows the top-side component placement for the EVM, as well as pin numbers and component polarity where necessary. A two-sided PCB was designed using the top layer for signal traces and a bottom layer split ground plane. The PCB dimensions are 3.5" x 2.0" with a design goal of maintaining all components on one side of a business card sized PCB. All components are standard OTS surface mount components and placed on the top-side of the PCB only. The copper etch, shown looking through the top of the PCB, for both top and bottom layers are also included in Figure 4 and Figure 5.
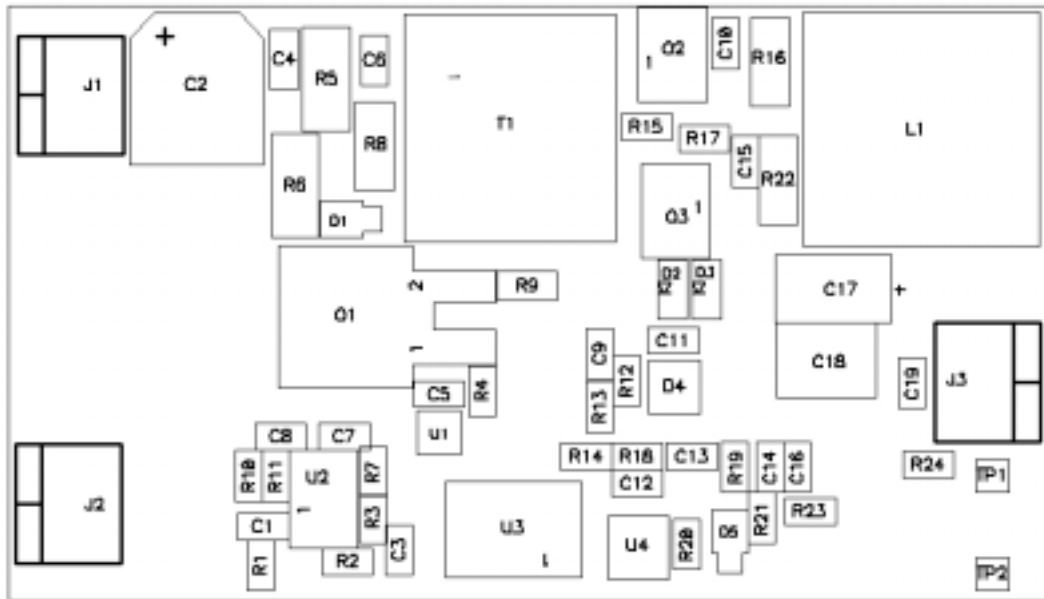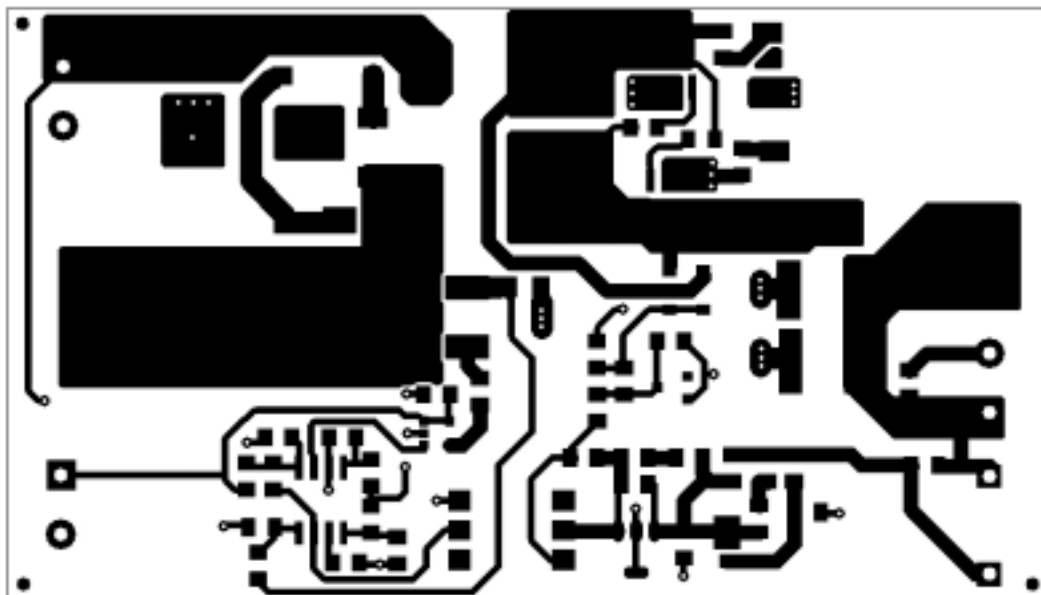

Figure 3. Topside Component Assembly

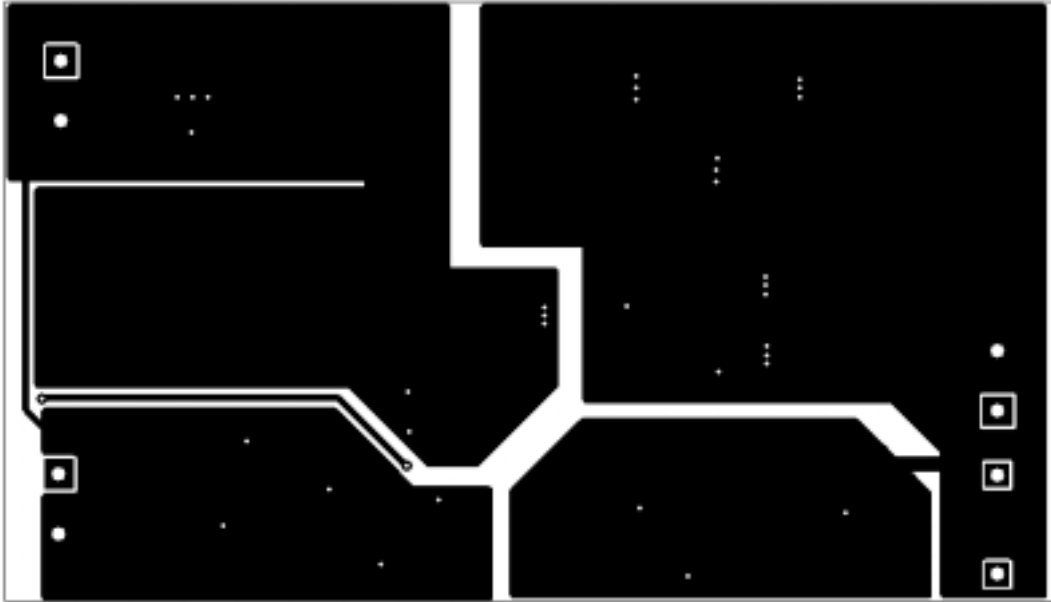**Figure 4. Top Layer – Signal Traces**

Figure 5. Bottom Layer – Isolated Grounds

12 List Of Materials

Table 1 below lists the EVM components as configured corresponding to the schematic shown in Figure 1. Part types and manufacturers can be modified according to specific application requirements.

Table 1. List of Materials

	Reference	Qty	Description	Manufacturer	Part Number
Capacitor	C1	1	Ceramic, X7R, 22 nF, 50 V, 10%	Vishay	VJ0805Y223KXXAAB
	C2	1	Aluminum, 33 µF, 100 V, 20%	Panasonic	ECEV2AA330P
	C3	1	Ceramic, NPO, 100 pF, 50 V, 5%	Vishay	VJ0805A101JXAAT
	C4	1	Ceramic, X7R, 47 nF, 100 V, 10%	Vishay	VJ1206Y473KXBAT
	C5, C8, C19	3	Ceramic, X7R, 100 nF, 50 V, 10%	Vishay	VJ0805Y104KXAAT
	C6	1	Ceramic, NPO, 270 pF, 100 V, 5%	Vishay	VJ0805A271JXBAT
	C7	1	Ceramic, NPO, 470 pF, 50 V, 5%	Vishay	VJ0805A471JXAAT
	C9, C11	2	Ceramic, X5R, 1.0 µF, 16 V, 20%	TDK	C2012X7R1C105M
	C10, C15	2	Ceramic, X7R, 3.9 nF, 50 V, 10%	Vishay	VJ0805Y392KXAAT
	C12	1	Ceramic, X7R, 12 nF, 50 V, 10%	Vishay	VJ0805Y123KXXAAB
	C13	1	Ceramic, X7R, 330 nF, 25 V, 10%	Vishay	VJ0805Y334KXXAT
	C14	1	Ceramic, X7R, 68 nF, 50 V, 10%	Vishay	VJ0805Y683KXXAAB
	C16	1	Ceramic, X7R, 180 nF, 25 V, 10%	Vishay	VJ0805Y184KXXAT
	C17	1	Tantalum, 470 µF, 6.3 V, 20%	AVX	TPSD477M006R0100
	C18	1	Ceramic, X5R, 47 µF, 16 V, 20%	TDK	C5750X5R1C476M

	Reference	Qty	Description	Manufacturer	Part Number
Diode	D1, D5	2	100 V, 2.5 A	Microsemi	UPR10
	D2, D3	2	Schottky, 40 V, 0.5 A	On Semiconductor	MBR0540T3
	D4	1	Zener, 5.1 V, 0.25 A	Fairchild Semiconductor	BZX84C5V1
Terminal Block	J1, J2, J3	3	2-pin, 15 A	OST	ED500/2DS
Inductor	L1	1	11 µH, 10 A, SMD Planar	Payton	90004
Transistor	Q1	1	NCH–FET, 9.3 A, 200 V	IR	IRF630NS
	Q2, Q3	2	NCH–FET, 25 A, 30 V	Vishay	Si7894DP
Resistor	R1	1	Thick Film, 49.9 Ω, 0.125 W, 1%	Vishay	CRCW080549R9F100RT6
	R2	1	Thick Film, 15 kΩ, 0.125 W, 1%	Vishay	CRCW08051502F100RT6
	R3	1	Thick Film, 931 kΩ, 0.125 W, 1%	Vishay	CRCW08059313F100RT6
	R4	1	Thick Film, 1.0 Ω, 0.125 W, 1%	Vishay	CRCW08051R00F100RT6
	R5, R6	2	Thick Film, 5.11 kΩ, 1 W, 1%	Vishay	CRCW25125111F100RT6
	R7	1	Thick Film, 88.7 kΩ, 0.125 W, 1%	Vishay	CRCW08058872F100RT6
	R8	1	Thick Film, 75 Ω, 0.5 W, 1%	Vishay	CRCW201075R0F100RT7
	R9	1	Power Metal Strip, 0.05 Ω, 0.25 W, 1%	Vishay	WSL1206_0.05_1.0%_R86
	R10, R12, R21	3	Thick Film, 100 Ω, 0.125 W, 1%	Vishay	CRCW08051000F100RT6
	R11, R14, R19	3	Thick Film, 1.3 kΩ, 0.125 W, 1%	Vishay	CRCW08051301F100RT6
	R13	1	Thick Film, 130 Ω, 0.125 W, 1%	Vishay	CRCW08051300F100RT6
	R15, R17	2	Thick Film, 1.5 Ω, 0.125 W, 1%	Vishay	CRCW08051R50F100RT6
	R16, R22	2	Thick Film, 10 Ω, 0.5 W, 1%	Vishay	CRCW201010R0F100RT7
	R18	1	Thick Film, 274 Ω, 0.125 W, 1%	Vishay	CRCW08052740F100RT6
	R20	1	Thick Film, 4.02 kΩ, 0.125 W, 1%	Vishay	CRCW08054021F100RT6
	R23	1	Thick Film, 10 kΩ, 0.125 W, 1%	Vishay	CRCW08051002F100RT6
	R24	1	Thick Film, 51.1 Ω, 0.125 W, 1%	Vishay	CRCW080551R1F100RT6
Transformer	T1	1	Planar, 25 W, 12:2	Pulse	PA0031
IC	U1	1	Single 2-A MOSFET driver	Texas Instruments	TPS2829DBV
	U2	1	High-speed voltage mode PWM	Texas Instruments	UCC35705D
	U3	1	Optocoupler	Isocom	CNY17–2SM
	U4	1	Adjustable precision shunt regulator	Texas Instruments	TL431CPKR

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