

High Efficiency DC-DC Converter Module

Device	Application	Input Voltage	Output Power	Topology	I/O Isolation
NCP12700	Module	9 to 36 Vdc	Up to 15 W	CCM/DCM Flyback	Isolated

Output Specification	
Output Voltage	12 Vdc nominal
Nominal Current	1.25 A
Full Load Efficiency	> 87%
Startup Time	< 30 ms
Over Power Protection	120 % - 150 %
Over Voltage Protection	16 Vdc

Circuit Description

The NCP12700 is fixed frequency, peak current mode PWM controller for single-ended switch mode power supplies (SMPS). Among its many features are a best-in-class startup linear regulator; programmability of switching frequency, soft start, and over-power protection; fully integrated slope compensation, and multiple protection functions necessary for designing efficient industrial, telecom, and transportation DC-DC power supplies with a minimum number of external components.

This design note describes a 12 V, 15 W flyback SMPS developed with the NCP12700BDNR2G controller. The SMPS operates from an input voltage range of 9 – 36 V while achieving greater than 87% full load efficiency. The SMPS was designed to operate in both continuous and discontinuous conduction mode depending on load current and input voltage.

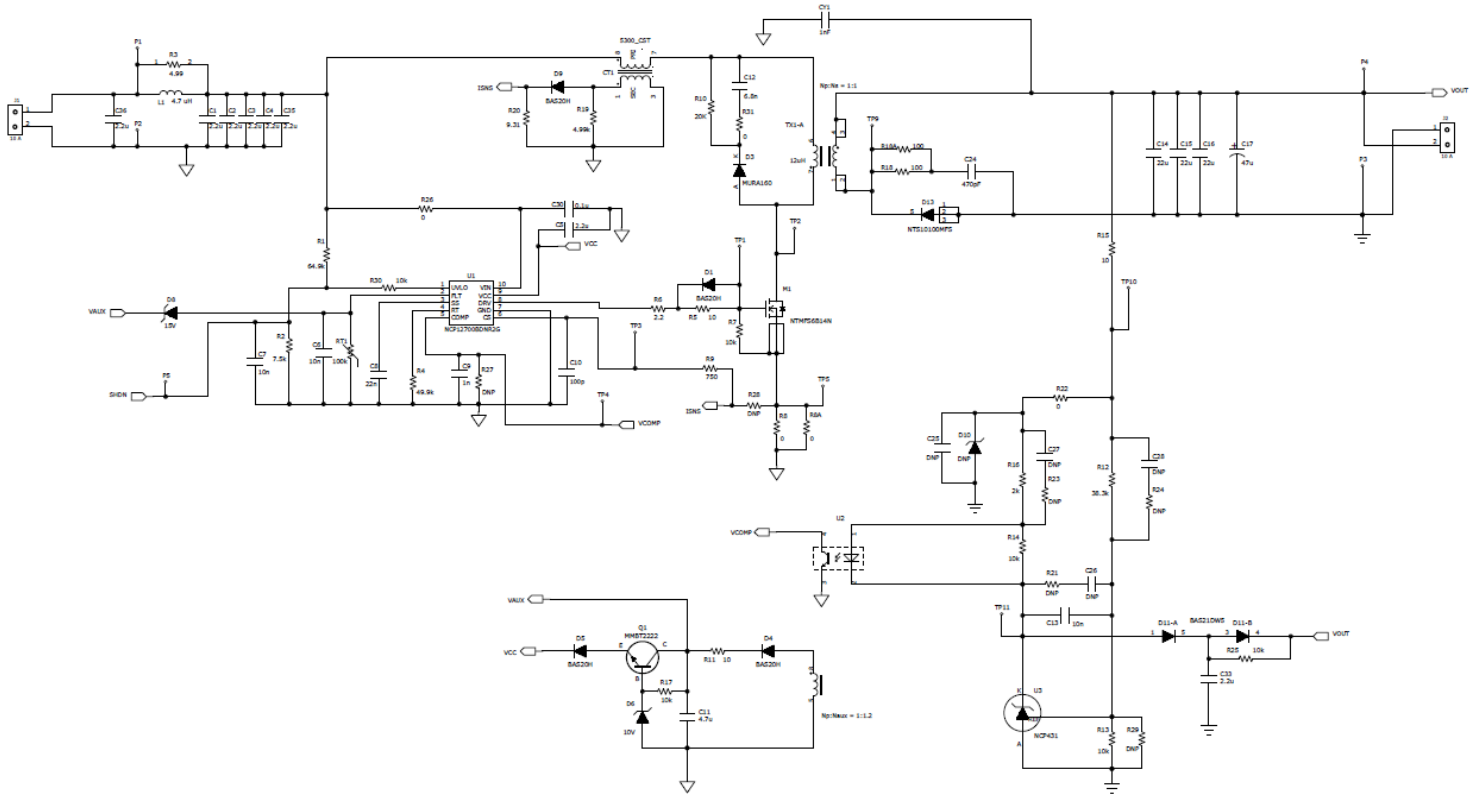
A full circuit schematic, bill of materials, transformer design details, and PCB artwork are provided. The design note also contains multiple operational waveforms and performance data highlighting the features and capabilities of the NCP12700.

Key Features

- Wide Input Range (9 – 120/200 V; MSOP10/WQFN10) Startup Regulator
- Startup Regulator Circuit capable of sourcing a minimum of 15 mA
- Programmable Over-Power Protection
- Integrated Slope Compensation
- Fault Input for Over Temperature and Output Over Voltage Fault Conditions, NTC Compatible
- 1 A / 2.8 A Source / Sink Gate Driver
- Programmable Soft Start
- Overload Protection with 30 ms Timer and 1 s Auto-recovery

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Circuit Schematic

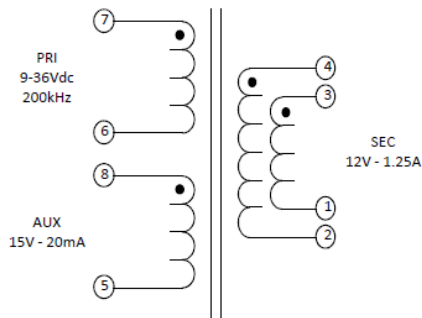
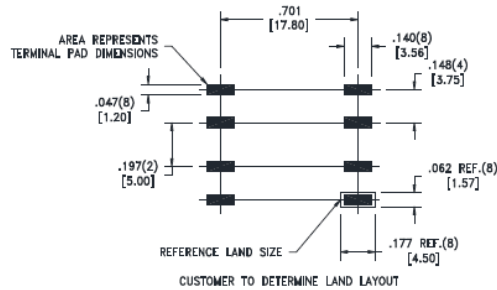
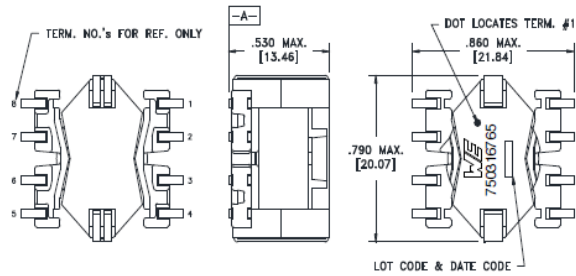


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Magnetics Design – Flyback Transformer

CUSTOMER TERMINAL	RoHS	LEAD(Pb)-FREE
Sn 96%, Ag 4%	Yes	Yes

more than you expect



Application of the transformer allows for the leadwires between terminals 1&2 and 3&4 to solder bridge.

Customer to tie terminals 1&2 and 3&4 on PC board.

ELECTRICAL SPECIFICATIONS @ 25° C unless otherwise noted:

PARAMETER	TEST CONDITIONS	VALUE
D.C. RESISTANCE	1-4 tie(1+2, 3+4), @20°C	0.020 ohms ±20%
D.C. RESISTANCE	5-8 @20°C	0.095 ohms ±10%
D.C. RESISTANCE	6-7 @20°C	0.022 ohms ±20%
INDUCTANCE	7-6 10kHz, 100mV, Ls	12.0µH ±10%
SATURATION CURRENT	7-6 20% rolloff from initial	9.5A
LEAKAGE INDUCTANCE	7-6 tie(1+2+3+4, 5+8), 100kHz, 10mV, Ls	100nH typ., 250nH max.
DIELECTRIC	1-8 tie(3+4, 5+6), 2250VAC, 1 second	1800VAC, 1 minute
DIELECTRIC	5-7 625VAC, 1 second	
TURNS RATIO	(8-5):(7-6)	1.2:1, ±1%
TURNS RATIO	(8-5):(4-1), tie(1+2, 3+4)	1.2:1, ±1%

GENERAL SPECIFICATIONS:

OPERATING TEMPERATURE RANGE: -40°C to +125°C including temp rise.

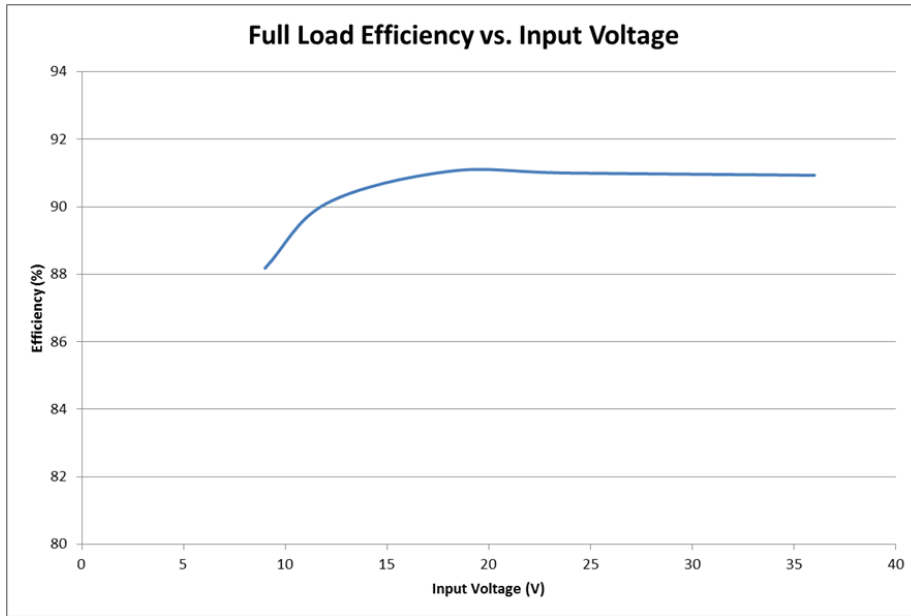
Designed to comply with the following requirements as defined by IEC60950-1, EN60950-1, UL60950-1/CSA60950-1 and AS/NZS60950.1:

- Functional insulation for a primary circuit at a working voltage of 265Vrms, 400Vpeak, Overvoltage Category II.

Efficiency Plots

Full Load Efficiency

Vin (V)	Pin (W)	Po (W)	Efficiency (%)
9	17.21	15.18	88.18
12	16.85	15.18	90.09
18	16.67	15.18	91.05
24	16.68	15.17	91.00
36	16.69	15.18	90.93



Full Load Efficiency > 88%

Figure 1: Full Load Efficiency vs. Input Voltage

Average Efficiency

Vin (V)	Pin (W)	Po (W)	Efficiency (%)
9	17.08	15.04	88.07
9	13.53	12.05	89.09
9	10.06	9.02	89.71
9	6.78	6.08	89.64
9	3.41	3.00	87.76
18	16.56	15.04	90.85
18	13.28	12.05	90.72
18	9.92	9.02	90.92
18	6.75	6.08	90.03
18	3.43	3.00	87.32

36	16.62	15.06	90.58
36	13.46	12.06	89.61
36	10.10	9.02	89.32
36	6.90	6.08	87.99
36	3.64	3.01	82.75

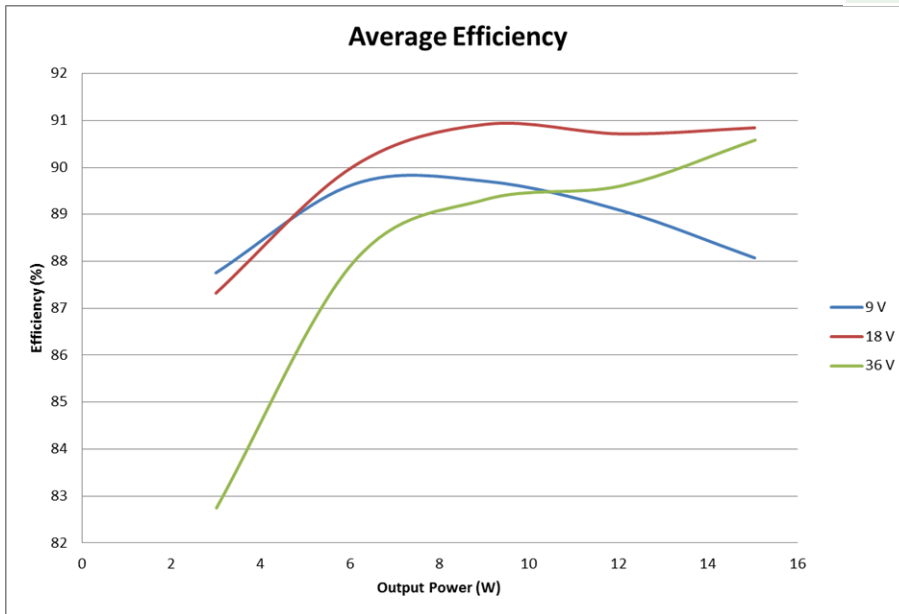


Figure 2: Average Efficiency vs Output Power

Description of Key Features

1. High Voltage Startup Regulator



Figures 3: Startup Regulator Operation

Startup Regulator Operation
 Ch. 1 (Yellow): VIN
 Ch. 2 (Blue): VCC
 Ch. 3 (Purple): VOUT
 Ch. 4 (Green): DRV

The NCP12700 features a high voltage startup regulator capable of operating from input voltages ranging from 9 – 200 V. The regulator is capable of sourcing > 15 mA with as little as 2 V of overhead. A capacitor in the range 1 – 10 μ F at the V_{CC} pin is recommended to ensure stability of the regulator. The input operating range, source current capability, and stability requirements of the regulator were designed for best-in-class performance providing the user with fast startup capability and requiring no additional components for ease of design. The regulator's drive capability ensures that the device can continue to self-bias for the duration of the startup period easing the design of the auxiliary winding. Once the application is in regulation it is recommended that an auxiliary winding from the power transformer be utilized for biasing of the supply to reduce the thermal stress on the controller.

The startup waveforms for the DC-DC Module at 9 and 36 V are shown in Figure 3. The V_{CC} voltage is quickly charged to 8 V, enabling switching of the application within 2.5 ms of the input power being applied. The application module reaches regulation in less than 25 ms and no voltage drop is observed on V_{CC} demonstrating the source capability of the regulator.

2. Input Over-Power Compensation

In wide input range power supplies the power delivery capability tends to increase at higher line voltages presenting thermal challenges for the supply designer. The NCP12700 features an integrated input over-power protection feature for limiting the output power capability of the application at higher line voltages. Shown in the Figure 4, the controller tracks an image of the input line voltage through the UVLO pin and sources current out of the current sense pin as the UVLO pin voltage increases. A series resistor between the CS pin at the controller and the current sensing element creates an offset voltage reducing the available peak current in the power supply and thereby reducing the power delivery capability. The current out of the CS pin has been limited to 200 μA allowing the designer to utilize the series resistor commonly included for high frequency filtering of the CS signal.

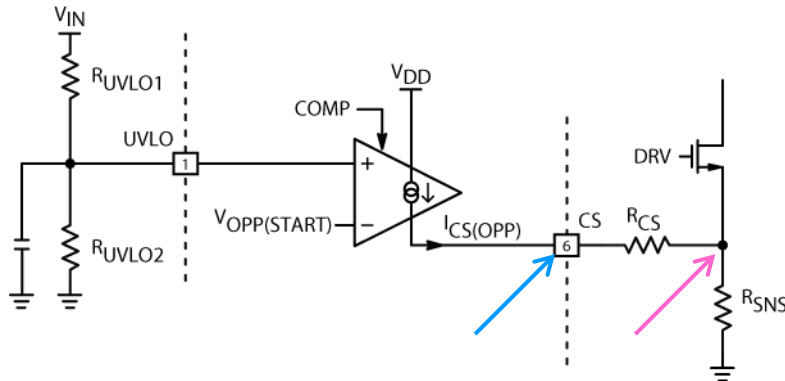


Figure 4: Over Power Protection Circuit



Figure 5: Over Power Protection Waveform

Ch. 1 (Yellow): COMP_{VCC}
 Ch. 2 (Blue): CS @ Pin
 Ch. 3 (Purple): CS @ R_{SNS}
 Ch. 4 (Green): DRV

The waveform in Figure 5 demonstrates the offset voltage and reduced peak current capability in the demonstration board. The waveform in blue shows how the current sense voltage at the controller is increased relative to the voltage across the current sensing element.

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The plot in Figure 6 shows the power supply overload current as a function of input voltage. The available overload current is practically constant across the input voltage showing the benefit of the over-power protection feature.

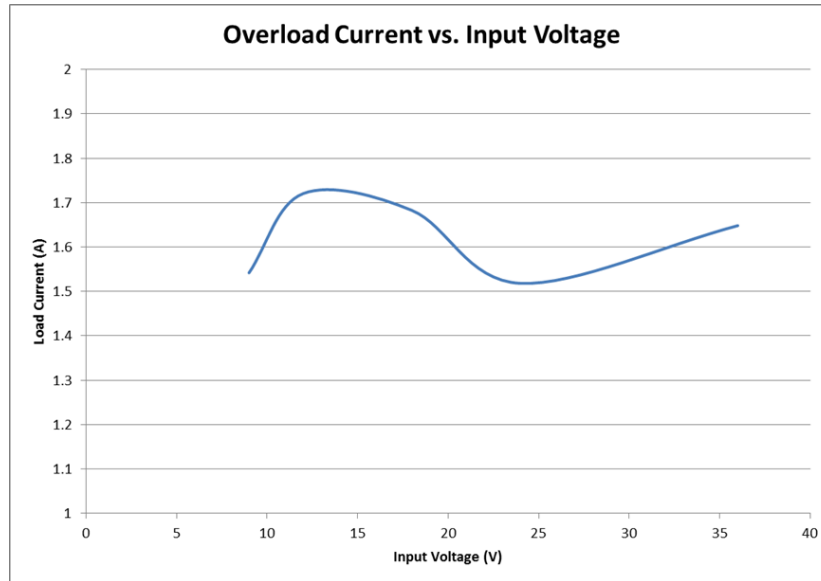


Figure 6: Overload Current vs Input Voltage

3. Slope Compensation

Peak current mode controlled power supplies are susceptible to subharmonic oscillations when operating in continuous conduction mode at higher duty cycles. The NCP12700 features fully integrated slope compensation effective for damping out the oscillations and ensuring a stable operating power supply. Figure 7 illustrates the basic principle of the integrated slope compensation in the NCP12700. A voltage ramp is subtracted from the drive terminating signal of a comparator in the PWM reset path. The ramp begins subtracting from the signal at a 40% duty cycle and ends at the 80% maximum duty cycle limit with a peak subtraction of 100 mV. The slope compensation is applied to both the PWM and Current Limit comparator ensuring stable operation regardless of the drive terminating comparator. The waveform in Figure 8 illustrates the compensating slope while showing the CS and COMP pin waveforms. The power supply operating in CCM at 60% duty cycle is in stable operation with no indication of subharmonic oscillation.

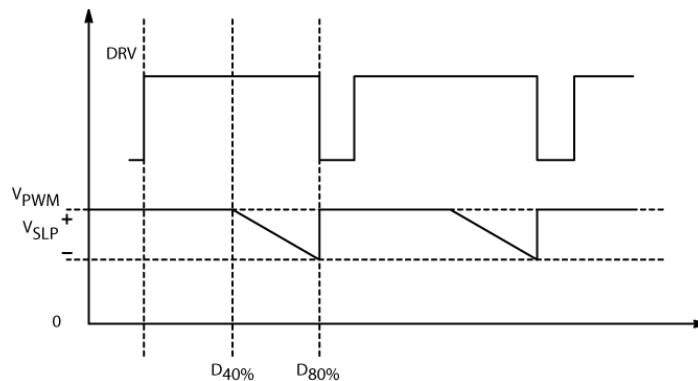


Figure 7: Slope Compensation Operation



Figure 8: Slope Compensation Waveforms

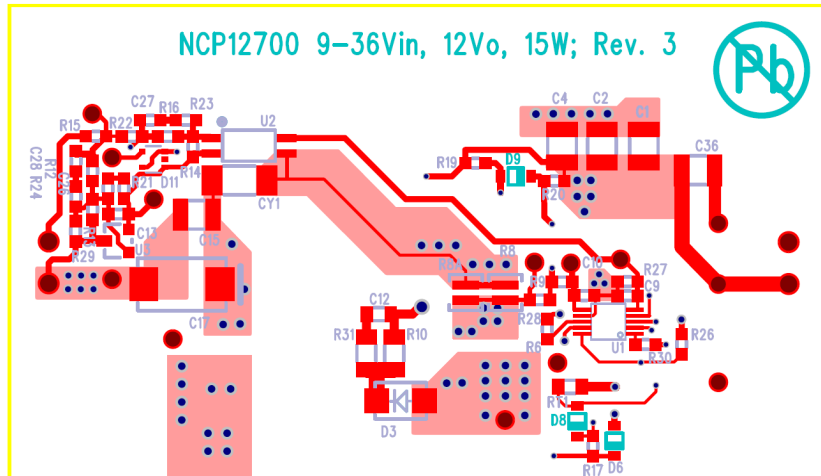
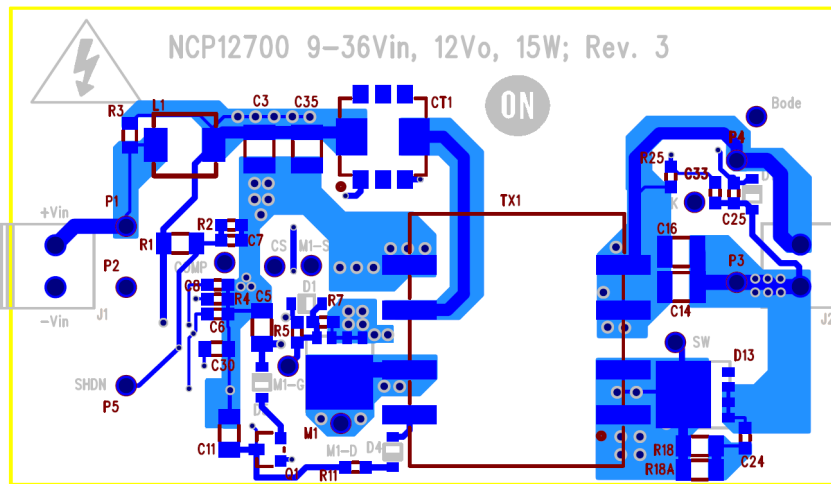
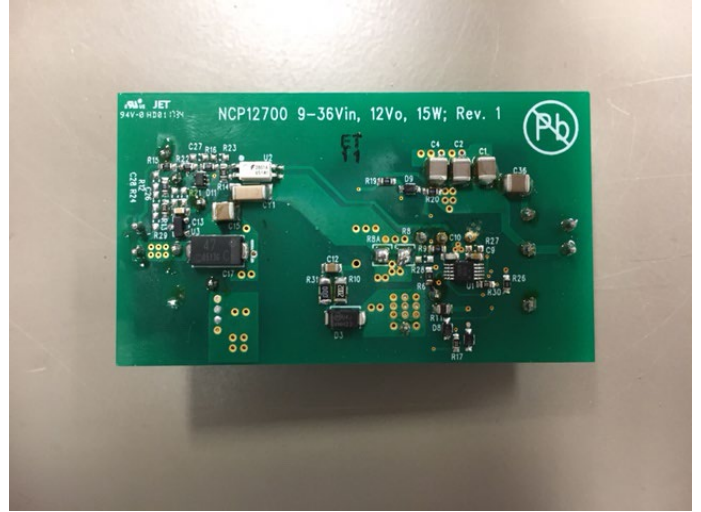
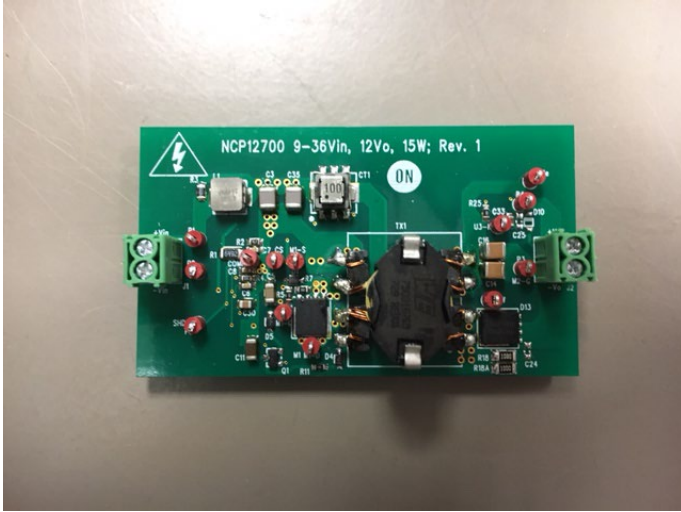
Ch. 2 (Blue): CS
 Ch. 3 (Purple): COMP
 Ch. 4 (Green): DRV

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Bill of Materials

REF DES	QTY	Description	Value	Tolerance	Footprint	Manufacturer	Manufacturer PN	Substitution
C1 - C4, C35, C36	6	Capacitor, Ceramic, X7R	2.2 uF, 100 V	20%	SMD, 1210	Kemet	C1210C225M1RACTU	Yes
C5	1	Capacitor, Ceramic, X7R	2.2 uF, 50 V	10%	SMD, 1206	Samsung	CL31B225KBHNNNE	Yes
C6, C7, C13	3	Capacitor, Ceramic, X7R	10 nF, 50 V	10%	SMD, 0603	Yageo	CC0603KRX7R9BB103	Yes
C8	1	Capacitor, Ceramic, X7R	22 nF, 50 V	10%	SMD, 0603	Yageo	CC0603KRX7R9BB223	Yes
C9	1	Capacitor, Ceramic, X7R	1 nF, 50 V	10%	SMD, 0603	Yageo	CC0603KRX7R9BB102	Yes
C10	1	Capacitor, Ceramic, COG	100 pF, 50 V	5%	SMD, 0603	Yageo	CC0603JRNPO9BN101	Yes
C11	1	Capacitor, Ceramic, X7R	4.7 uF, 50 V	10%	SMD, 1206	Murata	GRM31CR71H475KA12L	Yes
C12	1	Capacitor, Ceramic, X7R	6800 pF, 630 V	10%	SMD, 0805	Kemet	C0805C682KBRACTU	Yes
C14 - 16	3	Capacitor, Ceramic, X7R	22 uF, 25 V	10%	SMD, 1210	Murata	GRM32ER71E226KE15L	Yes
C17	1	Capacitor, Ceramic, X7R	47 uF, 16 V	10%	SMD, 2917	Panasonic	EEF-CX1C470R	Yes
C24	1	Capacitor, Ceramic, X7R	470 pF, 100 V	10%	SMD, 0603	Murata	GRM188R72A471KA01D	Yes
C25, C26, C27, C28	4	DNP	DNP					No
C30	1	Capacitor, Ceramic, X7T	0.1 uF, 250 V	10%	SMD, 0805	TDK	C2012X7T2E104K125AA	Yes
C33	1	Capacitor, Ceramic, X7R	2.2 uF, 50 V	10%	SMD, 0603	Murata	GRM188R61H225KE11D	Yes
CT1	1	Current Sense Transformer	1:100; 2 mH		SMD, 5300 CST 8P	Murata	53100C	Yes
CY1	1	Capacitor, Ceramic, X7R	1 nF, 250 Vac	10%	SMD, 1808	Johanson Dielectric	50R29W102KV3E-X1Y2-SC	Yes
D1, D4, D5, D9	4	Diode, Switching	200 V, 0.2 A		SMD, SOD-323	ON Semiconductor	BAS20HT1G	No
D3	1	Diode, Fast recovery	600 V, 1 A		SMD, SMA	ON Semiconductor	MURA160T3G	No
D6	1	Diode, Zener	10 V, 300 mW		SMD, SOD-323	ON Semiconductor	MM3Z10VT1G	No
D8	1	Diode, Zener	15 V, 300 mW		SMD, SOD-323	ON Semiconductor	MM3Z15VT1G	No
D10	1	DNP	DNP					No
D11	1	Diode, Switching	250 V, 0.2 A, Dual		SMD, SC-88A	ON Semiconductor	BAS21DW5T1G	No
D13	1	Diode, Schottky	100 V, 10 A		SMD, SOIC8 FL5	ON Semiconductor	NTS10100MFT1G	No
J1, J2	2	Terminal Block, 2 pos, in-line	300 V, 10 A		TH, 2POS, LS3.5MM	Phoenix Contact	1984617	Yes
L1	1	Power Inductor, Shielded	4.7 uH, 4.5 A	20%	IHLP 2020	Vishay	IHLP2020CZER4R7M11	Yes
M1	1	Transistor, MOSFET, Power	100 V, 50 A		SMD, SOIC8 FL5	ON Semiconductor	NTMFS6814NT1G	No
P1 - P5	5	Printed Circuit Pin	8 A		TH, 1POS, D1.02mm	Mill-Max	1179-0-00-15-00-00-33-0	Yes
Q1	1	Transistor, NPN, General Purpose	40 V, 0.6 A		SOT-23	ON Semiconductor	MMBT222ALT1G	No
R1	1	Resistor, 1/4 W	64.9 kΩ	1%	SMD, 1206	Stackpole	RMCF1206FT64K9	Yes
R2	1	Resistor, 1/10 W	7.5 kΩ	1%	SMD, 0603	Stackpole	RMCF0603FT7K50	Yes
R3	1	Resistor, 1/8 W	4.99 Ω	1%	SMD, 0805	Stackpole	RMCF0805FT4R99	Yes
R4	1	Resistor, 1/10 W	49.9 kΩ	1%	SMD, 0603	Stackpole	RMCF0603FT49K9	Yes
R5, R11, R15	3	Resistor, 1/10 W	10 Ω	1%	SMD, 0603	Stackpole	RMCF0603FT10R0	Yes
R6	1	Resistor, 1/10 W	2.2 Ω	1%	SMD, 0603	Stackpole	RMCF0603FT2R20	Yes
R7, R13, R14, R17, R25, R30	6	Resistor 1/10 W	10 kΩ	1%	SMD, 0603	Stackpole	RMCF0603FT10K0	Yes
R8, R8A	2	DNP - JUMPER TO GND						
R9	1	Resistor, 1/10 W	750	1%	SMD, 0603	Stackpole	RMCF0603FT750R	Yes
R10	1	Resistor, 1/8 W	20 kΩ	1%	SMD, 1206	Stackpole	RMCF1206FT20K0	Yes
R12	1	Resistor, 1/10 W	38.3 kΩ	1%	SMD, 0603	Stackpole	RMCF0603FT38K3	Yes
R16	1	Resistor, 1/10 W	2 kΩ	1%	SMD, 0603	Stackpole	RMCF0603FT2K00	Yes
R18, R18A	2	Resistor, 1/4 W	100 Ω	1%	SMD, 1206	Stackpole	RMCF1206FT100R	Yes
R19	1	Resistor, 1/10 W	4.99 kΩ	1%	SMD, 0603	Stackpole	RMCF0603FT4K99	Yes
R20	1	Resistor, 1/10 W	9.31 Ω	1%	SMD, 0603	Stackpole	RMCF0603FT9R31	Yes
R21, R23, R24, R27, R28, R29	6	DNP	DNP					No
R22, R26	2	Resistor, 1/10 W	0 Ω	1%	SMD, 0603	Stackpole	RMCF0603ZTOR00	Yes
R31	1	Resistor, 1/4 W	0 Ω	1%	SMD, 1206	Stackpole	RMCF1206ZTOR00	Yes
RT1	1	NTC Thermistor	100 kΩ	1%	SMD, 0805	Vishay	NCTS0805E3104JMT	Yes
TP1 - 5, 9 - 11	8	Testpoint, Red, 40 mil			TH, 1POS, D1.02mm	Keystone Electronics	5000	Yes
TX1	1	Flyback Transformer	12 uH, 6.25 A, Np:Ns = 1:1		SMD, RM6, Custom	Würth Electronics	750316765 REV01	No
U1	1	PWM Controller			SMD, Micro-10, 3x3 mm	ON Semiconductor	NCP12700BDNR2G	No
U2	1	Optocoupler	50 mA, 80-160%		SMD, SSOP-4	Fairchild	HMHA2801A	No
U3	1	Shunt Regulator	36 V, 100 mA		SOT-23	ON Semiconductor	NCP431AVSNT1G	No

DN05108/D Demo Board



References

NCP12700 Datasheet

NCP431 Datasheet