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Design Note – DN06075/D

12V Input, 5A DC-DC PWM Buck Controller + FET w/Ceramic Capacitors on the Output

Device	Application	Input Voltage	Output Voltage	Output Current	Topology
NCP3011	Test & Medical Equipment	9-18V	1.8V	0.01-5A	Buck

Table 1: Buck Power Supply

Characteristic	Min	Typ	Max	Unit
Input Voltage	9	12	18	V
Output Voltage		1.8		V
Output Current	.01	3	5	A
Oscillator Frequency	350	400	450	kHz
Output Voltage Ripple		10		mVpk-pk

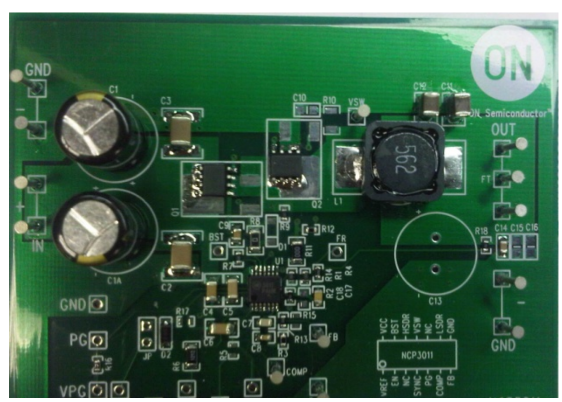
Circuit Description

This circuit is proposed for a wide varying +12V input (9V-18V) where there is a need to step-down the voltage to +5V @ 5A. The requirement specified a low output voltage ripple and all ceramic output capacitors for low noise environments such as medical devices and automated test equipment. Input capacitance can also be optimized for all ceramic but in this demo board configuration two electrolytic capacitors are used. Target efficiency is >85%.

The PCB for the NCP3011 is a 2-layer board for use in applications up to 50W. The synchronous buck converter uses voltage mode control, which can be compensated externally with a transconductance amplifier and type-III compensation which enables ceramic capacitors on the output. The soft start time is fixed. The NCP3011 demonstration board is a flexible design allowing the use of electrolytic capacitors or ceramic capacitors. It also allows the use of SO8-FL or D-PAK MOSFETs.

Key Features

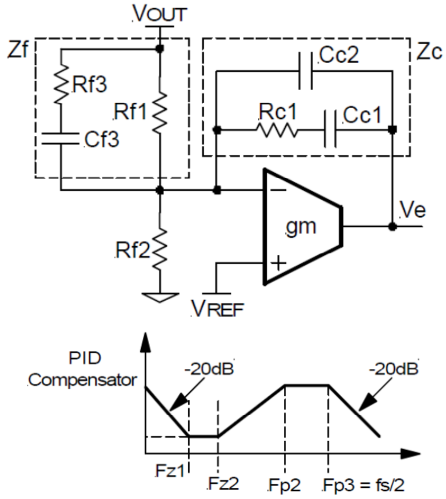
- High Efficiency
- Adjustable Current Limit
- Output Overvoltage and Output Undervoltage protection
- Short Circuit Protection
- Fixed Switching Frequency



Theory of Operation

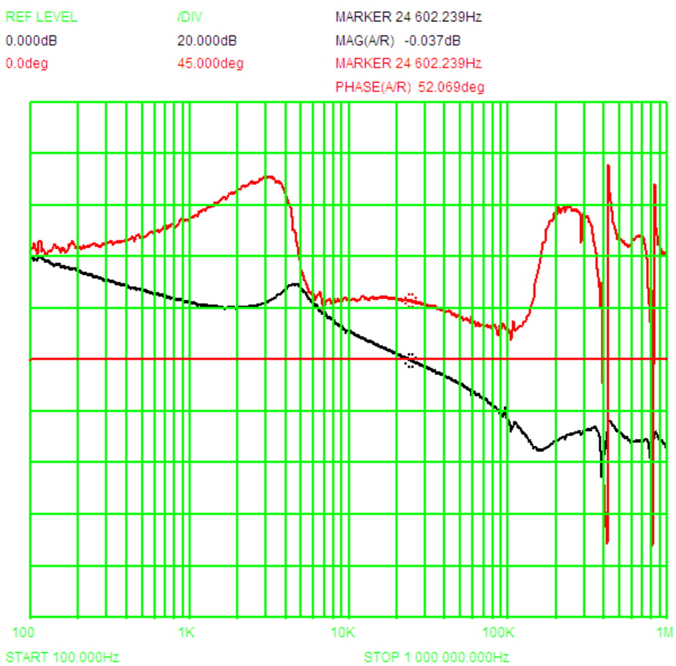
One feature of the NCP3011 controller is that when one follows a few simple design rules, the transconductance amplifier can be employed as a voltage feedback Error Amplifier. Theoretically, a transconductance amplifier is an equivalent voltage controlled current source. It multiplies the difference of input voltage with a certain gain and generates a current into the output node. It features high output impedance and it is stable by most of the output compensation components. The goal of the design is to provide a loop gain function with a high bandwidth (high zero-crossover frequency) and adequate phase margin. As a result, fast load response and good steady state output can be achieved.

- **Used when loop bandwidth is beyond the LC resonance and ceramic capacitors are used**
- **Rc1 > 2/gm (required)**
- **1/gm > Rf1//Rf2//Rf3 (desired)**

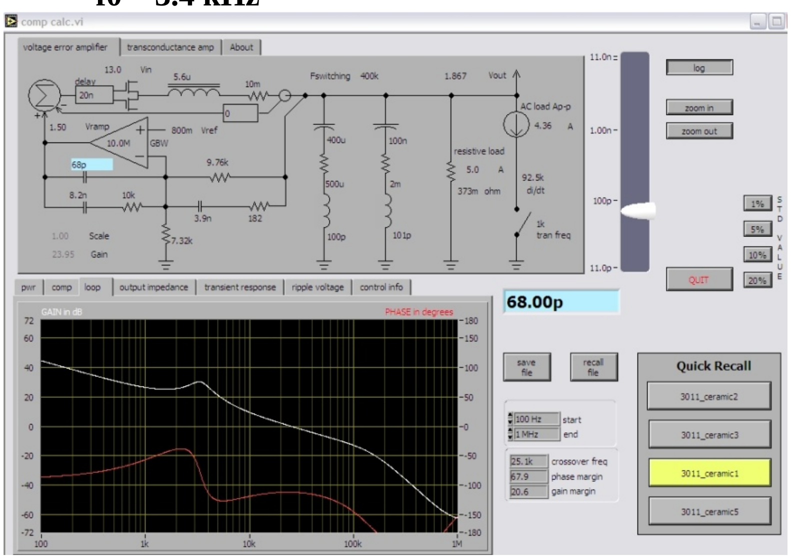


- **When conditions met (especially Rc1 > 2/gm), behavior is similar to a voltage amp**

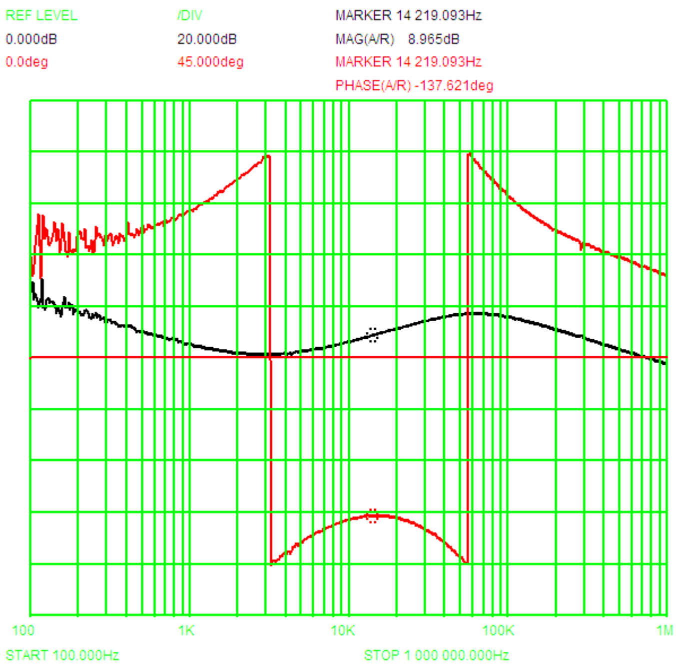
- **Measured Loop Response**
- **PM = 52 ^{o}**
- **f_cross = 24.6 kHz**
- **f0 ~ 3-4 kHz**



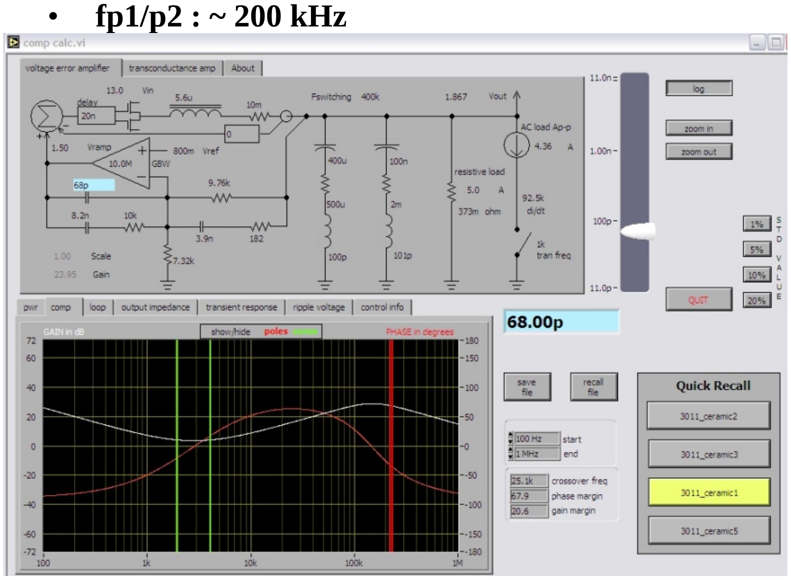
- **Predicted Loop Response**
  (utilizing CompCalc design tool: http://www.onsemi.com/pub/Collateral/COMPCALC.ZIP **)**
- **PM = 67.9 ^{o}**
- **f_cross = 25.1 kHz**
- **f0 ~ 3.4 kHz**



- **Measured Compensator Response**
- **Max Phase Boost: 128° @15 kHz**
- **fz1/z2 : ~ 2-5 kHz**
- **fp1/p2 : ~ 50-70 kHz**



- **Predicted Compensator Response**
  (utilizing CompCalc design tool: [**http://www.onsemi.com/pub/Collateral/COMPCALC.ZIP**](http://www.onsemi.com/pub/Collateral/COMPCALC.ZIP) **)**
- **Max Phase Boost: 125° @ ~20 kHz**
- **fz1/z2 : ~ 3-5 kHz**
- **fp1/p2 : ~ 200 kHz**



Note: CompCalc files with these values pre-loaded are available from the NCP3011 web page under “Design & Development Tools”

Performance

The following figures show typical performance of the NCP3011 demonstration boards.

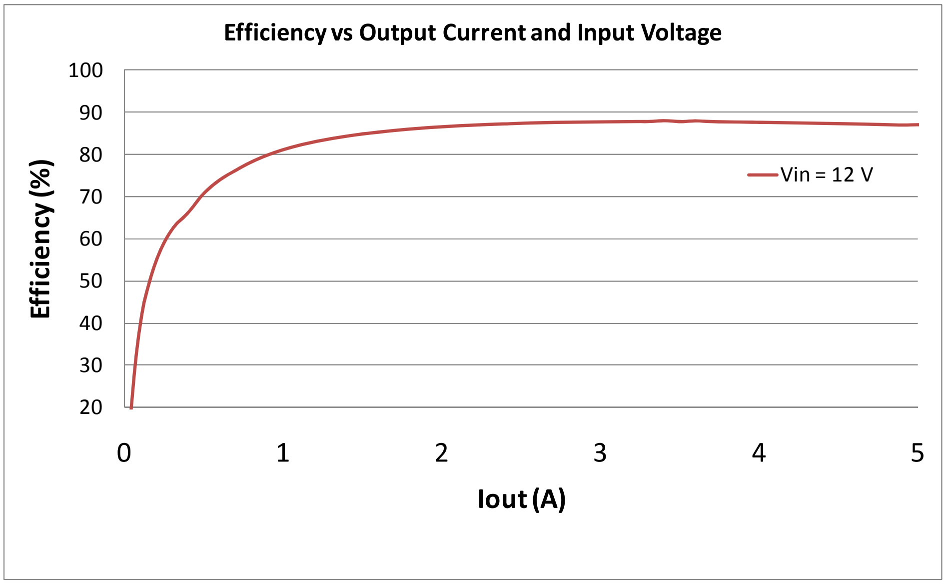


Figure 1: NCP3011 Efficiency at 12V with a 1.8V Output Voltage

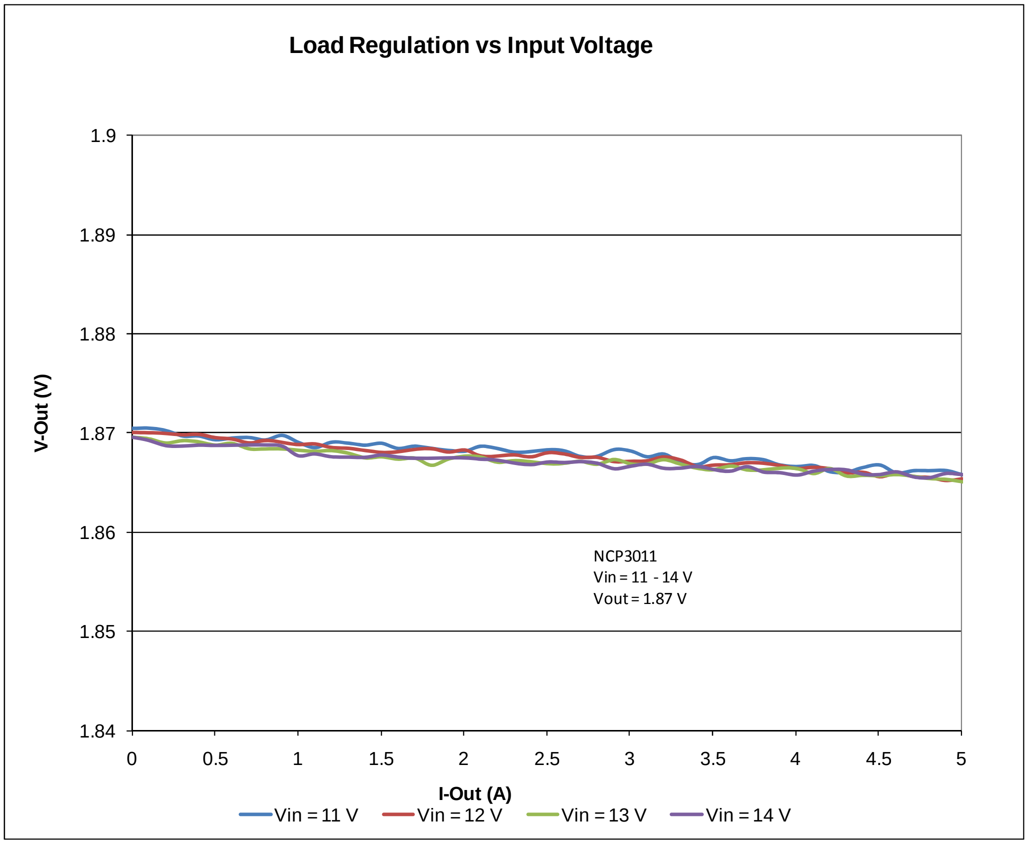


Figure 2: NCP3011 Load Regulation

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Schematics

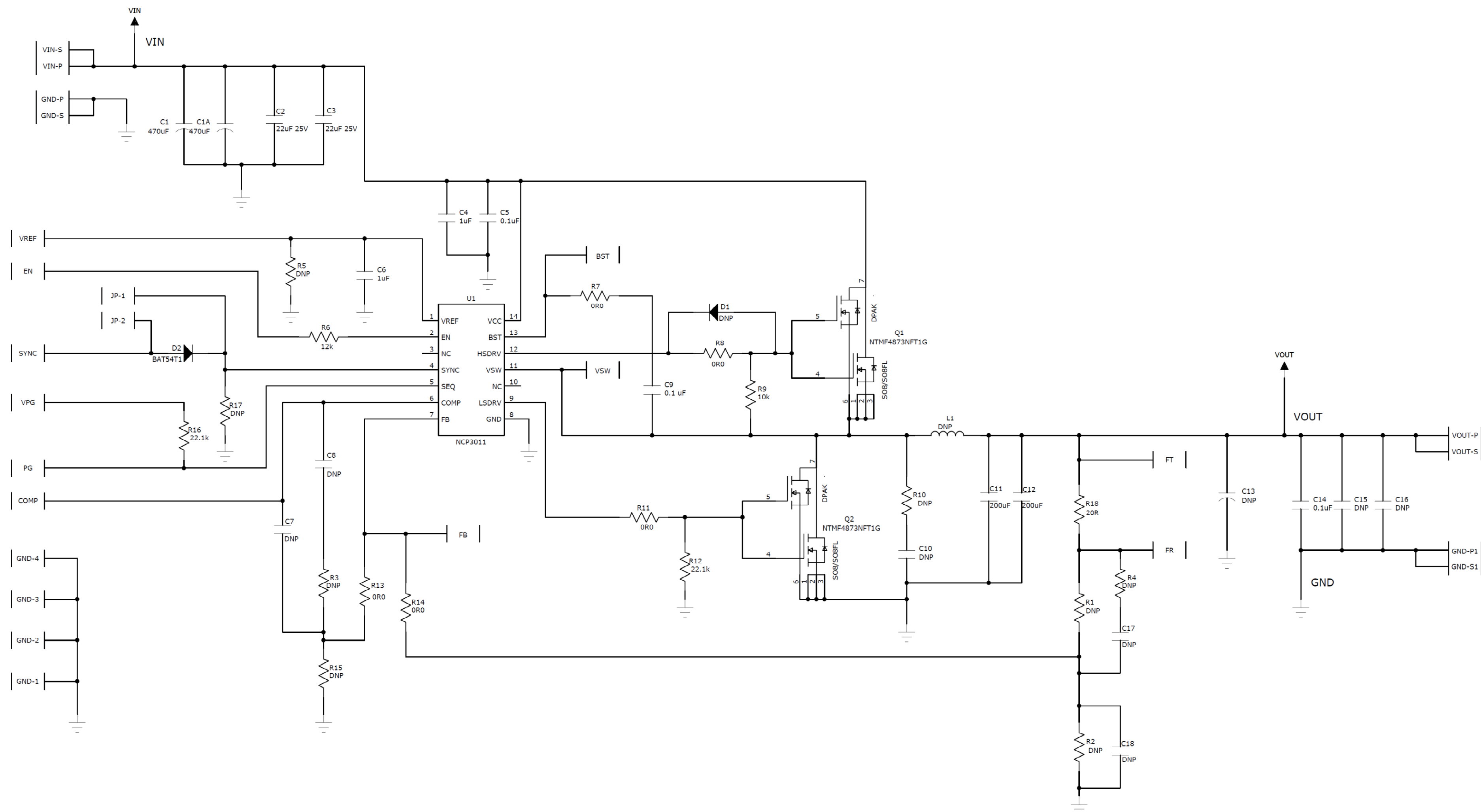

Figure 4: NCP3011 Schematic

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Table 2: NCP3011 BOM (1.8Voutput)

Qty	Reference	Value	Part Number	Description	PCB DECAL
1	C1	470uF			ECA_12.5
1	C1A	470uF			ECA_12.5
1	C2	22uF 25V	C4532X7R1E226M	Ceramic Chip Capacitor	2220CAP
1	C3	22uF 25V	C4532X7R1E226M	Ceramic Chip Capacitor	2220CAP
1	C4	1uF		Ceramic Chip Capacitor	1206CAP
1	C5	0.1uF		Ceramic Chip Capacitor	1206CAP
1	C6	1uF		Ceramic Chip Capacitor	1206CAP
1	C7	27pF		Ceramic Chip Capacitor	0603CAP
1	C8	2.7nF		Ceramic Chip Capacitor	0603CAP
1	C9	0.1 uF		Ceramic Chip Capacitor	0805CAP
1	C10	1.5 nF		Ceramic Chip Capacitor	0805CAP
1	C11	100uF*2	C3225X5R0J107M	Ceramic Chip Capacitor	1210CAP
1	C12	100uF*2	C3225X5R0J107M	Ceramic Chip Capacitor	1210CAP
1	C13	DNP			ECA_12.5
1	C14	0.1uF		Ceramic Chip Capacitor	0805CAP
1	C15	DNP		Ceramic Chip Capacitor	0805CAP
1	C16	DNP		Ceramic Chip Capacitor	0805CAP
1	C17	1.8nF		Ceramic Chip Capacitor	0603CAP
1	C18	DNP		Ceramic Chip Capacitor	0603CAP
1	L1	5.6 uH		SMT Inductor	MSS1260
1	Q1	NTMS4873NF	HSFET	Dual Use Footprint; SOPFL and DPAK MOSFET	COMBO2_SO8FL-DPAK
1	Q2	NTMS4873NF	LSFET	Dual Use Footprint; SOPFL and DPAK MOSFET	COMBO2_SO8FL-DPAK
1	R1	13.3k		SMT Resistor	0603RES
1	R2	10k		SMT Resistor	0603RES
1	R3	22.1k		SMT Resistor	0603RES
1	R4	499		SMT Resistor	0603RES
1	R5	DNP		SMT Resistor	0603RES
1	R6	12k	CRCW12060000Z0EA	Resistor	1206RES
1	R7	0R0	CRCW06030000Z0EA	SMT Resistor	0603RES
1	R8	0R0	CRCW12068R06FNEA	Resistor	1206RES
1	R9	10k	CRCW060310K0FKEA	SMT Resistor	0603RES
1	R10	1.18		Resistor	1206RES
1	R11	0R0	CRCW12060000Z0EA	Resistor	1206RES
1	R12	22.1k	CRCW060322K1FKEA	SMT Resistor	0603RES
1	R13	0R0	CRCW060310K0FKEA	SMT Resistor	0603RES
1	R14	0R0	CRCW06030000Z0EA	SMT Resistor	0603RES
1	R15	DNP		SMT Resistor	0603RES
1	R16	22.1k	CRCW0603750RFKEA	SMT Resistor	0603RES
1	R17	DNP		SMT Resistor	0603RES
1	R18	20R	CRCW060320R0FKEA	SMT Resistor	0603RES
1	U1	28 V 400 kHz	NCP3011	Synchronous PWM Controller	TSSOP-14
1	D1	DNP		Schottky Barrier Diodes	SOD_123_BAT54T1
1	D2	BAT54T1G	Sync Diode	Schottky Barrier Diodes	SOD_123_BAT54T1

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Vout	C7	C8	C10	C17	L1	R1	R2	R3	R4	R10	C11	C12
1.0V	27pF	2.7nF	1.5nF	1.8nF	5.6uH	15.8k	52.3k	22.1k	599	1.18	100uF*2	100uF*2
1.8V	68pF	8.2nF	1.5nF	3.9nF	5.6uH	9.76k	7.32k	10k	182	1.18	100uF*2	100uF*2
2.5V	27pF	2.7nF	1.5nF	1.8nF	5.6uH	15.8k	7.15k	22.1k	499	1.18	100uF*2	100uF*2
3.3V	27pF	2.7nF	1.5nF	2.7nF	5.6uH	10.5k	3.24k	22.1k	340	1.18	100uF*3	100uF*2
5.0V	27pF	2.7nF	1.5nF	1.8nF	6.8uH	15.4k	2.87k	22.1k	499	1.18	47uF*3	47uF*3

Table 3: Component Recommendations for Different Output Voltages

Design note created by Tim Kaske and Jim Hill, e-mail: Tim.Kaske@onsemi.com ; Jim.Hill@onsemi.com