NU1680C: Low Cost, None-firmware, High Integration Wireless Power Receiver

1 Feature

- Ultra-simple circuit structure with less than 12pcs components
- Low Cost and very simple application without extra firmware
- Integrated Low-Dropout LDO to Provide 5V Output Voltage, or real-time tracking external Battery Voltage to optimize the system efficiency
- Programmable and Configurable FOD gain and offset by Resisters
- Integrated high-efficiency synchronous rectifier without bootstrap capacitors
- Robust OVP, OCP, SCP and OTP Protection
- 10 Bits ADC for Battery voltage, Output current and temperature measurement
- Small Size with 16-QFN 3.0mm x 3.0mm, 0.5mm pitch

2 Applications

- WPC 5W BPP Compliant Receiver with Maximum 3.5W Received Power
- Wireless Power Receiver for TWS, Electric Toothbrush, Electric Shaver, E-Cigarette and others Consumer Equipment

3 Descriptions

NU1680C is a highly integrated wireless power receiver, which requires less quantity of surrounding components compared with NU1610. It gives the benefit of the very low total system cost and less PCB area for wireless power receiver solution. Also, since requires no firmware to program, it will much simplify the design effort and consolidate the solution more easily and quickly. It integrates a synchronous rectifier without bootstrap capacitors designed for a high efficiency purpose and low cost. Furthermore, it can regulate the output voltage tracking the battery voltage to further lower down the charging system power loss.

NU1680C can conduct communication with a transmitter system through ASK. The communication is compliant with WPC V1.2.4. FOD parameters can be configured by external resisters to pass the FOD test.

NU1680C also includes standard protection functions such as overcurrent protection, short-circuit protection, overvoltage protection and thermal shutdown. These provisions further enhance the reliability of the system solution.

The device is housed in a compact 3.0mm×3.0mm QFN package.

Content

4 Pin Configuration and Functions

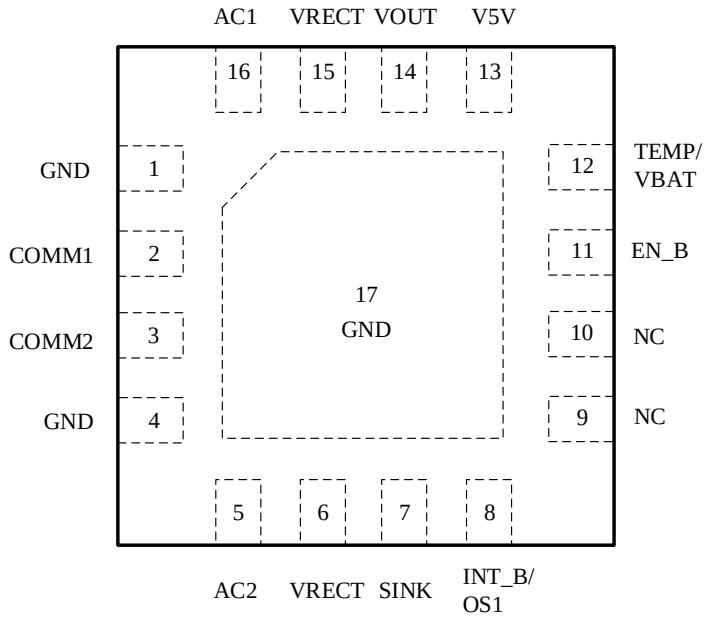


Figure 1. NU1680C-QFN Top View

Pin		I/O	Description
Name	No.		
GND	1, 4, 17	GND	System power and analog ground.
COMM1/COMM2	2/3	O	Open-drain output used to communicate with the transmitter. Connect a capacitor between this pin and AC1/AC2.
AC1/AC2	5/16	I	AC input power. Connect to the resonant circuit loop of L and C.
VRECT	6, 15	O	Output of the synchronous rectifier. Connect capacitor between this pin and ground.
SINK	7	O	Open-drain output for controlling the rectifier clamp. Connect a resistor between this pin and the VRECT pin.
INT_B/OS1	8	I/O	Open-drain, active low interrupt output. Pull up to V5V voltage with 10-kΩ resistor. Normally high, the device asserts low to report status and faults. If configured as FOD_RES_MODE, this PIN function as the input of the Offset of FOD parameter at load #0. If not use, connect to ground.
NC	9	/	Reserved.
NC	10	/	Reserved.
EN_B	11	I	A logic high input for power LDO output disable. There is internal pull down, keeping it floating if no use.

TEMP/VBAT	12	I	Temp sensing pin. Connect a R_{25} = 100K, beta = 4250 NTC resistor to ground. Or it can be configured as battery voltage sensing pin to make V_{out} being capable of tracking external Battery voltage before shipment. Leave it floating if no use.
V5V	13	O	5V power supply for IC internal use. Connect a typical 1uF/10V capacitor between this pin and ground.
VOUT	14	O	Output pin for load.

5 Specifications

5.1 Absolute Maximum Ratings

Pins	Rating	Units
AC1, AC2, COMM1, COMM2	-0.3~17	V
VRECT, SINK	-0.3~17	V
V5V, INT_B/OS1, EN_B, TEMP/VBAT	-0.3~6	V
VOUT	-0.3~10	V
Max Current on SINK	500	mA
Max Current on COMM1/2	500	mA
Max RMS Current on AC1/AC2	2	A
Operating Junction Temperature, T_J	-40~125	°C
Ambient Operating Temperature, T_A	-40~85	°C
Storage Temperature, T_{stg}	-55~125	°C

5.2 ESD Ratings

		UNIT
Human Body Model	+/-2000	V
Charged Device Model	+/-500	V

5.3 Package Thermal Ratings

		UNIT
Junction-to-ambient thermal resistance, $R_{\Theta JA}$ (FR4 double layer, 2oz, 1.9mm*1.9mm size of copper on IC layer and 8mm*8mm size of copper on another side)	38	°C/W

5.4 Electrical Characteristics

V_{RECT}=5.2V, T_j=-40 °C to 125°C (unless otherwise noted)

PARAMETERS		TEST CONDITIONS	MIN	TYP	MAX	UNIT
Power supply						
$V_{UVLO\_RECT\_RISE}$	V_{RECT} Under-voltage lock out threshold	V_{RECT} ramps up	2.9	3.05	3.2	V
$V_{UVLO\_RECT\_FALL}$		V_{RECT} ramps down		2.83		V
V_{UVLO_V5V}	Under-voltage lock out threshold	V5V ramps up	2.9	3.05	3.2	V
$V_{UVLO\_V5V\_HYS}$	Under-voltage lock out hysteresis voltage	V5V ramps down	80	220	360	mV
I_{Q_RECT}	Quiescent operating current into V_{RECT}	EN_B=low, no switching		2		mA
V5V LDO						
V_{V5V}	5V supplier	I_{V5V}=10mA	4.6	4.83	5.1	V
I_{V5V}	5V supply current limit	V_{V5V}=4.6V			80	mA
I_{SHORT}	5V short current	V_{V5V}=1V			360	mA
OUTPUT REGULATION (POWER LDO)						
V_{OUT}	Output voltage range			5.0		V
V_{OUT_ACC}	Output voltage accuracy	V_{OUT}=5V, I_{OUT}=1mA	4.85	5	5.15	V
V_{OUT_REG}	Output voltage regulation	V_{OUT}=5V, I_{OUT}=1A	-3		3	%
I_{LIM_RANGE}	Current limit range (Sending EPT packet)	V_{OUT}=5V	1.2	1.4	1.6	A
Synchronous Rectifier Bridge						
R_{DSON}	ON impedance of Rectifier MOSFET	VRECT=6V		100		mΩ
TMOT	minimum ON time			350		ns
Protection						
T_{OTP}	Thermal Shut Down	Temp rising threshold		150		°C
T_{OTP_HYS}	Thermal Shut Down hysteresis	Temp falling threshold		25		°C
V_{SC}	Output short protection			1		V

V_{OVP1}	VRECT Low-Level over voltage protection threshold	SINK ON and soft protection	12.1	12.8	13.5	V
V_{OVP1_HYS}	VRECT over voltage recovery hysteresis		0.4	0.6	0.9	V
V_{OVP2}	VRECT High-Level over voltage protection threshold	SINK ON and internal hard protection	14.6	15.4	16.2	V
V_{OVP2_HYS}	VRECT over voltage recovery		6.7	8.5	9.5	V
SINK						
R_{SINK}	Pulldown resistance of SINK pin	I=100mA			7	Ω
I_{LKG_SINK}	SINK pin leakage current	SINK=5.5V	-1		1	μA
EN_B						
V_{IH_ENB}	Input voltage logic high	Input rising	1.5			V
V_{IL_ENB}	Input voltage logic low	Input falling			0.6	V
R_{ENB}	Logic pin input impedance	Pull down to GND		2		MΩ
INT_B/OS1						
V_{OL_INTB}	INT_B/OS1 pin output low	I=1mA			0.2	V
I_{LKG_INT}	INT_B/OS1 leakage current	V=0V and 5V	-1		1	μA
BIAS Current for FOD parameters configure and Temperature sense						
I_{Bias}	Current flow through pins and resister (TEMP, INT_B/OS1)	Tested on TEMP/VBAT, INT_B/OS1 pins.	3.8	4	4.2	μA

Note: * means performance is guaranteed by design.

6 Functional Block Diagram

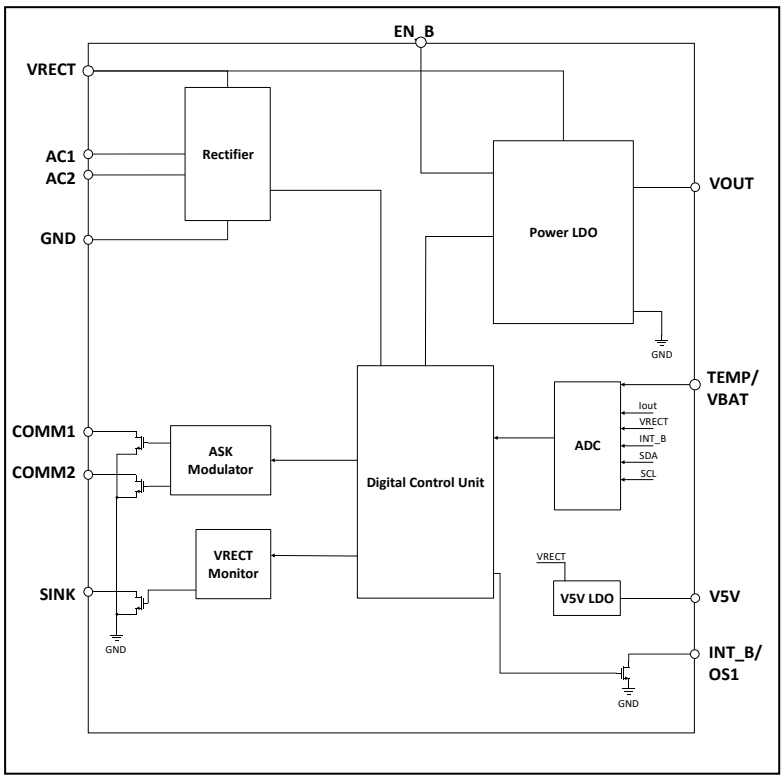


Figure 2. Function Block Diagram

7 Typical Characteristics

The following testing is using NU1020+NU1513 wireless transmitter EVM with MPA2 Tx Coil.

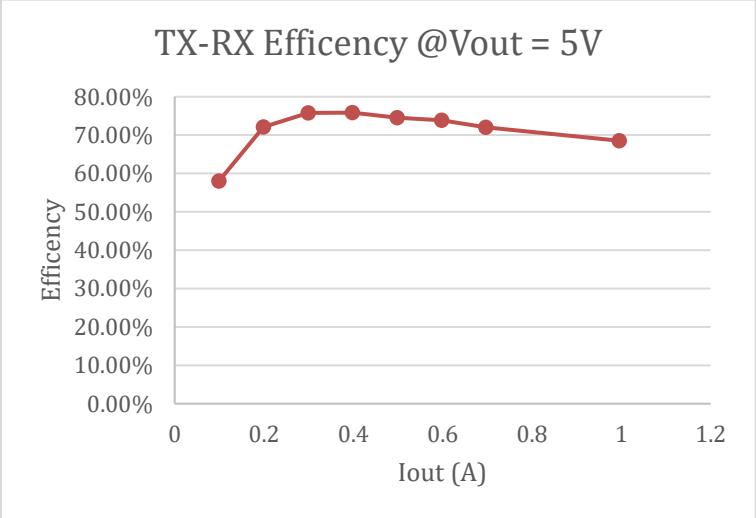


Figure 3. Efficiency: VOUT=5V

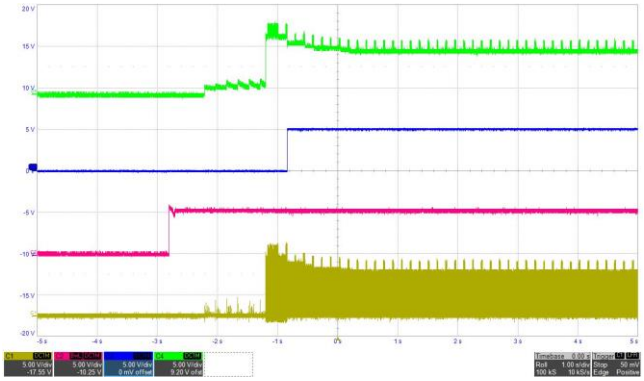


Figure 4. Start up by Adapter: VOUT=5V, IOUT=0.5A

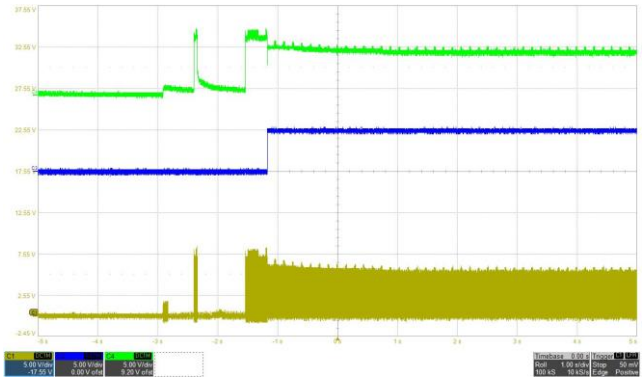


Figure 5. Start up by Rx: VOUT=5V, IOUT=0.5A

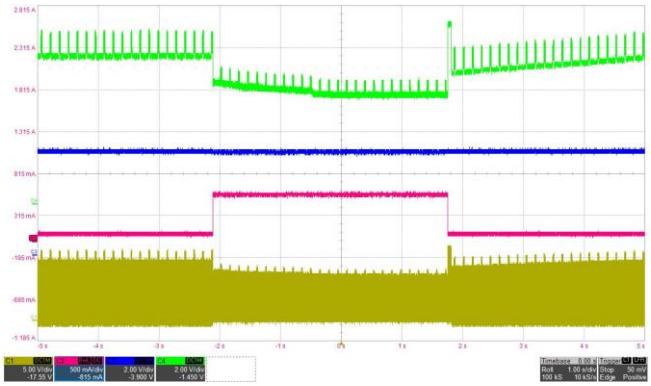


Figure 6. Transient Response: VOUT=5V, IOUT=0A to 0.5A; 0.5A to 0A

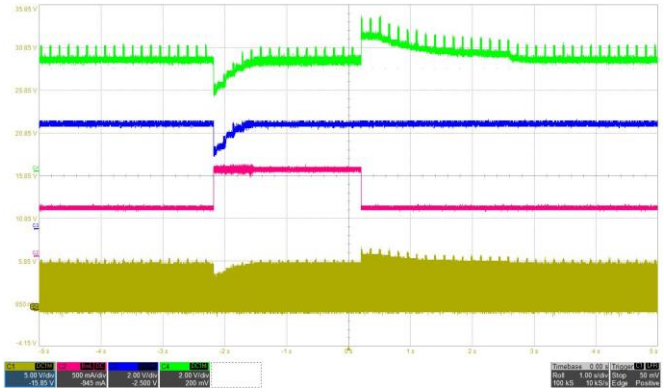


Figure 7. Transient Response: VOUT=5V, IOUT=0.5A to 1A; 1A to 0.5A

Note: (1) Figure 4: CH1-AC1; CH2-VIN_Adapter; CH3-V_{out}; CH4-V_{rect}
(2) Figure 5: CH1-AC1; CH2-N/A; CH3-V_{out}; CH4-V_{rect}
(3) Figure 6~7: CH1-AC1; CH2-I_{out}; CH3- V_{out}; CH4-V_{rect}
(4) The typical characteristics were tested at TA = 25°C, unless otherwise noted

8 Application Descriptions

8.1 System Overview

In a wireless power transfer system, the transmitter system generates magnetic field by feeding AC current into a transmitting coil. The magnetic field is coupled to a receiving side coil and the coupled energy is further maximized by matching the transmitter side impedance. The outputs of the resonant circuit are connected to the AC1 and AC2 pin of the IC which are the inputs to the on-chip synchronous rectifier. The rectifier output is an unregulated voltage connected to the VRECT pin of the IC. To provide a well-regulated voltage source or current source to the downstream circuit, an ultra-low dropout LDO is connected between the VRECT pin and the OUT pin.

The communication between the transmitter side (Tx) and receiver side (Rx) is needed to provide feedback on the power requirement from the receiver to the transmitter. NU1680C is equipped with amplitude modulated communication compliant with WPC standard. The Rx to Tx communication is implemented by turning on the COMM1 and COMM2 internal switches and inserting additional capacitance to the Rx resonant circuit. This modulation of Rx impedance can be detected on the Tx side as amplitude modulation of its coil voltage and current waveform.

Protection is a critical requirement to wireless power receivers, especially the over-voltage protection on the VRECT pin. The coupling factor between Tx and Rx, hence the coupled energy between Tx and Rx, can change suddenly and significantly as the proximity between Rx and Tx coils is altered by end users without notice. When the coupled energy increases rapidly, the VRECT voltage can rise and potentially exceed its maximum voltage rating to cause IC damage. NU1680C incorporates comprehensive two levels of over-voltage protection against any transient conditions.

8.2 Power Supply

When the receiving coil is placed in the magnetic field created by the transmitter analog ping, DC voltage is established on the VRECT pin through the body diode of the rectifier MOSFET initially. V5V follows VRECT voltage through an inner start up circuit. When V5V is above UVLO, the 5V LDO, which provides IC internal bias voltage, is powered up to turn on internal circuit blocks, such as Digital Control Unit, protection circuits and rectifier switches. In addition, the communication from Rx to Tx takes place to instruct Tx to deliver power. Two capacitors of typical value of 4.7uF to 10uF should be placed at the VRECT pin to provide DC voltage to the IC.

When the receiving coil is removed from the magnetic field, or the transmitter is turned off, the voltage of the VRECT pin is discharged by the load connected to the OUT pin and IC operating current. If the V5V voltage drops below UVLO, the IC enters shutdown mode.

8.3 Synchronous Rectifier

The NU1680C has an integrated synchronous rectifier to ensure efficient AC-to-DC conversion, especially for the heavy output load. It has built in a reliable and efficient switch control algorithm to minimize the dead-time while eliminating the possibility of the shoot-through inside the rectifier.

8.4 Power LDO

The output voltage of the Power LDO is 5V. During start up, the Power LDO will turn on when the voltage on VRECT Pin ramp up to 7.2V.
The LDO is protected by the over-current protection. During the over-current protection, SINK switches are turned on to limit the coupled energy. And an interrupt will be triggered to AP/MCU for more action.
LDO has a soft-start feature to prevent in-rush current caused by charging output capacitor during the startup. The soft start gradually turns on the LDO to control and limit its current.

8.5 Over-Voltage Protection

Since the feedback loop between Rx and Tx is inherently slow, the transmitter is unable to reduce the power output instantly when the overvoltage condition occurs on the receiver side. The delay can be in the range of tens or even hundreds of milli-seconds which is a long time enough to damage the IC. The over-voltage protection circuit engages immediately upon the occurrence of the over-voltage condition. There are two level over voltage protection. Firstly, reach the low level OVP1 threshold, the protection circuit will create a 'bleeding' resistor (One 220Ω resistors in 0805 packages are recommended) to the VRECT pin to dissipate the power through the resistor by SINK Pin. And, IC is disabled sending EPT and sending CE more quickly.
Secondly, if it reaches the high level OVP2, Sending EPT and trig the hard protection which cut off the energy charging into the VRECT circuit immediately.

8.6 Over-Current Protection

NU1680C integrates a reliable over current protection circuit. Current of the LDO is sensed and compared to the over-current protection threshold, 1.4A. If the current exceeds the threshold, the internal the over-current protection circuit is triggered, and the Power LDO will limit the output current and send EPT to Tx to turn off the wireless transmitting.

8.7 Short-Circuit Protection

NU1680C integrates a reliable short-circuit protection. If the output of power LDO is lower than 1V, the internal protection circuit is triggered, and the Power LDO will be turned off to protect the IC.

8.8 External Temperature Protection

NU1680C integrates a high and low temperature protection for Battery or other external components. To use this function, connect a R_{25} = 100K, beta = 4250 NTC resistor between TEMP/VBAT and ground.
For high temperature protection, if the temperature rises to 80°C, IC will trig the temperature protection and send EPT to Tx.

For low temperature protection, if the temperature of target component is below 0°C, IC will trigger the temperature protection and send EPT to Tx.

8.9 IC Over-Temperature Protection

To avoid the junction of NU1680C being higher than 150°C, when the die of IC temperature reaches this point, the IC will send EPT to Tx to cut off the wireless charging.

8.10 Tracking Battery Voltage

NU1680C can enable the function of regulating V_{out} to track the Battery voltage by implementing the battery voltage connected to TEMP/VBAT Pin before shipment. This function is capable to simply the backward charging circuit design.

8.11 INT_B/OS1, SINK, EN_B

INT_B/OS1 pin is an open-drain and low active pin. Connect a resistor (e.g. 10K) between this pin and V5V. This pin is pulled high during normal mode. Under any protection, the INT_B/OS1 pin is pulled low to indicate a fault condition. If not use this pin, connect this pin to ground.
Recommend connecting a SMD0805 package of 220R between SINK Pin and VRECT Pin to dissipate the over energy during some extreme condition. The pull-down duration time of SINK Pin is typical 200ms when over voltage occurrence.
EN_B is LOW active pin to enable or disable the power LDO of NU1680C. Leave this pin floating if not use.

8.12 ADC

NU1680C integrates an accurate 10bit ADC which takes inputs from internal signals such as VRECT voltage, output current. These signals are used to calculate the proper received power to report to Tx during power transfer stage.
NU1680C samples the signal on NTC or Battery voltage by TEMP/VBAT Pin to realize the temperature protection and battery voltage tracking function.
Also, during power on start-up, ADC will sense the resisters connected to INT_B/OS1 to enter into FOD_RES_MODE mode to configure the FOD parameters.

9 Layout Guidelines

Top Layer shown as Figure 8,

- Resonant capacitor C7/C8/C9/C21, COMM capacitor C1/C2 should be placed on the left side of IC, the closer the better.
- The trace to coil L1 should be large width.
- Two VRECT capacitors should be placed on each side respectively.
- Place some Via on IC thermal pad pin for good thermal conduction.

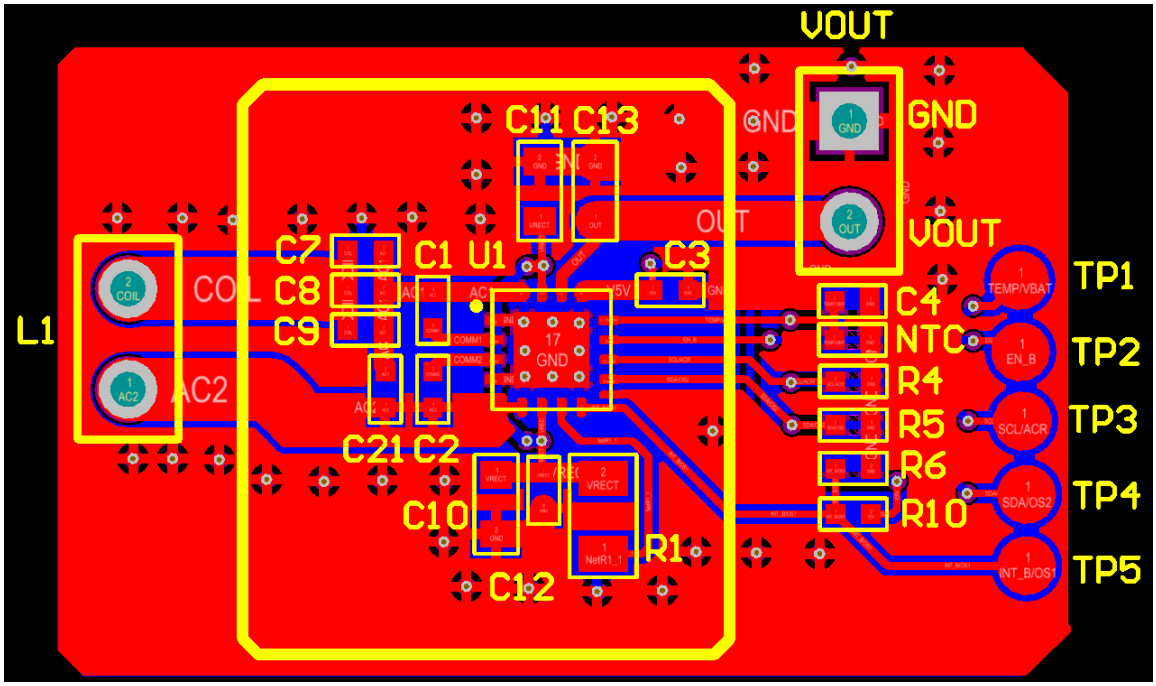


Figure 8: Top layer

Bottom Layer partly shown as Figure 9, Only one consideration needs to be taken care of that at least >=0.3mm width copper connect two VRECT Pins and place at least two Via on each side.

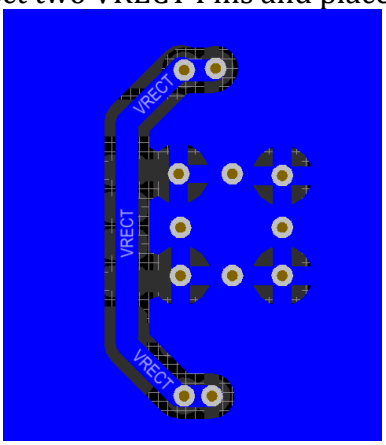
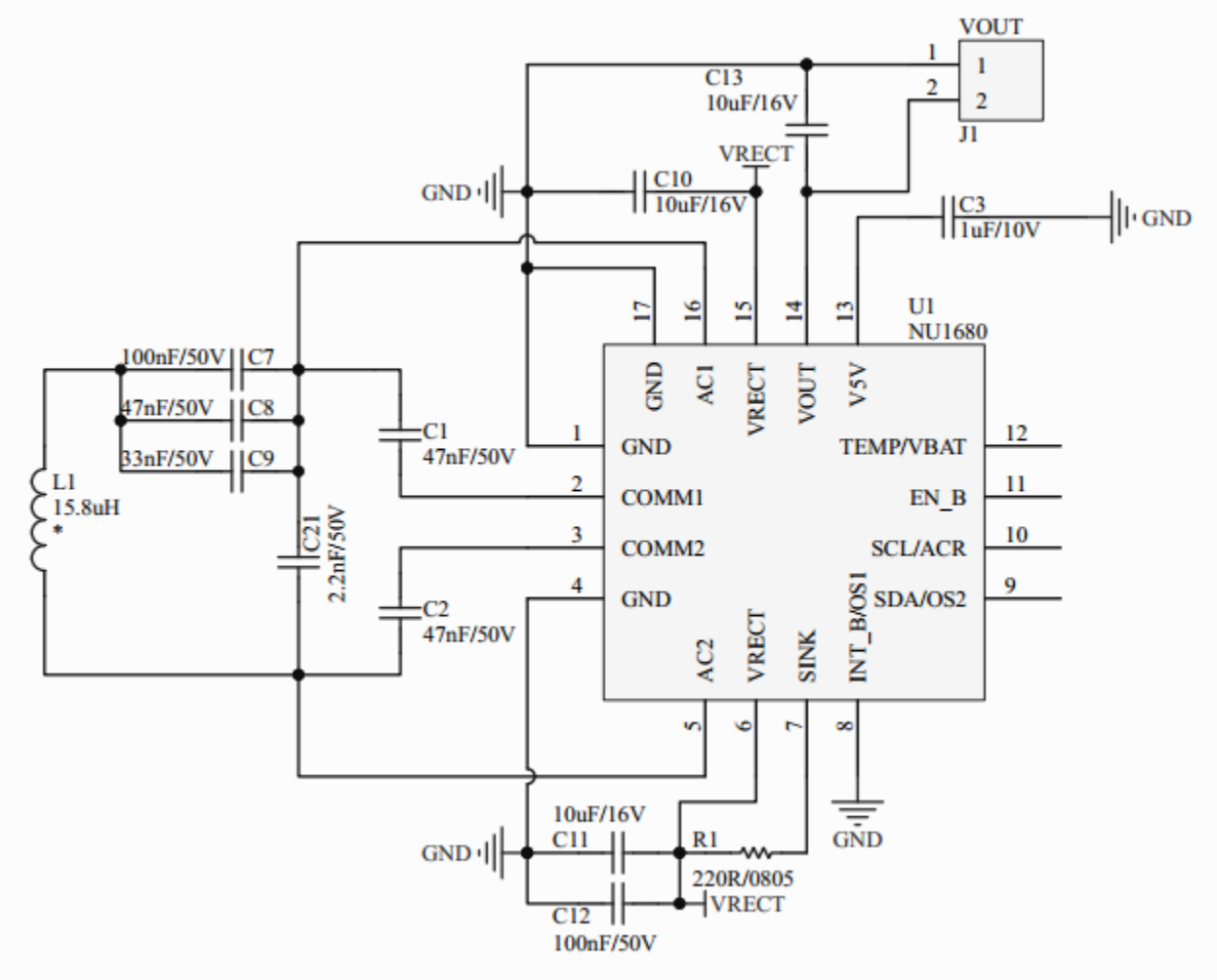


Figure 9: Bottom layer

Note: Make the resonant power routing loop as small as possible and keep away from another signal circuit.

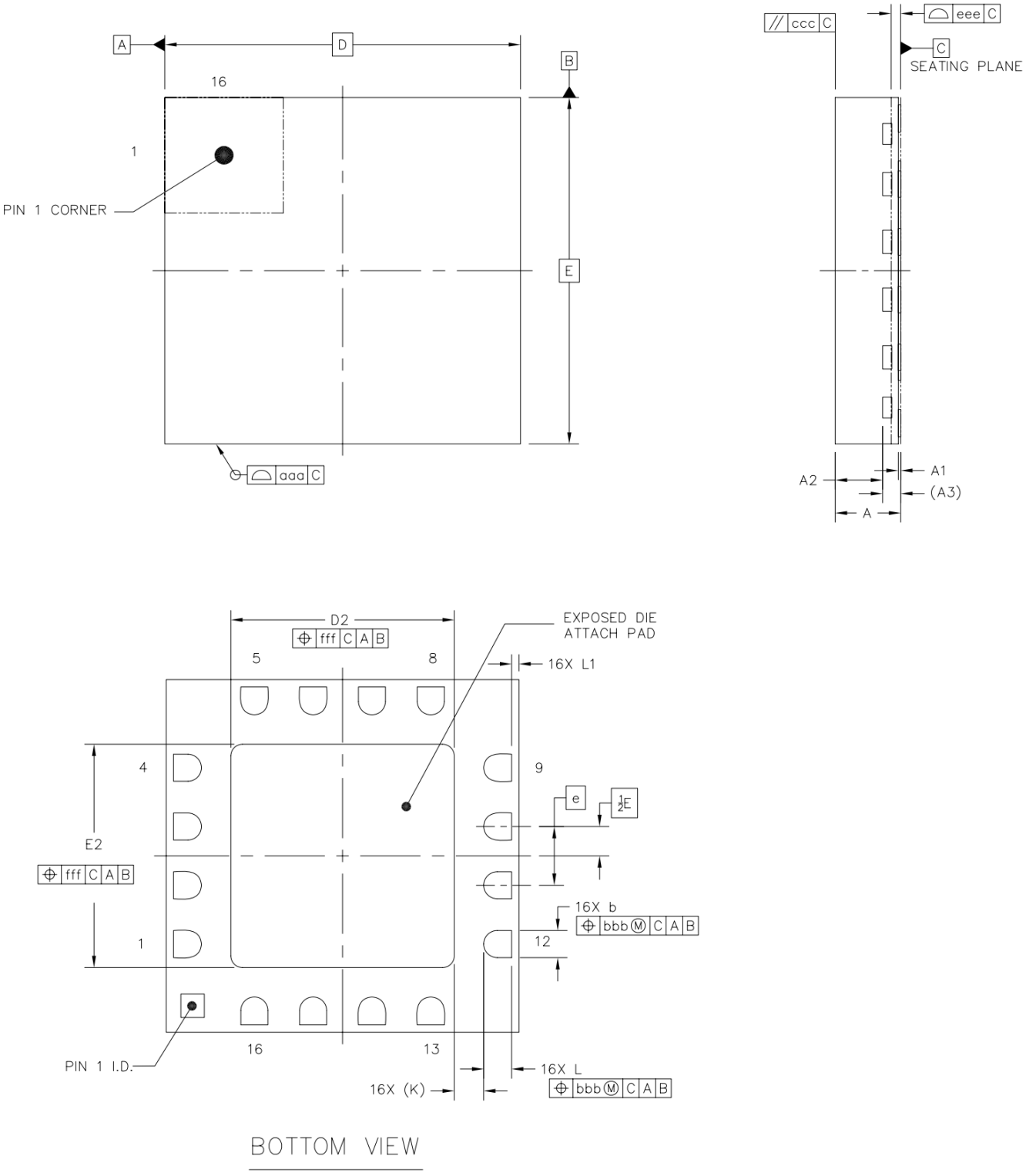
10 Typical application circuit



11 Package Information

Orderable Device	Status	Package Type	Package Drawing	Pins	Eco Plan	Lead/Ball Finish	MSL Peak Temp	Op Temp©	Device Marking
NU1680CQDHB	Release	QFN	QDH	16	Green(RoHS & No Sb/Br	Cu/Sn Ag Cu	Level-2	-40 to 125	NU1680CQDHB

12 Mechanical Data



		SYMBOL	MIN	NOM	MAX
TOTAL THICKNESS		A	0.5	0.55	0.6
STAND OFF		A1	0	0.02	0.05
MOLD THICKNESS		A2	---	0.4	---
L/F THICKNESS		A3		0.152 REF	
LEAD WIDTH		b	0.18	0.23	0.28
BODY SIZE	X	D		3 BSC	
	Y	E		3 BSC	
LEAD PITCH		e		0.5 BSC	
EP SIZE	X	D2	1.8	1.9	2
	Y	E2	1.8	1.9	2
LEAD LENGTH		L	0.1375	0.2375	0.3375
LEAD EDGE TO PKG EDGE		L1		0.0625 REF	
LEAD TIP TO EXPOSED PAD EDGE		K		0.25 REF	
PACKAGE EDGE TOLERANCE		aaa		0.1	
MOLD FLATNESS		ccc		0.1	
COPLANARITY		eee		0.08	
LEAD OFFSET		bbb		0.1	
EXPOSED PAD OFFSET		fff		0.1	

13 Revision Histories

	Date	Changes
V1.0	Feb/06/2020	First release.