

# NCP1351PRINTGEVB

## NCP1351 16 V/32 V – 40 W Printer Power Supply Evaluation Board User's Manual



ON Semiconductor®

<http://onsemi.com>

### Eval Board User's Manual

#### Description

The present document describes a printer power supply operated by the NCP1351, a fixed  $t_{on}$ /variable  $t_{off}$  time controller. The board can deliver 10 W average on a 16 V output and 30 W average on a 32 V output with a transient peak power capability of 80 W. It however exhibits a low standby power: below 150 mW at no load whatever the input voltage. Let us first review the benefit of using the NCP1351:

#### The NCP1351 at a Glance

##### *Fixed $t_{on}$ , Variable $t_{off}$ Current-mode Control:*

Implementing a fixed peak current mode control (hence the more appropriate term “quasi-fixed”  $t_{on}$ ), the NCP1351 modulates the off time duration according to the output power demand. In high power conditions, the switching frequency increases until a maximum is hit. This upper limit depends on an external capacitor selected by the designer. In light load conditions, the off time expands and the NCP1351 operates at a lower frequency. As the frequency reduces, the contribution of all frequency-dependent losses accordingly goes down (driver current, drain capacitive losses, switching losses), naturally improving the efficiency at various load levels.

##### *Peak Current Compression at Light Loads:*

Reducing the frequency will certainly force the converter to operate into the audible region. To prevent the transformer mechanical resonance, the NCP1351 gradually reduces – compresses – the peak current setpoint as the load becomes lighter. When the current reaches 30% of the nominal value, the compression stops and the off duration keeps expanding towards low frequencies.

##### *Low Standby-power:*

The frequency reduction technique offers an excellent solution for designers looking for low standby power converters. Also, compared to the skip-cycle method, the smooth off time expansion does not bring additional ripple in no-load conditions: the output voltage remains quiet.

##### *Natural Frequency Dithering:*

The quasi-fixed  $t_{on}$  mode of operation improves the EMI signature since the switching frequency varies with the natural bulk ripple voltage.

##### *Extremely Low Start-up Current:*

Built on a proprietary circuitry, the NCP1351 startup section does not consume more than 10  $\mu$ A during the startup sequence. The designer can thus easily combine startup time and standby consumption.

##### *Overload Protection Based on Fault Timer:*

Every designer knows the pain of building converters where a precise over current limit must be obtained. When the fault detection relies on the auxiliary  $V_{CC}$ , the pain even increases. Here, the NCP1351 observes the lack of feedback current and starts a timer to countdown. At the end of its charge, the timer either triggers an auto-recovery sequence (auto-restart, B and D versions) or permanently latches-off (A and C). On C and D versions the fault timer is started at an output power corresponding to 60% of the maximum deliverable power; to allow transient peak power delivery.

##### *Latch Fault Input:*

A dedicated input lets the designer externally trigger the latch to build additional protections such as over-voltage (OVP) or over-temperature (OTP).

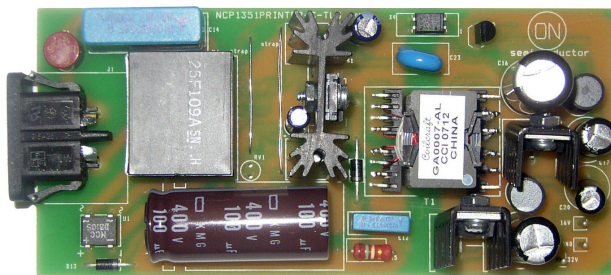


Figure 1. NCP1351 Evaluation Board

# NCP1351PRINTGEVB

## The Schematic

The design must fulfill the following specifications:

- Input Voltage: 88 – 265 Vac
- Output Voltage: 16 V @ 0.625 A and 32 V @ 1 A Nominal (40 W); with Transient 80 W Peak Power Capability during 40 ms, and 62 W Peak during 400 ms
- Over Power Protection below 100 W for the Whole Input Voltage Range (LPS)
- Latched Short-circuit Protection
- Latched Over-voltage Protection
- Latch Recovery Time below 3 s
- Brown-out Protection
- Start-up Time below 3 s

In order to deliver the peak output power, the NCP1351 will increase its switching frequency up to the upper limit set by the  $C_T$  capacitor. To not jeopardize the EMI test compliance, the switching frequency should be kept below 150 kHz. We will choose 100 kHz to have a good margin. As a result the switching frequency at nominal load will be around 50 kHz. Since we need to deliver 80 W of transient peak power while ensuring the power will never be above 100 W, we will use the C version of NCP1351, specially tailored for this kind of application. When the controller

detects a need for a frequency higher than 60 kHz, implying an overload condition, it will start to charge the timer capacitor: if the overload disappears, the timer capacitor goes back to zero. If the fault remains, the timer capacitor voltage reaches 5 V and latches off the controller. During the fault condition, the power supply will anyway deliver the output power while the switching frequency is below its maximum value of 100 kHz.

The transformer has been derived using the Excel<sup>®</sup> spreadsheet available from the ON Semiconductor website which also gives transformer parameters. We came up to the following values:

$$L_p = 270 \mu\text{H}$$

$$N_p:N_s = 1:0.2$$

$$N_p:N_{aux} = 1:0.2$$

$$I_{pk} = 3 \text{ A}$$

The transformer has been manufactured by Coilcraft (www.coilcraft.com). The leakage inductance is kept around 3% of the primary inductance, leading to a good efficiency and reduced losses in no-load conditions. The schematic appears on Figure 2. The converter operates in DCM at nominal power; and for peak power it goes CCM with close to 50% duty-cycle at low mains and stays CCM at high line.

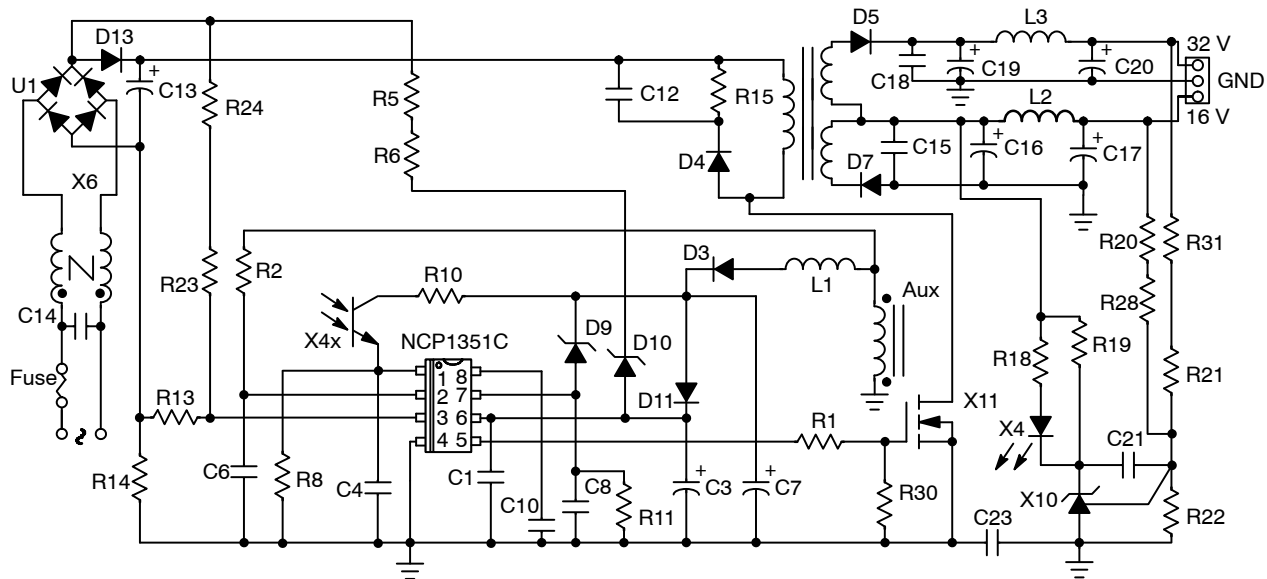
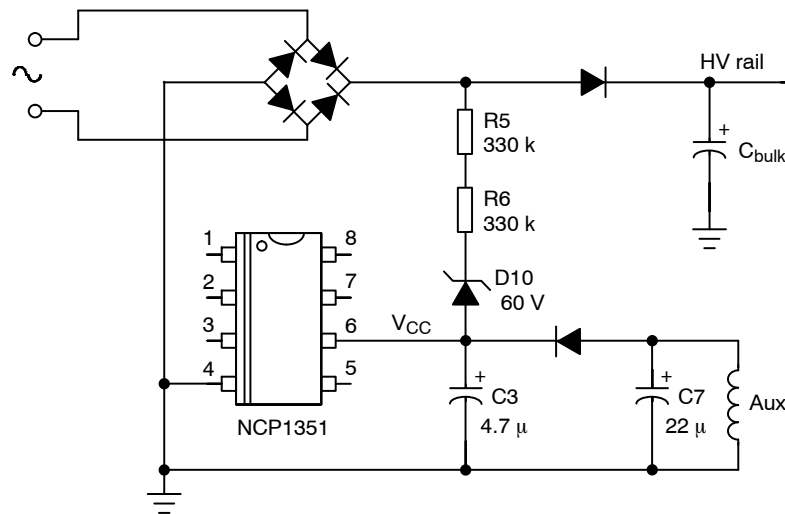


Figure 2. The Simplified 40 W Printer Board Featuring the NCP1351 Controller

## NCP1351PRINTGEVB

Two 330 k $\Omega$  resistors in series with a 60 V zener diode ensure a clean start-up sequence with the 4.7  $\mu$ F capacitor ( $C_3$ ), not from the bulk capacitor as it is usually done; but from the fully rectified, unfiltered haversine. This configuration allows for a quick release time after the

controller is latched (a direct connection to the AC line would also work). Despite a small value for  $C_3$ , the  $V_{CC}$  still maintains in no-load conditions thanks to the split configuration:



**Figure 3. The split  $V_{CC}$  configuration helps to start-up in a small period of time ( $C_3$  to charge alone) but the addition of a second, larger capacitor ( $C_7$ ), ensures enough  $V_{CC}$  in standby.**

The primary-side feedback current is fixed to roughly 300  $\mu$ A via  $R_8$  and an additional bias is provided for the TL431. 1 mA at least must flow in the TL431 in worse case conditions (full load). Failure to respect this will degrade the power supply output impedance and regulation will suffer. A 2.7 k $\Omega$  value for  $R_{19}$  has proven to do just well, without degrading the standby power.

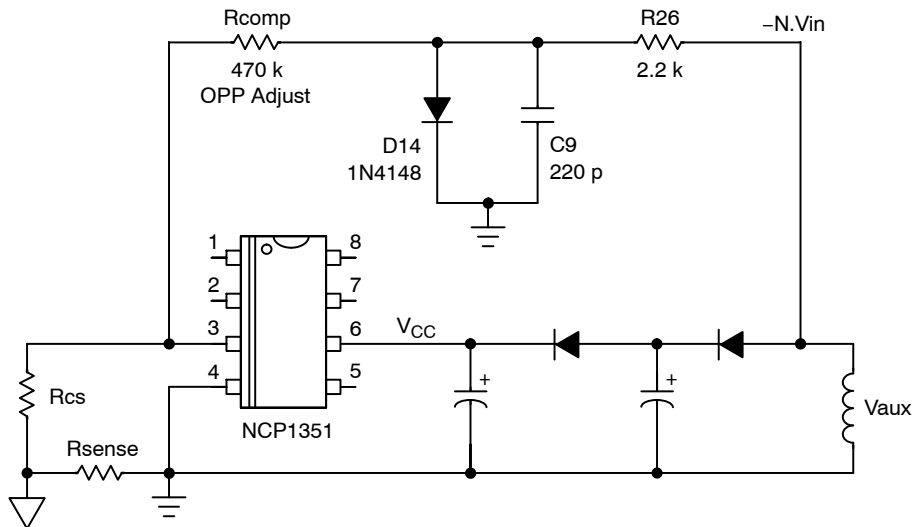
The overvoltage protection uses a 17 V zener diode ( $D_9$ ) connected to the auxiliary  $V_{CC}$ . When the voltage on this rail exceeds 17 V plus the NCP1351 5 V latch trip point (total is thus 22 V), the circuit latches-off and immediately pulls the  $V_{CC}$  pin down to 6 V. The reset occurs when the injected current into the  $V_{CC}$  pin falls below a few  $\mu$ A, that is to say when the power supply is disconnected from the mains outlet. To speed-up this reset phase, a connection to the fully rectified haversine resets the system faster (Figure 3).

To satisfy the maximum power limit, we don't need to add a true Over Power Protection (OPP) circuit since our

NCP1351C transiently authorizes higher power, but safely latches off if the overpower lasts too long. To ensure a fault timer duration of at least 500 ms (to be able to deliver the 62 W power peak during 400 ms), the timer capacitor  $C_{10}$  must be 1.5  $\mu$ F. This value will be adjusted depending on the specification, according to the maximum peak power duration the adapter must sustain.

If anyway a constant overpower protection is needed over the whole input voltage range, a simple arrangement can be used: given the negative sensing technique, we can use a portion of the auxiliary signal during the on time, as it also swings negative. However, we don't want this compensation for short  $T_{ON}$  durations since standby power can be affected. For this reason, we can insert a small integrator made of  $C_9$ - $R_{26}$  (see Figure 4). To avoid charging  $C_9$  during the flyback stroke,  $D_{14}$  clamps the positive excursion and offers a stronger negative voltage during the on time.

# NCP1351PRINTGEVB



**Figure 4. A Simple Arrangement Provides an Adjustable Overpower Power Compensation**

A simple resistor connected between the auxiliary winding (that swings negative during the ON time) and the CT capacitor ensure a stable operation in CCM despite the duty cycle above 50% at very low line, due to the ripple on the bulk capacitor. The unique features of NCP1351C allow using a 100  $\mu$ F bulk capacitor while delivering the transient peak power and ensuring the output is still regulated during line drop-outs.

Finally, the clamping network maintains the drain voltage below 520 V at high-line (375 Vdc) which provides 85% derating for the 600 V BVdss device.

### Measurements

Once assembled, the board has been operated during 15 min at full power to allow some warm-up time. We used a WT210A from Yokogawa to perform all power related measurements coupled to an electronic ac source.

**Table 1. EFFICIENCY**

| $V_{IN}$ ( $P_{OUT}$ ) | 120 Vac | 230 Vac |
|------------------------|---------|---------|
| 40 W                   | 84.4%   | 85.4%   |
| 25 W                   | 85.9%   | 85.9%   |
| 10 W                   | 86.0%   | 85.1%   |
| 5 W                    | 85.5%   | 83.2%   |
| 2 W                    | 83.4%   | 79.5%   |
| 1 W                    | 77.7%   | 73.3%   |
| 0.5 W                  | 70.0%   | 66.3%   |

**Table 2. NO-LOAD POWER**

| $V_{IN}$ ( $P_{OUT}$ ) | 120 Vac | 230 Vac |
|------------------------|---------|---------|
| No-load                | 75 mW   | 140 mW  |

### Overpower Protection Level:

The power supply is able to deliver a peak power of 85 W during 500 ms from 85 Vac to 270 Vac.

It can deliver a constant output power of more than 40 W, but less than 80 W over the same input voltage range.

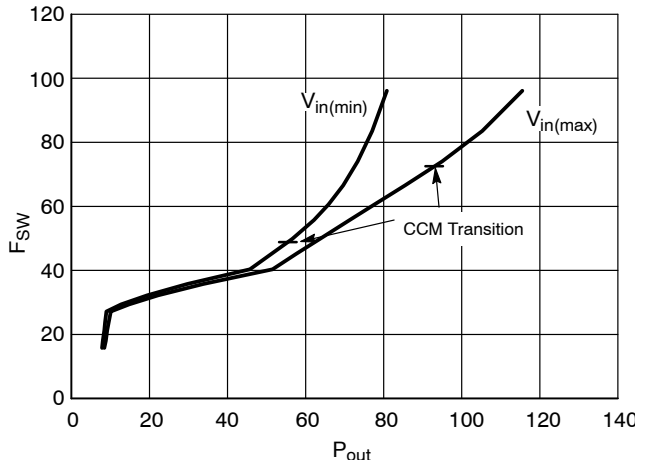
**Table 3. START-UP TIME**

| $V_{IN}$ ( $P_{OUT} = 40$ W) | 85 Vac | 230 Vac |
|------------------------------|--------|---------|
| Start-up Duration            | 2.7 s  | 0.5 s   |

In the above tables, we can see the excellent efficiency, especially at light load conditions thanks to the natural frequency foldback of the NCP1351.

The no-load standby power stays below 150 mW at high line, a good performance for a dual output power supply able to deliver 80 W. Please note that the high-voltage probe observing the drain was removed and the load totally disconnected to avoid leakage.

Despite operation in the audible range, we did not notice any noise problems coming from either the transformer or the RCD clamp capacitor.



**Figure 5. Switching Freq. Variations vs. Output Load**

# NCP1351PRINTGEVB

## Scope Shots

Below are some oscilloscope shots gathered on the evaluation board:

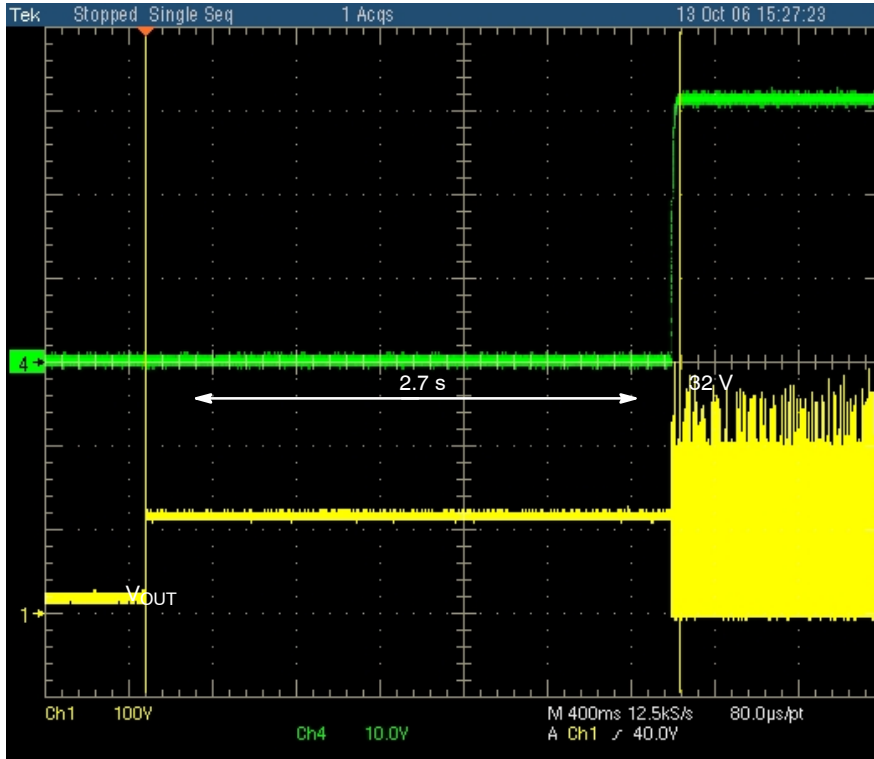


Figure 6. Start-up Time,  $V_{IN} = 85 \text{ Vac}$

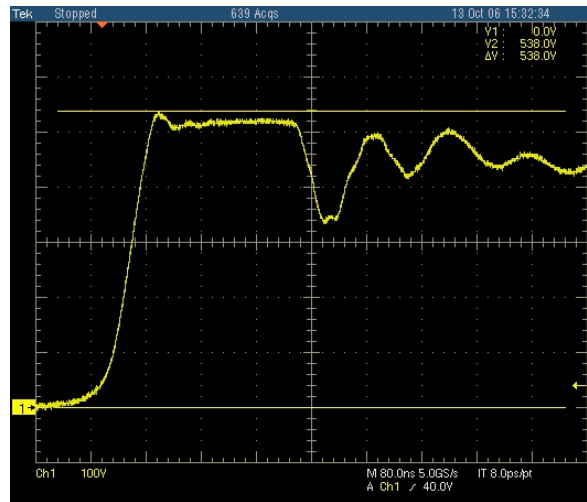
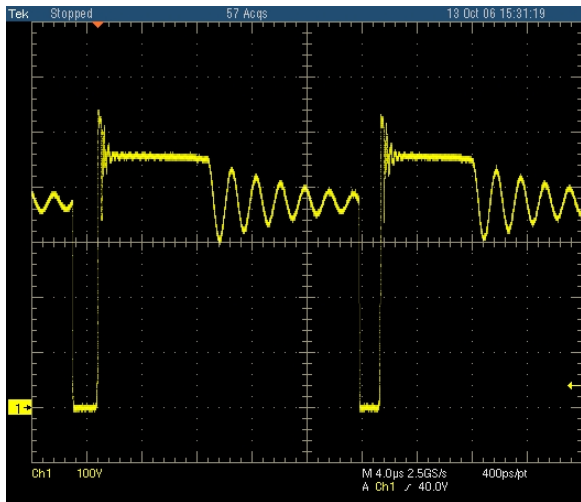


Figure 7. Maximum Output Power,  $V_{IN} = 265 \text{ Vac}$

## Conclusion

The printer power supply built with the NCP1351 exhibits an excellent performance on several parameters like the efficiency and the low-load standby. The transient switching frequency increase allows to deliver peak power during a limited time; but if the overpower lasts longer than the set fault timer, the controller safely latches off.

The limited number of surrounding components around the controller associated to useful features (timer-based protection, latch input...) makes the NCP1351 an excellent choice for cost-sensitive printer adapter designs.

# NCP1351PRINTGEVB

## PCB LAYOUT

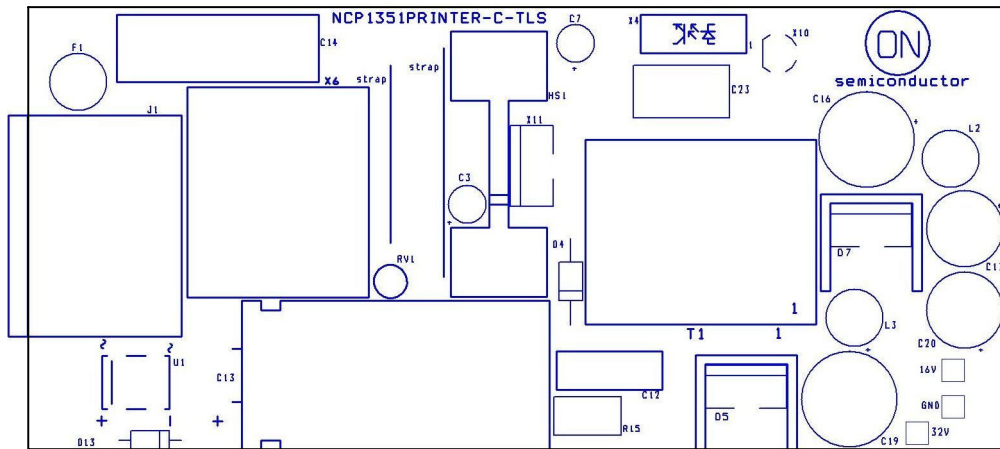


Figure 8. Top Side Components

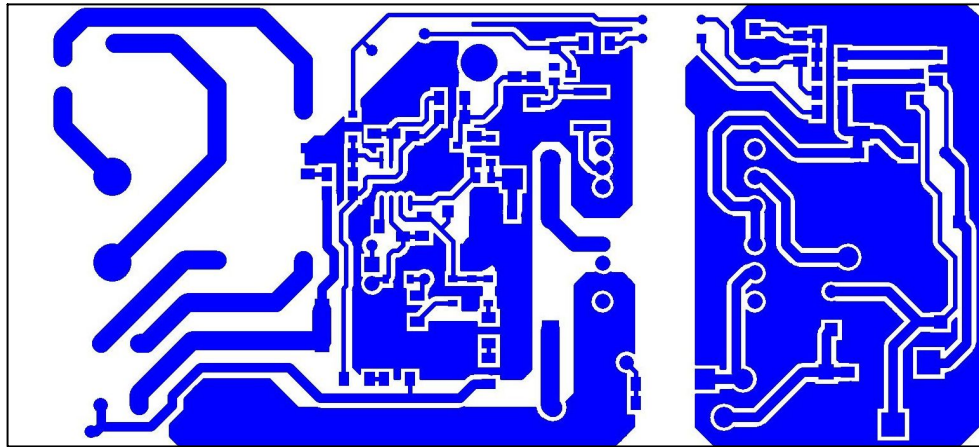


Figure 9. Copper Traces

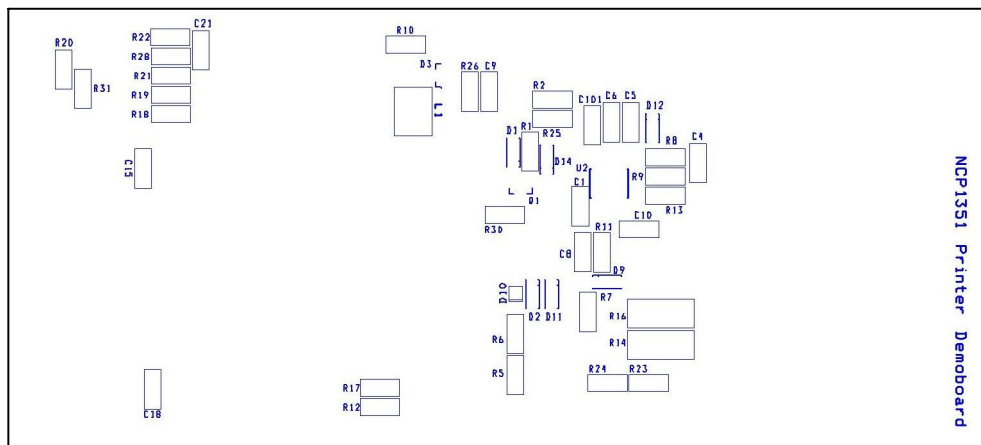
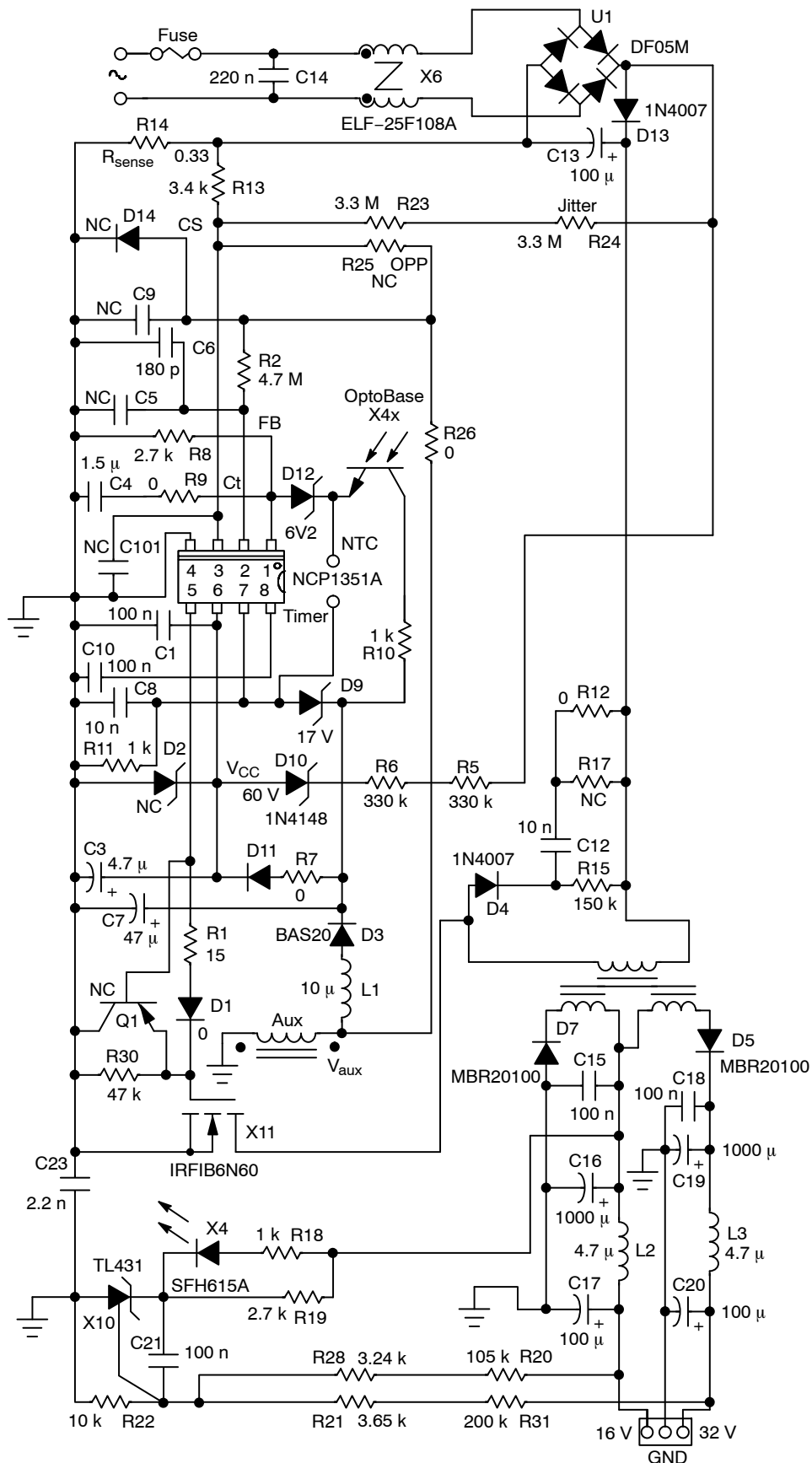


Figure 10. SMD Components

# NCP1351PRINTGEVB



**Figure 11. Schematic for the NCP1351 40 W Printer Evaluation Board**

# NCP1351PRINTGEVB

**Table 4. BILL OF MATERIAL FOR THE NCP1351 40 W PRINTER EVALUATION BOARD**

| Designator            | Qty. | Description                  | Value                | Tolerance | Footprint           | Manufacturer         | Manufacturer Part Number | Substitution Allowed | Lead Free |
|-----------------------|------|------------------------------|----------------------|-----------|---------------------|----------------------|--------------------------|----------------------|-----------|
| C1, C4, C15, C18, C21 | 5    | SMD Capacitor                | 100 nF/50 V          | 5%        | SOD-1206            | Vishay               | VJ1206Y104KXAA           | Yes                  | Yes       |
| C3                    | 1    | Electrolytic Capacitor       | 4.7 $\mu$ F/50 V     | 20%       | Radial – OD 5 mm    | Panasonic            | ECEA1HN100U              | Yes                  | Yes       |
| C6                    | 1    | SMD Capacitor                | 180 pF/50 V          | 5%        | SOD-1206            | Vishay               | VJ1206A181KXAA           | Yes                  | Yes       |
| C7                    | 1    | Electrolytic Capacitor       | 47 $\mu$ F/50 V      | 20%       | Radial – OD 5 mm    | Panasonic            | ECA1HM470                | Yes                  | Yes       |
| C8                    | 1    | SMD Capacitor                | 10 nF/50 V           | 5%        | SOD-1206            | Vishay               | VJ1206Y103KXAA           | Yes                  | Yes       |
| C10                   | 1    | SMD Capacitor                | 1.5 $\mu$ F          | 10%       | SOD-1206            | Murata               | GRM31MR71C155K           | Yes                  | Yes       |
| C12                   | 1    | Film Capacitor               | 10 nF/630 V          | 5%        | Radial              | Epcos                | B32521N8103J             | Yes                  | Yes       |
| C13                   | 1    | Electrolytic Capacitor       | 100 $\mu$ F/400 V    | 20%       | Radial – OD 20 mm   | United chemicon      | EKXG401ELL101MMN3S       | Yes                  | Yes       |
| C14                   | 1    | X2 Capacitor                 | 330 nF/250 Vac       | 20%       | Radial              | Epcos                | B32923A2334M             | Yes                  | Yes       |
| C16                   | 1    | Electrolytic Capacitor       | 1,000 $\mu$ F/50 V   | 20%       | Radial – OD 12.5 mm | Panasonic            | ECA1HHG102               | Yes                  | Yes       |
| C17                   | 1    | Electrolytic Capacitor       | 100 $\mu$ F/50 V     | 20%       | Radial – OD 10 mm   | Panasonic            | EEUEB1H101S              | Yes                  | Yes       |
| C19                   | 1    | Electrolytic Capacitor       | 1,000 $\mu$ F/25 V   | 20%       | Radial – OD 12.5 mm | Panasonic            | ECA1EHG102               | Yes                  | Yes       |
| C20                   | 1    | Electrolytic Capacitor       | 100 $\mu$ F/25 V     | 20%       | Radial – OD 10 mm   | Panasonic            | EEUEB1E101               | Yes                  | Yes       |
| C23                   | 1    | Y1 Capacitor                 | 2.2 nF/250 Vac       | 20%       | Radial              | TDK                  | CD12-E2GA222MYNS         | Yes                  | Yes       |
| D1                    | 1    | SMD Resistor                 | 0 $\Omega$ /0.25 W   | 5%        | SOD-1206            | Vishay               | CRCW12060000Z0EA         | Yes                  | Yes       |
| D3                    | 1    | High-voltage Switching Diode | 200 mA/200 V         | -         | SOT-23              | ON Semiconductor     | BAS20LT1G                | No                   | Yes       |
| D4                    | 1    | Fast-recovery Rectifier      | 1 A/600 V            | -         | Axial               | ON Semiconductor     | 1N4937G                  | No                   | Yes       |
| D5, D7                | 2    | Schottky Rectifier           | 20 A/100 V           | -         | TO-220              | ON Semiconductor     | MBR20100CTG              | No                   | Yes       |
| D9                    | 1    | Zener Diode                  | 17 V/0.5 W           | 5%        | SOD-123             | ON Semiconductor     | MMSZ5247BT1G             | No                   | Yes       |
| D10                   | 1    | Zener Diode                  | 60 V/0.5 W           | 5%        | SOD-123             | ON Semiconductor     | MMSZ5264BT1G             | No                   | Yes       |
| D11                   | 1    | Switching Diode              | 200 mA/75 V          | -         | SOD-123             | ON Semiconductor     | MMSD4148T1G              | No                   | Yes       |
| D12                   | 1    | Zener Diode                  | 6.2 V/0.5 W          | 5%        | SOD-123             | ON Semiconductor     | MMSZ5234BT1G             | No                   | Yes       |
| D13                   | 1    | Standard Rectifier           | 1 A/1,000 V          | -         | Axial               | ON Semiconductor     | 1N4007G                  | No                   | Yes       |
| HS1                   | 1    | Heatsink                     | 13.4°C/W             | -         | Radial              | Aavid Thermalloy     | 531002B02500G            | Yes                  | Yes       |
| HS2, HS3              | 2    | TO-220 Heatsink              | 24°C/W               | -         | -                   | Aavid Thermalloy     | 577202B00000G            | Yes                  | Yes       |
| U1                    | 1    | Rectifier Bridge             | 1 A/600 V            | -         | DIP-4               | Micro Commercial Co. | DB105-BP                 | No                   | Yes       |
| U2                    | 1    | CMOS IC                      | -                    | -         | SOIC-8              | ON Semiconductor     | NCP1351CDR2G             | No                   | Yes       |
| X4                    | 1    | Optocoupler                  | -                    | -         | DIP-4               | CEL-NEC              | PS2501-1-H-A             | No                   | Yes       |
| X6                    | 1    | Common-mode Choke            | 2 $\times$ 15 mH/1 A | -         | Radial              | Panasonic            | ELF-25F108A              | No                   | Yes       |
| X10                   | 1    | Shunt Regulator              | 2.5-36 V             | 5%        | TO-92               | ON Semiconductor     | TL431CLPG                | No                   | Yes       |
| X11                   | 1    | Power MOSFET N-Channel       | 3 A/600 V            | -         | TO-220              | Rohm                 | 2SK2792                  | No                   | Yes       |
| T1                    | 1    | Transformer                  | -                    | -         | Radial              | Coilcraft            | GA0007-AL                | No                   | Yes       |
| J1                    | 1    | Connector                    | 230 Vac              | -         | Radial              | Qualtek              | 771W-X2/02               | Yes                  | Yes       |
| F1                    | 1    | Fuse                         | 2 A/250 Vac          | T         | Radial              | Wickmann             | 37212000411              | Yes                  | Yes       |
| L1                    | 1    | SMD Inductor                 | 10 $\mu$ H           | -         | SMD                 | Coilcraft            | DO1605T-ML               | No                   | Yes       |
| L2, L3                | 2    | Inductor                     | 4.7 $\mu$ H/4.3 A    | 20%       | Radial              | API Delevan Inc.     | 4554-4R7M                | Yes                  | Yes       |
| R1                    | 1    | SMD Resistor                 | 15 $\Omega$ /0.25 W  | 5%        | SOD-1206            | Vishay               | CRCW120615R0JNEA         | Yes                  | Yes       |

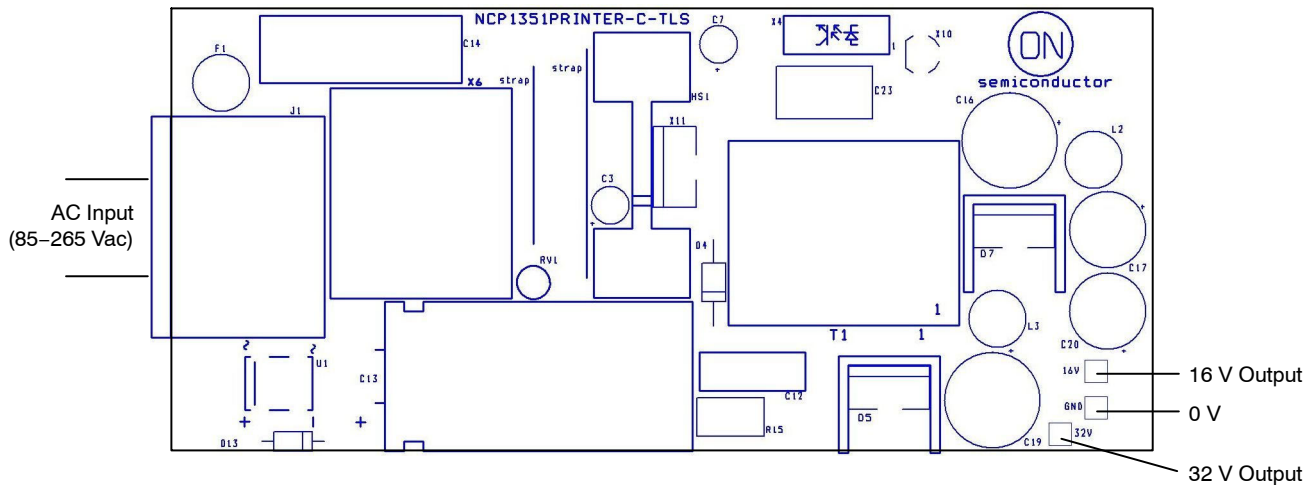


# NCP1351PRINTGEVB

**Table 4. BILL OF MATERIAL FOR THE NCP1351 40 W PRINTER EVALUATION BOARD** (continued)

| Designator    | Qty. | Description  | Value                  | Tolerance | Footprint | Manufacturer | Manufacturer Part Number | Substitution Allowed | Lead Free |
|---------------|------|--------------|------------------------|-----------|-----------|--------------|--------------------------|----------------------|-----------|
| R2            | 1    | Resistor     | 4.7 M $\Omega$ /0.33 W | 5%        | Axial     | -            | -                        | Yes                  | Yes       |
| R5, R6        | 2    | SMD Resistor | 330k $\Omega$ /0.25 W  | 1%        | SOD-1206  | Vishay       | CRCW1206330RFKEA         | Yes                  | Yes       |
| R7            | 1    | SMD Resistor | 0 $\Omega$ /0.25 W     | 5%        | SOD-1206  | Vishay       | CRCW1206000Z0EA          | Yes                  | Yes       |
| R8, R19       | 2    | SMD Resistor | 2.7 k $\Omega$ /0.25 W | 5%        | SOD-1206  | Vishay       | CRCW12062R70JNEA         | Yes                  | Yes       |
| R9, R12       | 2    | SMD Resistor | 0 $\Omega$ /0.25 W     | 5%        | SOD-1206  | Vishay       | CRCW1206000Z0EA          | Yes                  | Yes       |
| R10, R11, R18 | 3    | SMD Resistor | 1 k $\Omega$ /0.25 W   | 5%        | SOD-1206  | Vishay       | CRCW12061K00JNEA         | Yes                  | Yes       |
| R13           | 1    | SMD Resistor | 3.4 k $\Omega$ /0.25 W | 1%        | SOD-1206  | Vishay       | CRCW12063K40FKEA         | Yes                  | Yes       |
| R14           | 1    | SMD Resistor | 0.33 $\Omega$ /0.5 W   | 1%        | SOD-1206  | -            | -                        | Yes                  | Yes       |
| R15           | 1    | Resistor     | 150 k $\Omega$ /2 W    | 5%        | Axial     | -            | -                        | Yes                  | Yes       |
| R20           | 1    | SMD Resistor | 100 k $\Omega$ /0.25 W | 1%        | SOD-1206  | Vishay       | CRCW1206100KFKEA         | Yes                  | Yes       |
| R21           | 1    | SMD Resistor | 56 k $\Omega$ /0.25 W  | 1%        | SOD-1206  | Vishay       | CRCW120656K0FKEA         | Yes                  | Yes       |
| R22           | 1    | SMD Resistor | 10 k $\Omega$ /0.25 W  | 1%        | SOD-1206  | Vishay       | CRCW120610K0FKEA         | Yes                  | Yes       |
| R23, R24      | 2    | SMD Resistor | 3.3 M $\Omega$ /0.25 W | 5%        | SOD-1206  | Vishay       | CRCW12063M30JNEA         | Yes                  | Yes       |
| R26           | 1    | SMD Resistor | 0 $\Omega$ /0.25 W     | 1%        | SOD-1206  | Vishay       | CRCW12060000FKEA         | Yes                  | Yes       |
| R28           | 1    | SMD Resistor | 8.2 k $\Omega$ /0.25 W | 1%        | SOD-1206  | Vishay       | CRCW12068K20FKEA         | Yes                  | Yes       |
| R30           | 1    | SMD Resistor | 47 k $\Omega$ /0.25 W  | 1%        | SOD-1206  | Vishay       | CRCW120647K0FKEA         | Yes                  | Yes       |
| R31           | 1    | SMD Resistor | 180 k $\Omega$ /0.25 W | 1%        | SOD-1206  | Vishay       | CRCW1206180KFKEA         | Yes                  | Yes       |

## TEST PROCEDURE



**Figure 12. Test Procedure Schematic**

**WARNING:** Be careful when manipulating the boards in operation, lethal voltages up to 600 V are present on the primary side. An isolation transformer is also recommended for safer manipulations.

### Necessary Equipment

- 1 current limited 230 Vrms AC source (current limited to avoid board destruction in case of a defective part)
- 1 DC volt-meter able to measure up to 50 V DC
- 2 programmable electronic loads

### Test Procedure

1. Apply 110 Vac on the Vin pins. Output pins are left floating.
2. Measure the output voltage between pins +16 V et GND and between +32 V and GND with a volt-meter on the 50 V range. The measurements should be respectively 16 and 32 volts ( $\pm 10\%$ ).

## NCP1351PRINTGEVB

3. Connect an electronic load between pins +32 V and GND, and set up a current of 1 A. Connect another electronic load between pins +16 V and GND, and set up a current of 0.625 A. Measure the output voltages that should be respectively 16 and 32 volts ( $\pm 10\%$ ).
4. Change the voltage applied on the Vin pins to 230 Vac. Measure the output voltages that should again be respectively 16 and 32 volts ( $\pm 10\%$ ).
5. Change the current setpoint for the electronic load connected between pins +32 V and GND to 2.8 A.

The power supply should go to short-circuit protection. Measure the output voltages that should be 0 V.

6. Change the current setpoint for the electronic load connected between pins +32 V and GND back to 1 A. Turn off the AC voltage source. Wait 5 seconds. Apply it again, the outputs should rise again. Measure the output voltages that should again be respectively 16 and 32 volts ( $\pm 10\%$ ).
7. If every step has gone well, the board is considered to be ok.

**onsemi**, **Onsemi**, and other names, marks, and brands are registered and/or common law trademarks of Semiconductor Components Industries, LLC dba "**onsemi**" or its affiliates and/or subsidiaries in the United States and/or other countries. **onsemi** owns the rights to a number of patents, trademarks, copyrights, trade secrets, and other intellectual property. A listing of **onsemi**'s product/patent coverage may be accessed at [www.onsemi.com/site/pdf/Patent-Marking.pdf](http://www.onsemi.com/site/pdf/Patent-Marking.pdf). **onsemi** is an Equal Opportunity/Affirmative Action Employer. This literature is subject to all applicable copyright laws and is not for resale in any manner.

The evaluation board/kit (research and development board/kit) (hereinafter the "board") is not a finished product and is not available for sale to consumers. The board is only intended for research, development, demonstration and evaluation purposes and will only be used in laboratory/development areas by persons with an engineering/technical training and familiar with the risks associated with handling electrical/mechanical components, systems and subsystems. This person assumes full responsibility/liability for proper and safe handling. Any other use, resale or redistribution for any other purpose is strictly prohibited.

**THE BOARD IS PROVIDED BY ONSEMI TO YOU "AS IS" AND WITHOUT ANY REPRESENTATIONS OR WARRANTIES WHATSOEVER. WITHOUT LIMITING THE FOREGOING, ONSEMI (AND ITS LICENSORS/SUPPLIERS) HEREBY DISCLAIMS ANY AND ALL REPRESENTATIONS AND WARRANTIES IN RELATION TO THE BOARD, ANY MODIFICATIONS, OR THIS AGREEMENT, WHETHER EXPRESS, IMPLIED, STATUTORY OR OTHERWISE, INCLUDING WITHOUT LIMITATION ANY AND ALL REPRESENTATIONS AND WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, TITLE, NON-INFRINGEMENT, AND THOSE ARISING FROM A COURSE OF DEALING, TRADE USAGE, TRADE CUSTOM OR TRADE PRACTICE.**

**onsemi** reserves the right to make changes without further notice to any board.

You are responsible for determining whether the board will be suitable for your intended use or application or will achieve your intended results. Prior to using or distributing any systems that have been evaluated, designed or tested using the board, you agree to test and validate your design to confirm the functionality for your application. Any technical, applications or design information or advice, quality characterization, reliability data or other services provided by **onsemi** shall not constitute any representation or warranty by **onsemi**, and no additional obligations or liabilities shall arise from **onsemi** having provided such information or services.

**onsemi** products including the boards are not designed, intended, or authorized for use in life support systems, or any FDA Class 3 medical devices or medical devices with a similar or equivalent classification in a foreign jurisdiction, or any devices intended for implantation in the human body. You agree to indemnify, defend and hold harmless **onsemi**, its directors, officers, employees, representatives, agents, subsidiaries, affiliates, distributors, and assigns, against any and all liabilities, losses, costs, damages, judgments, and expenses, arising out of any claim, demand, investigation, lawsuit, regulatory action or cause of action arising out of or associated with any unauthorized use, even if such claim alleges that **onsemi** was negligent regarding the design or manufacture of any products and/or the board.

This evaluation board/kit does not fall within the scope of the European Union directives regarding electromagnetic compatibility, restricted substances (RoHS), recycling (WEEE), FCC, CE or UL, and may not meet the technical requirements of these or other related directives.

FCC WARNING – This evaluation board/kit is intended for use for engineering development, demonstration, or evaluation purposes only and is not considered by **onsemi** to be a finished end product fit for general consumer use. It may generate, use, or radiate radio frequency energy and has not been tested for compliance with the limits of computing devices pursuant to part 15 of FCC rules, which are designed to provide reasonable protection against radio frequency interference. Operation of this equipment may cause interference with radio communications, in which case the user shall be responsible, at its expense, to take whatever measures may be required to correct this interference.

**onsemi** does not convey any license under its patent rights nor the rights of others.

LIMITATIONS OF LIABILITY: **onsemi** shall not be liable for any special, consequential, incidental, indirect or punitive damages, including, but not limited to the costs of requalification, delay, loss of profits or goodwill, arising out of or in connection with the board, even if **onsemi** is advised of the possibility of such damages. In no event shall **onsemi**'s aggregate liability from any obligation arising out of or in connection with the board, under any theory of liability, exceed the purchase price paid for the board, if any.

The board is provided to you subject to the license and other terms per **onsemi**'s standard terms and conditions of sale. For more information and documentation, please visit [www.onsemi.com](http://www.onsemi.com).

## ADDITIONAL INFORMATION

### TECHNICAL PUBLICATIONS:

Technical Library: [www.onsemi.com/design/resources/technical-documentation](http://www.onsemi.com/design/resources/technical-documentation)  
onsemi Website: [www.onsemi.com](http://www.onsemi.com)

ONLINE SUPPORT: [www.onsemi.com/support](http://www.onsemi.com/support)

For additional information, please contact your local Sales Representative at [www.onsemi.com/support/sales](http://www.onsemi.com/support/sales)