Reference Design RD-345

Fairchild Motion-SPM® FNA41560 – One-Shunt Design

The following reference design supports design of FNA41560. It should be used in conjunction with the FNA41560 datasheet as well as Fairchild’s application notes (AN-9070, AN-9071, AN-9072) and technical support team. Please visit Fairchild’s website at http://www.fairchildsemi.com.

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<td>300–400V&lt;sub&gt;DC&lt;/sub&gt;</td>
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<td>One Shunt Solution (Single Ground)</td>
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Key Features

**FNA41560**
- 600V-15A 3-phase IGBT inverter bridge including control ICs for gate driving and protection
- Easy PCB layout due to built-in bootstrap diode and independent V<sub>S</sub> pin
- Divided negative DC-link terminals for inverter current-sensing applications
- Single-grounded power supply due to built-in HVIC
- Built-in NTC thermistor for over-temperature monitoring
- Isolation rating of 2000V<sub>rms</sub>/min.

**1N4749A**
- Silicon planar power Zener diodes, DO-41 glass case
- 24V/1.0W rating Zener diode
- For use in stabilizing and clipping circuits with high power rating
- Standard Zener voltage tolerance: ±5%
1. Schematics

Figure 1. Block Diagram of Air Conditioner
Figure 2. Reference Design for 3-Phase Inverter
2. Key Parameter Design

2.1. Selection of Bootstrap Capacitance (C_{BS})

The bootstrap Capacitor can be calculated by:

\[ C_{BS} = R \frac{I_{Leak} \times \Delta t}{\Delta V_{BS}} \]  

(1)

where:

\( \Delta t \) = maximum on pulsewidth of high-side IGBT;
\( \Delta V_{BS} \) = the allowable discharge voltage of the \( C_{BS} \) (voltage ripple); and
\( I_{Leak} \) = maximum discharge current of the \( C_{BS} \).

Normally, \( I_{Leak} \) consists of the following items:
- Gate charge for turning the high-side IGBT on
- Quiescent current to the high-side circuit in the HVIC
- Level-shift charge required by level-shifters in HVIC
- Leakage current in the bootstrap diode
- \( C_{BS} \) capacitor leakage current (ignored for non-electrolytic capacitors)
- Bootstrap diode reverse recovery charge

Practically, 2mA of \( I_{Leak} \) is recommended for \( \mu \)Mini DIP SPM family in Motion-SPM\textsuperscript{®} products. (\( I_{PBS} \) (operating \( V_{BS} \) supply current) value in datasheet)

**Calculation Examples of \( C_{BS} \)**

\[ I_{Leak} = \text{circuit current (I_{PBS})} = 2mA \text{ (recommendation value)} \]
\[ \Delta V_{BS} = \text{discharged voltage} = 0.1V \text{ (recommendation value)} \]
\[ \Delta t = \text{maximum on pulse width of high-side IGBT} = 2ms \text{ (depends on system)} \]

\[ C_{BS.min} = \frac{I_{Leak} \times \Delta t}{\Delta V_{BS}} = \frac{2mA \times 0.2ms}{0.1V} = 4.0 \times 10^{-6} \]

\( \Rightarrow \) More than 2~3times \( \rightarrow 8\mu F \rightarrow \) standard nominal capacitance 10\( \mu \)F

2.2. Selection of Shunt Resistor

The value of shunt resistor is calculated by the following equations.

Maximum SC (Short Circuit) current trip level

\[ I_{SC(max)} = 1.5 \times I_c \text{ (rated current)} \]  

(3)

SC trip reference voltage

\[ V_{SC} = \text{min.0.45V, typ.0.5V, max.0.55V (from datasheet)} \]  

(4)
Shunt resistance:

\[
I_{SC(max)} = \frac{V_{SC(max)}}{R_{SHUNT(min)}} \rightarrow R_{SHUNT(min)} = \frac{V_{SC(max)}}{I_{SC(max)}} \\
(5)
\]

If the deviation of shunt resistor is limited below ±5%:

\[
R_{SHUNT(typ)} = \frac{R_{SHUNT(min)}}{0.95}, \quad R_{SHUNT(max)} = R_{SHUNT(typ)} \times 1.05
\]

And the actual SC trip current level becomes:

\[
I_{SC(typ)} = \frac{V_{SC(typ)}}{R_{SHUNT(typ)}}, \quad I_{SC(min)} = \frac{V_{SC(min)}}{R_{SHUNT(max)}}, \quad I_{SC(min)} = \frac{V_{SC(min)}}{R_{SHUNT(max)}}
\]

The power rating of shunt resistor is calculated by the following equation:

\[
P_{SHUNT} = \frac{I_{rms}^2 \times R_{SHUNT} \times \text{Margin}}{\text{Derating Ratio}}
\]

- Maximum load current of inverter \((I_{rms})\)
- Shunt resistor typical value at \(T_c=25^\circ C\) \((R_{SHUNT})\)
- Derating ratio of shunt resistor at \(T_{SHUNT}=100^\circ C\)
- (from datasheet of shunt resistor)
- Safety margin (determined by customer)

### 2.3. Shunt Resistor Calculation Examples

#### Calculation Conditions

- **DUT**: FNA41560, tolerance of \(R_{SHUNT}: ±5\%\),
- **SC trip reference voltage**: \(V_{SC(min)}=0.45V, V_{SC(typ)}=0.50V, V_{SC(max)}=0.55V\)
- **\(I_{SC(max)}\)**: \(1.5 \times I_C = 1.5 \times 15 = 22.5A\)
- **\(R_{SHUNT(min)}\)**: \(V_{SC(max)} / I_{SC(max)} = 0.55V / 22.5A = 24.4m\Omega\)
- **\(R_{SHUNT(typ)}\)**: \(R_{SHUNT(min)} / 0.95 = 24.4m\Omega / 0.95 = 25.7m\Omega\)
- **\(R_{SHUNT(max)}\)**: \(R_{SHUNT(typ)} \times 1.05 = 25.7m\Omega \times 1.05 = 27.0m\Omega\)
- **\(I_{SC(min)}\)**: \(V_{SC(min)} / R_{SHUNT(max)} = 0.45V / 27.0m\Omega = 16.66A\)
- **\(I_{SC(typ)}\)**: \(V_{SC(typ)} / R_{SHUNT(typ)} = 0.50V / 25.7m\Omega = 19.43A\)

### 2.4. Power Rating of Shunt Resistor Calculation Example

#### Calculation Conditions

- Maximum load current of inverter \((I_{rms})\): \(5A_{rms}\)
- Shunt resistor value at \(T_c=25^\circ C\) \((R_{SHUNT})\): \(24.8m\Omega\)
- Derating ratio of shunt resistor at \(T_{SHUNT}=100^\circ C\): 70%
- Safety margin: 20%
- \(P_{SHUNT} = \frac{I_{rms}^2 \times R_{SHUNT} \times \text{Margin}}{\text{Derating ratio}} = (5^2 \times 0.0248 \times 1.2) / 0.7 = 1.1W\)
  (Therefore, the proper power rating of shunt resistor is over 2.0W)
2.5. Temperature Monitoring Circuit

Figure 3 is R-T curve of the integrated NTC thermistor in μMini DIP SPM® package. For R-T table of NTC thermistor, refer to application note μMini DIP SPM® (AN-9070).

![R-T Curve]

Figure 3. R-T Curve of NTC Thermistor in μMini DIP SPM® Package

Figure 4 is example of a temperature-sensing circuit by NTC thermistor. In this reference design, $R_{TH}$ is 6.8kΩ and Figure 5 is V-T curve at $R_{TH}=6.8kΩ$, $V_{CC}=3.3V$ or 5.0V.

![Temperature-Sensing Circuit by NTC Thermistor]

Figure 4. Temperature-Sensing Circuit by NTC Thermistor
Figure 5. V-T Curve of Temperature-Sensing Circuit in Reference Design
2.6. Print Circuit Board (PCB) Layout Guidance

Figure 6. PCB Layout Guidance

- Power GND Copper
- Main Electrolytic capacitor
- Snubber capacitor
- Connect to Motor
- Power Source Copper

- Wiring between N, N, N and shunt resistor should be as short as possible.
- It is recommended to connect control GND and Power GND at only one point. (Not copper pattern and don't make a loop in GND pattern.) And this wiring should be as short as possible.
- Connecting Cc filter's capacitor to control GND is not to Power GND.
- The Vcc RC filter should be placed to SPM as close as possible.
- The capacitor between Vcc and COM should be placed to SPM as close as possible.
- The Vcc RC filter should be placed to SPM as close as possible.
- The isolation distance between high voltage block and low voltage block should be kept.
- The capacitor and Zener diode should be located close to terminals.

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3. Related Resources

FNA41560 – Smart Power Module Motion-SPM®

AN-9070 – Smart Power Module Motion-SPM® in μMini DIP SPM® User Guide

AN-9071 – Smart Power Module Motion-SPM® in μMini DIP SPM® Thermal Performance Information

AN-9072-Smart Power Module Motion-SPM® in Mini DIP SPM® Mounting Guidance

http://www.fairchildsemi.com/referencedesign/

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