

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>.

Application	Fairchild Device	Input Voltage Range	Typical Power Rating	Topology
Home Appliance (Air-Conditioner)	FNA41560 1N4749A	300~400V _{DC}	1500W	One Shunt Solution (Single Ground)

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_S 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_{rms}/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%

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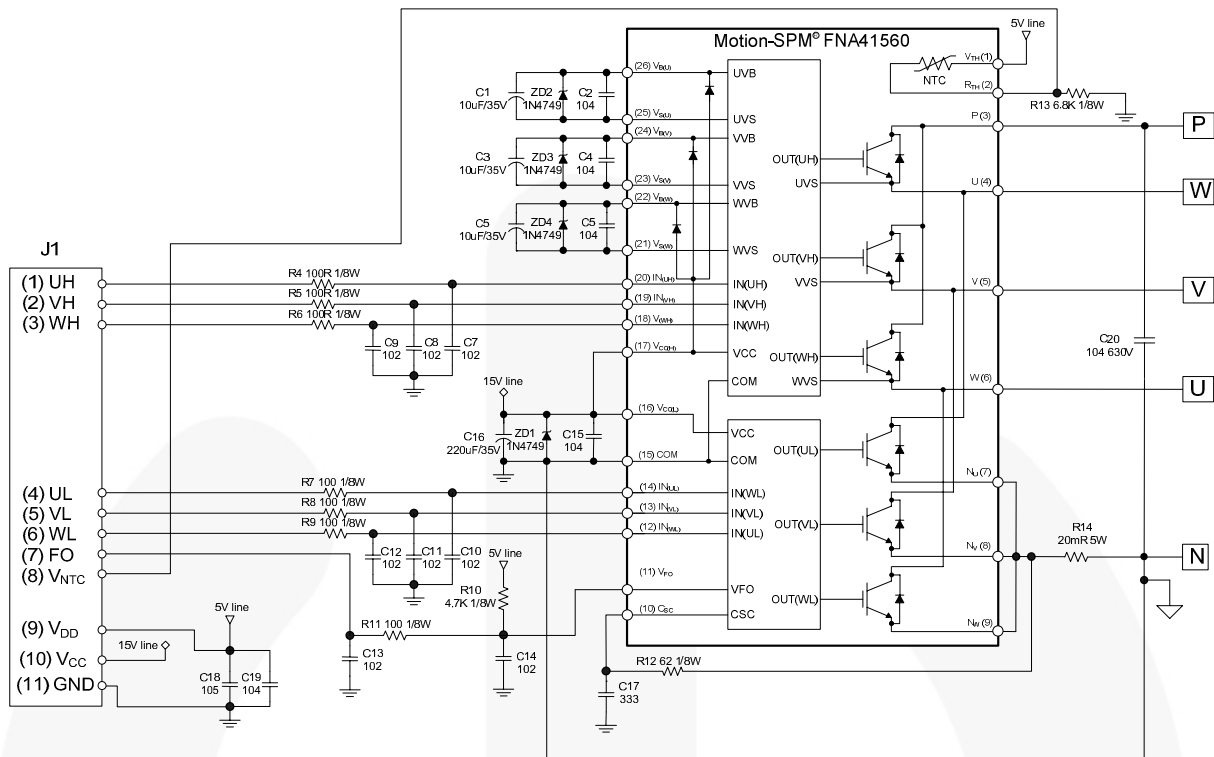


Figure 2. Reference Design for 3-Phase Inverter

2. Key Parameter Design

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

The bootstrap Capacitor can be calculated by:

$$C_{BS} = R \frac{I_{Leak} \times \Delta t}{\Delta V_{BS}} \quad (1)$$

where:

Δt = maximum on pulswidth of high-side IGBT;

ΔV_{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 μ Mini DIP SPM family in Motion-SPM® products. (I_{PBS} (operating V_{BS} supply current) value in datasheet)

Calculation Examples of C_{BS}

I_{Leak} = circuit current (I_{PBS}) = 2mA (recommendation value)

ΔV_{BS} = discharged voltage = 0.1V (recommendation value)

Δt = maximum on pulse width of high-side IGBT = 2ms (depends on system)

$$C_{BS_min} = \frac{I_{Leak} \times \Delta t}{\Delta V_{BS}} = \frac{2mA \times 0.2ms}{0.1V} = 4.0 \times 10^{-6} \quad (2)$$

→ More than 2~3times → 8 μ F → standard nominal capacitance 10 μ 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

$$I_{SC(max)} = 1.5 \times I_C \text{ (rated current)} \quad (3)$$

SC trip reference voltage

$$V_{SC} = \text{min.0.45V, typ.0.5V, max.0.55V (from datasheet)} \quad (4)$$

Shunt resistance:

$$I_{SC(max)} = V_{SC(max)} / R_{SHUNT(min)} \rightarrow R_{SHUNT(min)} = V_{SC(max)} / I_{SC(max)} \quad (5)$$

If the deviation of shunt resistor is limited below $\pm 5\%$:

$$R_{SHUNT(typ)} = R_{SHUNT(min)} / 0.95, R_{SHUNT(max)} = R_{SHUNT(typ)} \times 1.05 \quad (6)$$

And the actual SC trip current level becomes:

$$I_{SC(typ)} = V_{SC(typ)} / R_{SHUNT(typ)}, I_{SC(min)} = V_{SC(min)} / R_{SHUNT(max)} \quad (7)$$

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

$$P_{SHUNT} = (I_{rms}^2 \times R_{SHUNT} \times \text{Margin}) / \text{Derating Ratio} \quad (8)$$

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

2.3. Shunt Resistor Calculation Examples

Calculation Conditions

- DUT: FNA41560, tolerance of R_{SHUNT} : $\pm 5\%$,
- SC trip reference voltage: $V_{SC(min)}=0.45\text{V}$, $V_{SC(typ)}=0.50\text{V}$, $V_{SC(max)}=0.55\text{V}$
- $I_{SC(max)}$: $1.5 \times I_C = 1.5 \times 15 = 22.5\text{A}$
- $R_{SHUNT(min)}$: $V_{SC(max)} / I_{SC(max)} = 0.55\text{V} / 22.5\text{A} = 24.4\text{m}\Omega$
- $R_{SHUNT(typ)}$: $R_{SHUNT(min)} / 0.95 = 24.4\text{m}\Omega / 0.95 = 25.7\text{m}\Omega$
- $R_{SHUNT(max)}$: $R_{SHUNT(typ)} \times 1.05 = 25.7\text{m}\Omega \times 1.05 = 27.0\text{m}\Omega$
- $I_{SC(min)}$: $V_{SC(min)} / R_{SHUNT(max)} = 0.45\text{V} / 27.0\text{m}\Omega = 16.66\text{A}$
- $I_{SC(typ)}$: $V_{SC(typ)} / R_{SHUNT(typ)} = 0.5\text{V} / 25.7\text{m}\Omega = 19.43\text{A}$

2.4. Power Rating of Shunt Resistor Calculation Example

Calculation Conditions

- Maximum load current of inverter (I_{rms}): $5A_{rms}$
- Shunt resistor value at $T_C=25^\circ\text{C}$ (R_{SHUNT}): $24.8\text{m}\Omega$
- Derating ratio of shunt resistor at $T_{SHUNT}=100^\circ\text{C}$: 70%
- Safety margin: 20%
- $P_{SHUNT} = (I_{rms}^2 \times R_{SHUNT} \times \text{Margin}) / \text{Derating ratio} = (5^2 \times 0.0248 \times 1.2) / 0.7 = 1.1\text{W}$
(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 μ Mini DIP SPM® package. For R-T table of NTC thermistor, refer to application note μ Mini DIP SPM® (AN-9070).

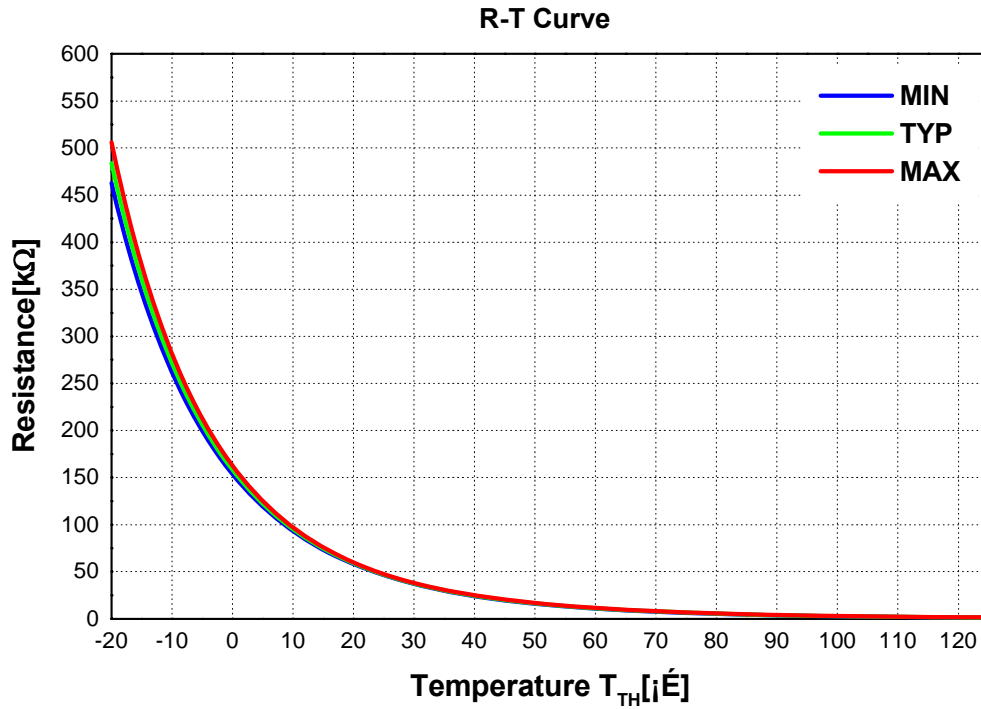


Figure 3. R-T Curve of NTC Thermistor in μ Mini DIP SPM® Package

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

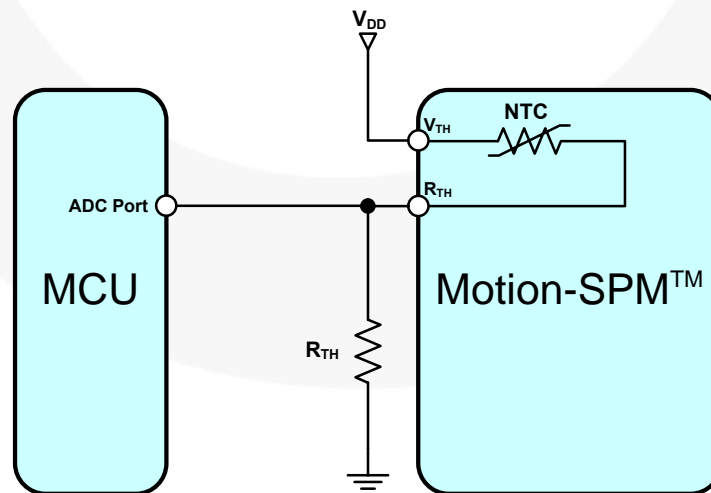


Figure 4. Temperature-Sensing Circuit by NTC Thermistor

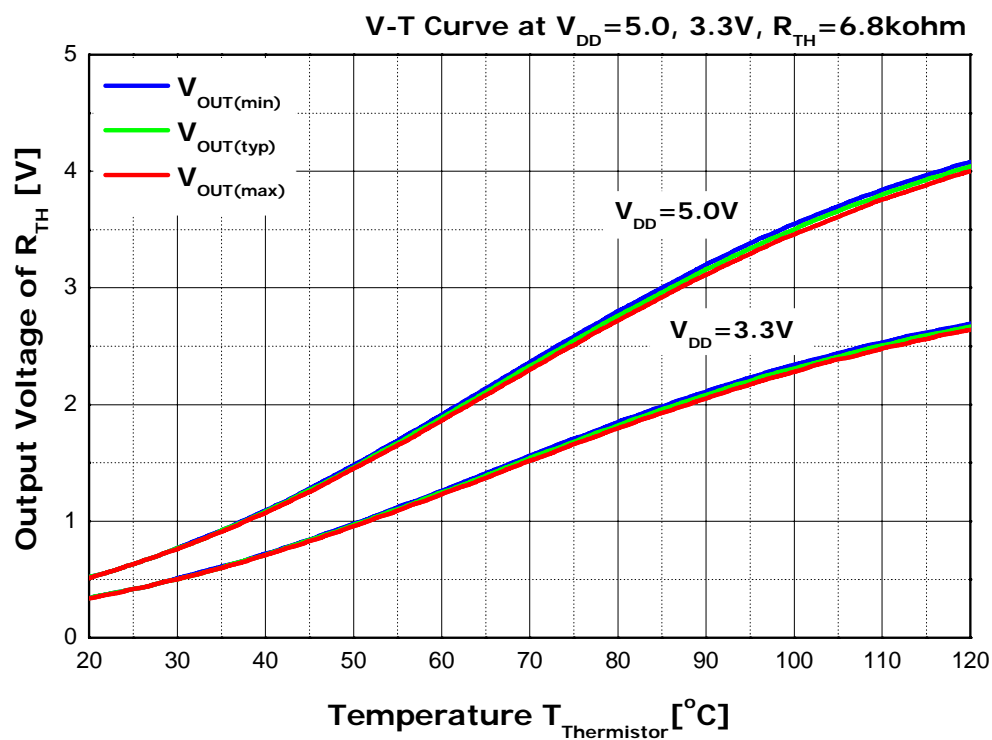


Figure 5. V-T Curve of Temperature-Sensing Circuit in Reference Design

3. Related Resources

[*FNA41560 – Smart Power Module Motion-SPM®*](#)

[*AN-9070 – Smart Power Module Motion-SPM® in \$\mu\$ Mini DIP SPM® User Guide*](#)

[*AN-9071 – Smart Power Module Motion-SPM® in \$\mu\$ Mini DIP SPM® Thermal Performance Information*](#)

[*AN-9072-Smart Power Module Motion-SPM® in Mini DIP SPM® Mounting Guidance*](#)

[*http://www.fairchildsemi.com/referencedesign/*](http://www.fairchildsemi.com/referencedesign/)

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