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%

1. Schematics

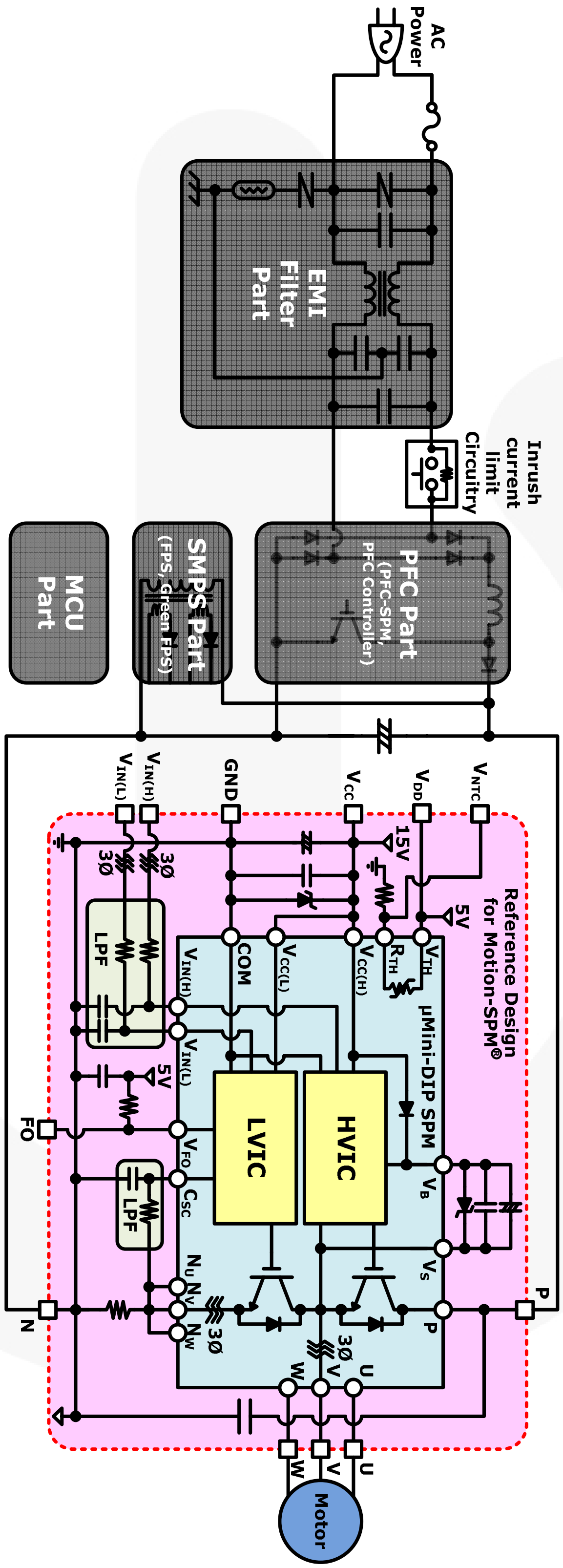

Figure 1. Block Diagram of Air Conditioner

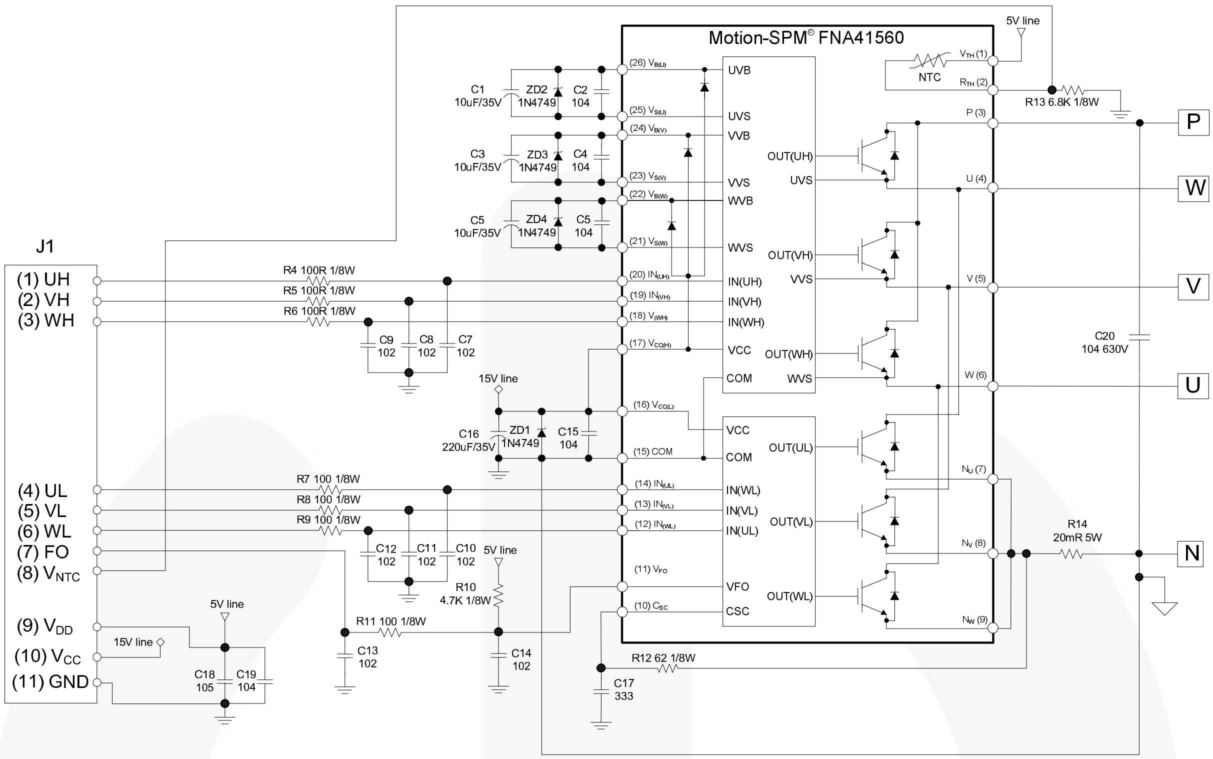

Figure 2. Reference Design for 3-Phase Inverter

2. Key Parameter Design

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

The bootstrap Capacitor can be calculated by:

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

where:
Δt = maximum on pulsewidth 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 μMini 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 → 8μF → standard nominal capacitance 10μF

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 x I_C (rated current) (3)

SC trip reference voltage

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

Shunt resistance:

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

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

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

And the actual SC trip current level becomes:

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

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

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

- Maximum load current of inverter (I_{rms})
- Shunt resistor typical value at T_C=25°C (R_{SHUNT})
- Derating ratio of shunt resistor at T_{SHUNT}=100°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 x I_C = 1.5 x 15 = 22.5A
- $R_{SHUNT(min)}$: $V_{SC(max)}$ / $I_{SC(max)}$ = 0.55V / 22.5A = 24.4mΩ
- $R_{SHUNT(typ)}$: $R_{SHUNT(min)}$ / 0.95 = 24.4mΩ / 0.95 = 25.7mΩ
- $R_{SHUNT(max)}$: $R_{SHUNT(typ)}$ x 1.05 = 25.7mΩ x 1.05 = 27.0mΩ
- $I_{SC(min)}$: $V_{SC(min)}$ / $R_{SHUNT(max)}$ = 0.45V / 27.0mΩ = 16.66A
- $I_{SC(typ)}$: $V_{SC(typ)}$ / $R_{SHUNT(typ)}$ = 0.5V / 25.7mΩ = 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°C ($_{RSHUNT}$): 24.8mΩ
- Derating ratio of shunt resistor at T_{SHUNT}=100°C: 70%
- Safety margin: 20%
- P_{SHUNT} (I^2_{rms} x R_{SHUNT} x Margin) / Derating ratio)=(5^2 x 0.0248 x 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).*

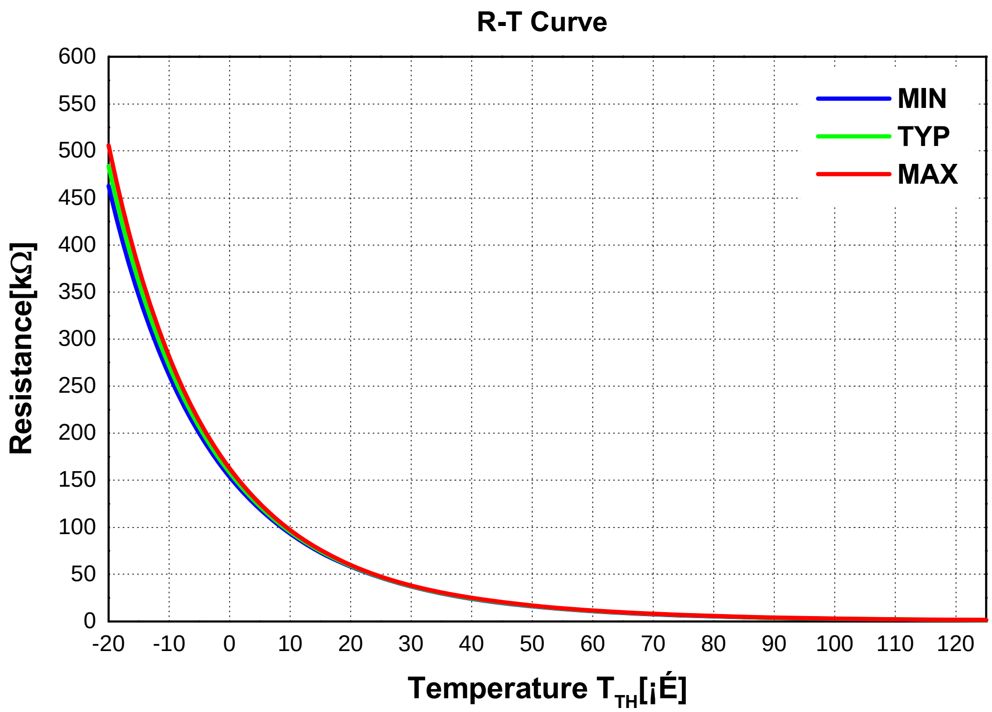

Figure 3. R-T Curve of NTC Thermistor in μMini DIP SPM® Package

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.

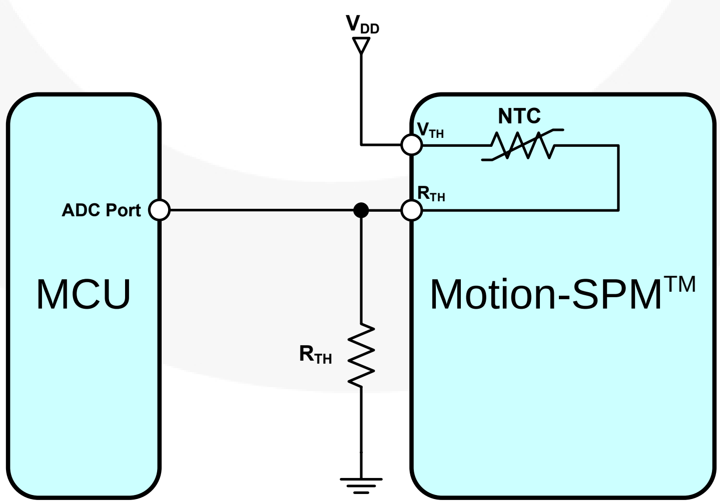

Figure 4. Temperature-Sensing Circuit by NTC Thermistor

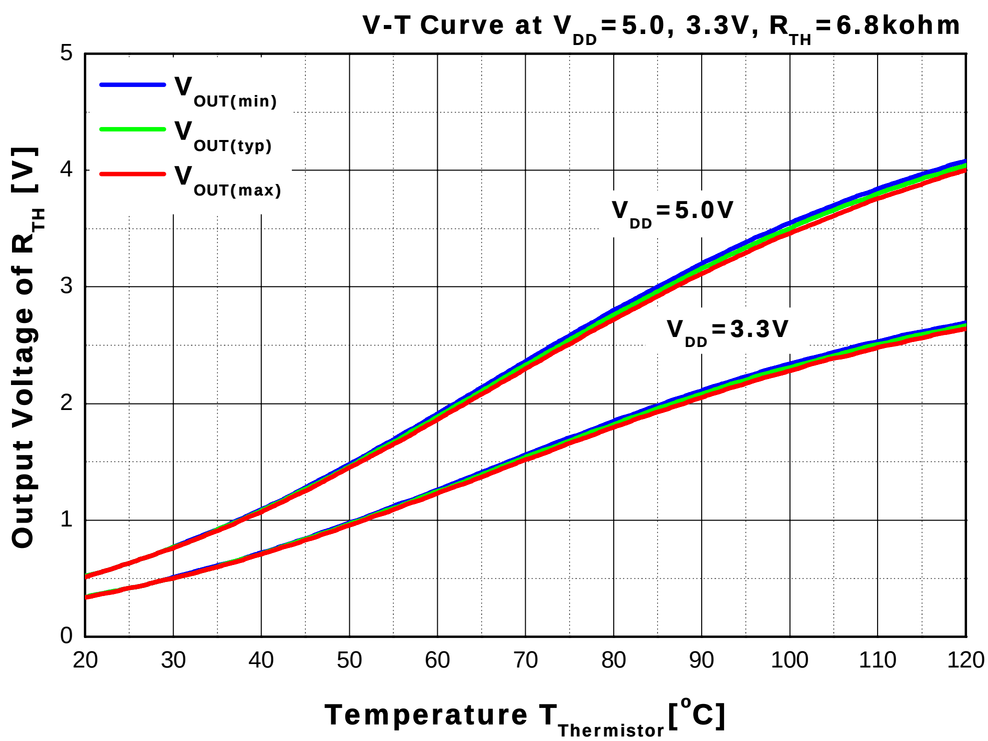

Figure 5. V-T Curve of Temperature-Sensing Circuit in Reference Design

2.6. Print Circuit Board(PCB) Layout Guidance

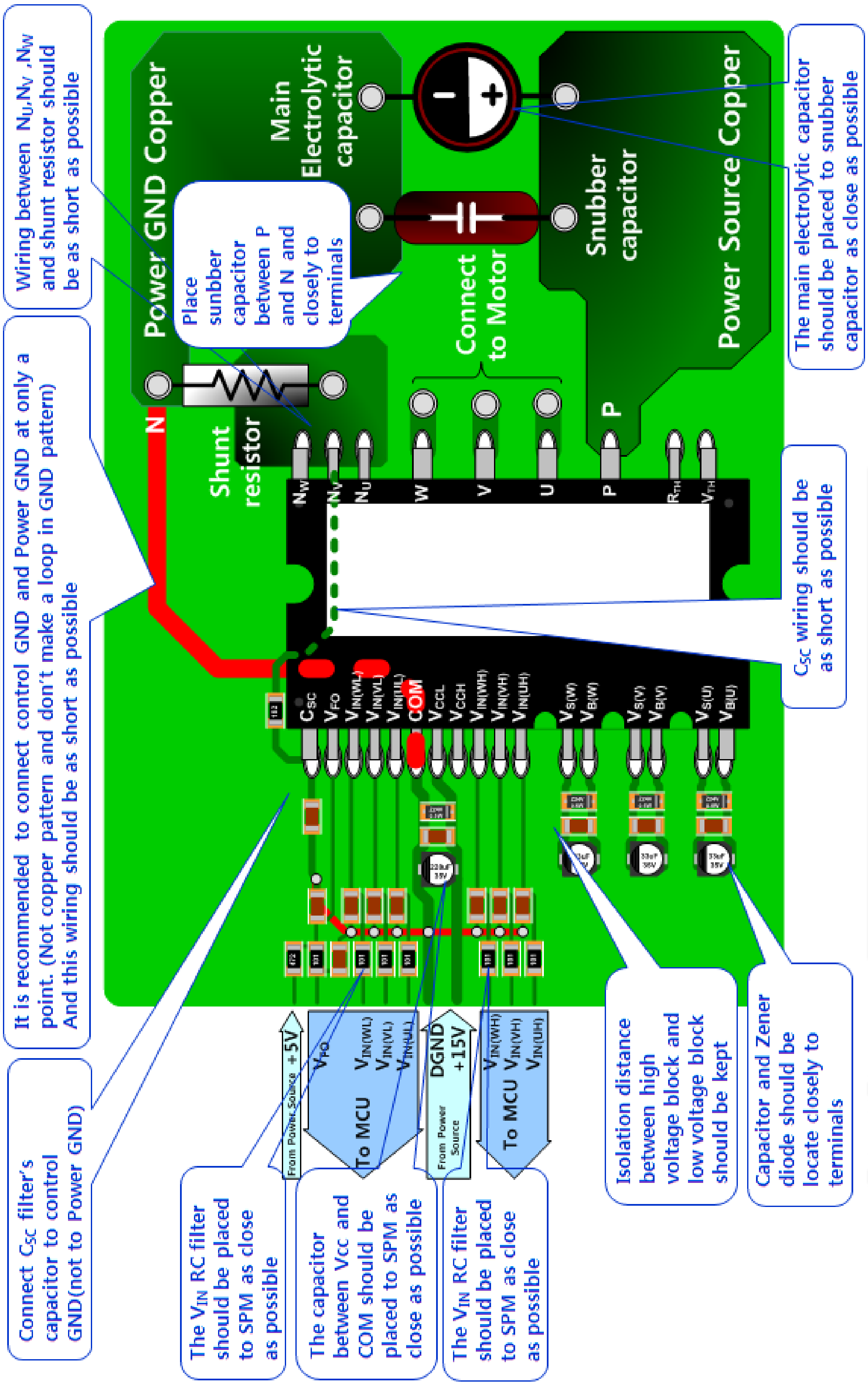

Figure 6. PCB Layout Guidance

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/