Non-isolated Switching Regulators Application Guide 2020

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1. Selection Guide

Non-isolated switching regulators are mainly divided into fixed voltage output type and POL type:

Fixed voltage output K78 series: it is fully compatible with traditional 78XX series and applications; with the output current range of 0.5~2A, low static power consumption, high output voltage accuracy, and efficiency up to 96%, this series is the upgraded traditional linear regulators product.

POL power supply: (Point-Of-Load) is load power which provides low-voltage, high-current, and fast transient response for high-speed chips such as DSP, FPGA, and ASIC.

In terms of product selection, you can choose according to the following process:

The steps are shown as below.

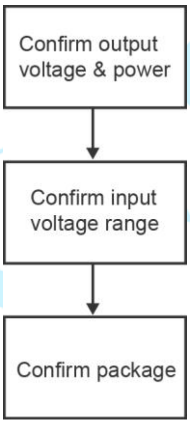

Diagram 1-1 Steps of selecting switching regulators

1) Steps of selecting traditional fixed voltage output products: (diagram 1-1)

■First, confirm output voltage and power.

Output voltage and output current come first when selecting a power supply. Non-isolated switching regulators have a full range of output voltages: 1.2V, 1.5V, 1.8V, 2.5V, 3.3V, 5V, 6.5V, 9V, 12V, 15V and 24V.

Regarding output power, the regulators are suffixed with rated output currents such as 500mA and 1000mA. At present, available output currents are 500mA, 1000mA, 1500mA, 2000mA and 10A.

After the actual working current of the load is calculated, rated output current can be determined once the load is confirmed. The load current determines power and affects the

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converter’s reliability and price. It is suggested that the converter is used in a load range of 30%-80% of its output power at ambient temperature. Choosing the correct output current is one of the key factors in successful design, incorrect selection may lead to lower reliability. Given that the converter has to be used at high temperature of over 70℃for a long time, please contact our sales department for more information.

■Second, confirm input voltage range.

MORNSUN’s non-isolated products are of step-down circuit design, so the input voltage should be greater than the output voltage. Common input ranges are 4.75-28V, 6.5-32V, 4.75-18V and 9-72V. The specific dropout voltage value can be checked in the datasheet.

■Third, confirm output voltage.

Output voltage needed is relatively different since the load is different. The common types of output voltage are: 1.2V, 1.5V, 1.8V, 3.3V, 5V, 9V, 12V, 15V, 24V, etc.

■Fourth, confirm package.

The regulators are mainly in DIP, SIP, SMD and chassis package, the first two types can be supplied with bent input pins for horizontal mount. In either form they are compatible with LM78XX linear regulators.

2) Steps of selecting POL:

■First, confirm the output current.

The output current of the non-isolated POL power supply is usually in three types of 6A, 10A and 16A.

■Second, select control logic.

POL power control logic is divided into two categories: positive logic (P) and negative logic (N).

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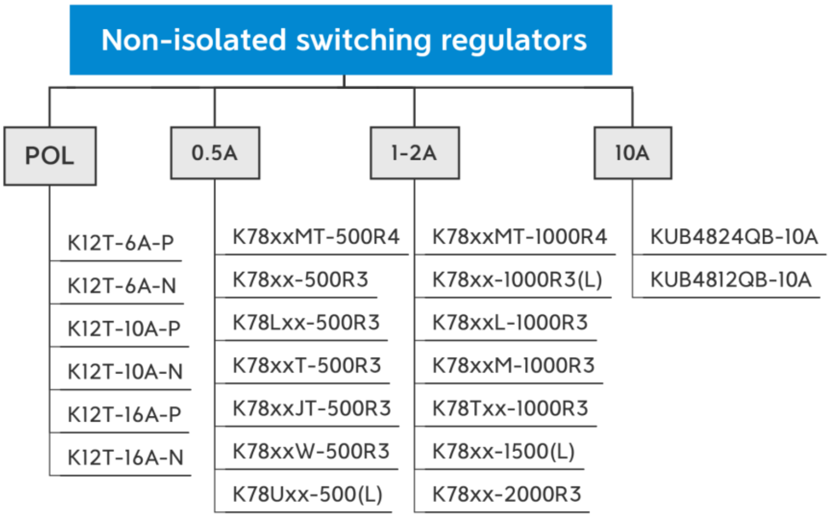

Diagram 1-2 Selection Block Diagram

2. Testing Suggestions

It is important that the switching regulators performance is tested and verified in the actual application to ensure that it is suitable. Common test methods include,

2.1. Test Circuit

Kelvin-style test method is a standard one as shown in diagram 2-1.

Test conditions: ambient temperature Ta=25℃, humidity <75%.

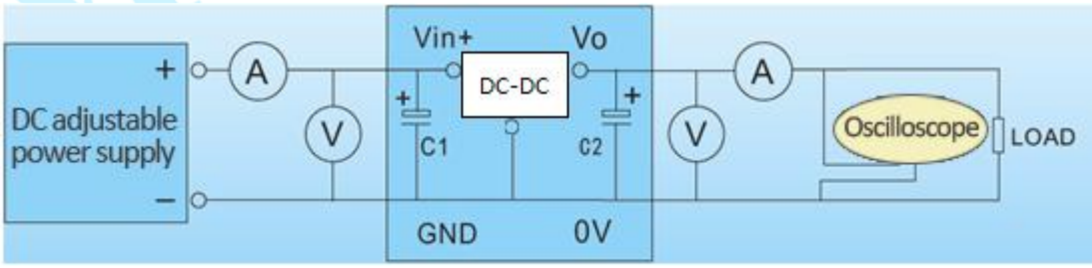

Diagram 2-1 Kelvin-style test method

Test instruments: DC adjustable regulated power supply (wide enough input voltage range), ammeter A (accuracy: 0.001A), voltmeter V (accuracy: 0.001V), electronic load, oscilloscope.

Notes:

1) Wire connection: the less wire loss, the better. A multi-strand copper wire with 1mm diameter is the best choice to avoid excessive voltage drop. When the load current is large

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shorten the distance between the output pins and the load and increase the cross-sectional area of the connecting wire to reduce the excessive voltage drop;

2) It is suggested to test the output by using contact measuring method with a single pole to prevent measurement errors. The contact measuring method helps reduce external interference and the single pole provides a common ground for the input and output; (See "ripple and noise")

3) To acquire an accurate voltage and ripple measurement the output capacitive should be within specification and the measurement should be may between 10%-100% of rated load;

4) For more details please refer to datasheet.

2.2. Testing Method for Performance of Switching Regulator

Prior to testing it is important to ensure that the switching regulator is correctly connected and that the input and load parameters are within specification. This will ensure that test results are a true reflection of the performance of the device.

2.2.1. Output voltage accuracy

V_{outnom}: output voltage at nominal input voltage and full load	Output voltage accuracy $= \frac{V_{out} - V_{outnom}}{V_{outnom}} \times 100\%$
V_{out}: tested output voltage at nominal input voltage	

e.g. (K7812-500R2): V_{outnom}=12V, rated load=500mA, V_{out}=12.039V,

Output voltage accuracy = $\frac{12.039 - 12.000}{12.000} \times 100\% = 0.325\%$.

2.2.2. Line regulation:

V_{outn}: output voltage at nominal input voltage and rated load	Line regulation $= \frac{V_{mdev} - V_{outn}}{V_{outnom}} \times 100\%$
V_{outh}: output voltage at rated load when input voltage at its upper limit	
V_{outl}: output voltage at rated load when input voltage at its lower limit	
V_{mdev} V_{outh} or V_{outl} which is deviated from V_{outn} more	

e.g. (K7805-500R2): rated load = 500mA， V_{outh} = 5.01V, V_{outl} = 5.00V, V_{outnom} = 5.01V,

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$$\text{Line regulation} = \frac{5.00 - 5.01}{5.01} \times 100\% = -0.2\%$$

2.2.3. Load regulation:

V_{b1}: output voltage at nominal input voltage and 10% load	Loadregulation $= \frac{V_b - V_{b0}}{V_{b0}} \times 100\%$
V_{b2} : output voltage at nominal input voltage and 100% load	
V_{b0} : output voltage at nominal input voltage and 50% load	
V_b : V_{b1} or V_{b2} which is deviated from V_{b0} more	

e.g. (K7805-500R2): When load is 100%, V_{b2} = 5.01V. When load is 10%, V_{b1} = 5.02V. When load is 50%, V_{b0} = 5.02V,

$$\text{Load regulation} = \frac{5.01 - 5.02}{5.02} \times 100\% = -0.2\%$$

2.2.4. Efficiency:

V_{in} : nominal input voltage	Efficiency $\eta = \frac{I_{out} \times V_{out}}{I_{in} \times V_{in}} \times 100\%$
I_{out} : output current at full load	
V_{out} : output voltage at full load	
I_{in} : input current	

e.g. (K7805-500R2): V_{in} = 12V, V_{out} = 4.951V, I_{in} = 113.7mA,

$$\eta = \frac{500 \times 4.951}{113.7 \times 24} \times 100\% = 90.72\%$$

2.2.5. Ripple and noise:

Ripple and noise is the periodic and random AC variation superimposed on the DC output, which affects output accuracy and usually is calculated as a peak-to-peak (mVP-P).

First, set oscilloscope bandwidth 20MHz to effectively prevent high-frequency noise.

Second, test with parallel cable measuring method as shown in diagram 2-2.

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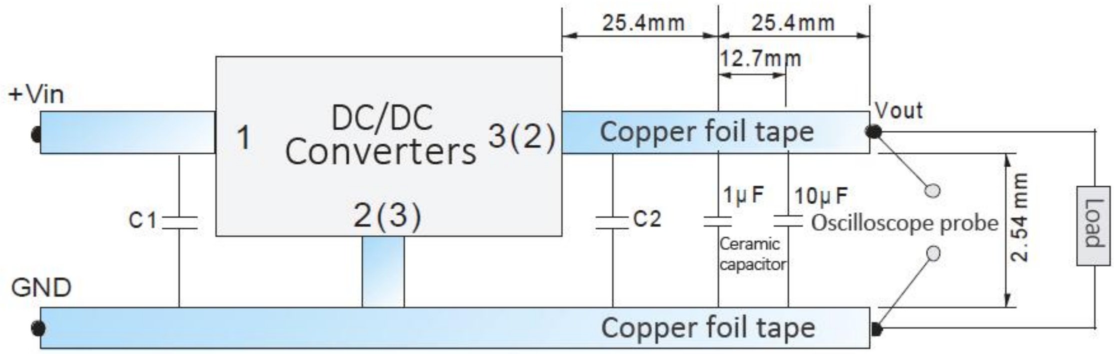

Diagram 2-1 Parallel cable measuring method

Notes:

a) C1: a high-frequency ceramic capacitor with 1uF capacitance;

b) C2: an electrolytic capacitor with 10uF capacitance and a twice withstand voltage higher than that of the switching regulator;

c) Distance between two paralleled copper foils is 2.5 mm and, of which the sum of voltage drops should be less than 2% of nominal output voltage.

The actual tested ripple and noise will vary depending on different circuits and external components. Diagram 2-3 shows the actual tested ripple and noise waveform.

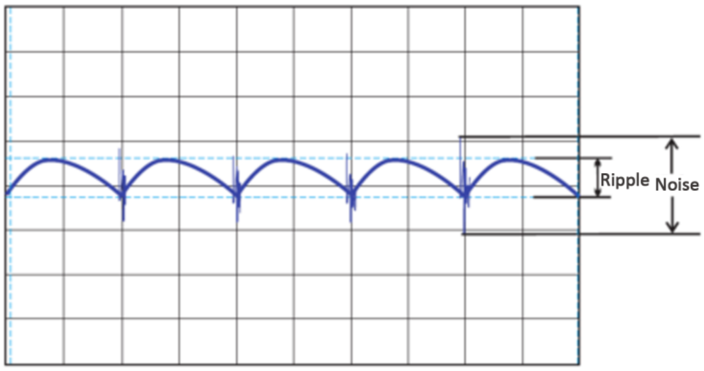

Diagram 2-2 Waveform of Ripple & Noise Test

2.2.6. Dynamic load:

When the load varies greatly, all the power supplies have a corresponding response time. During this time, the power supply's output voltage will produce instantaneous overshoot and then return to normal state. Dynamic response is an important indicator of switching regulators performance and is measured by the overshoot and the response time. Common testing method is as shown in Diagram 2-4.

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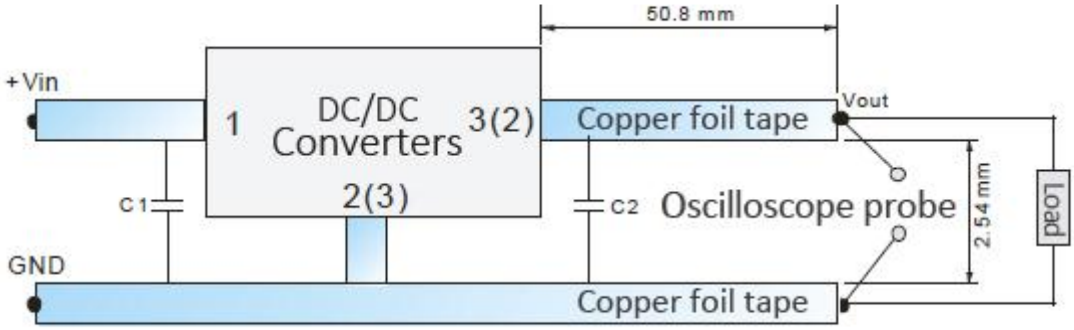

Diagram 2-3 Connection of dynamic load Test

The specific measurement method is to use an electronic load to simulate the sudden change in load. Set the load current at 25% -50% -25% and 50% -75% -50% of the rated load. Next, set the current jumping and falling slope 0.08-0.1A /uS. Last, measure the maximum deviation of the output voltage and response time with an oscilloscope. Waveform of dynamic load test is as shown in Diagram 2-5.

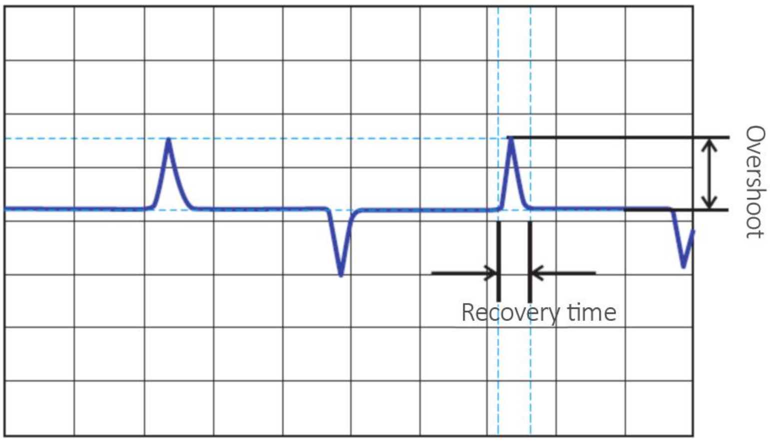

Diagram 2-4 Waveform of dynamic load Test

2.2.7. Start-up time:

Start-up time refers to the delay between the application of the input voltage and the output voltage output voltage reaching its specified output value, this is normally tested at full rated load. In practical design the start-up time and ripple & noise must be considered when designing external filters as this may affect the measured start up delay time.

Diagram 2-6 shows the actual tested start-up time waveform.

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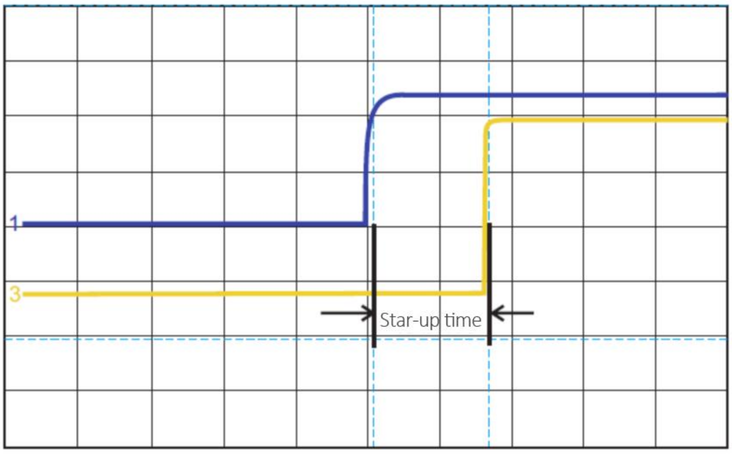

Diagram 2-6 Waveform of Start-up Time Test

2.2.8. Temperature rise test:

The temperature rise test is usually conducted using a thermal imaging camera or thermocouple. The former may be subject to deviation from the actual value due to emissivity. Testing using a thermocouple is a more accurate measurement method and is therefore recommended.

For example, given that the ambient temperature T_a is 25℃, and the measured temperature of power supply T_c is 60℃. Then the temperature rise ΔT is 35℃ ($\Delta T = T_c - T_a$= 60℃-25℃ =35℃).

Note: The temperature of the switching regulator will vary due to device power, shell material and internal design, etc. In a confined space, there is no natural ventilation. It is recommended when applying these switching regulators that they are placed away from components that may be sensitive to temperature or isolate them.

3. Applications of Switching Regulators

3.1. Typical Application

A typical application of K78 series is shown in following Diagram 3-1.

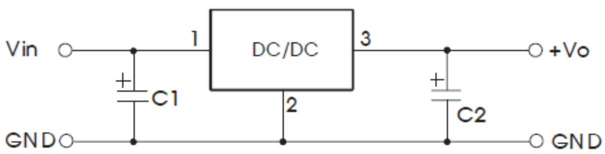

Diagram 3-1 Typical application

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The typical output is a BUCK circuit with a recommended external capacitance of 10uF.

3.2. Negative Output Application

Some of MORNSUN's non-isolated products support negative output. According to BUCK and BUCKBOOST circuit characteristics, negative voltage output can be achieved by connecting pins 2 and 3, as shown in Diagram 3-2.

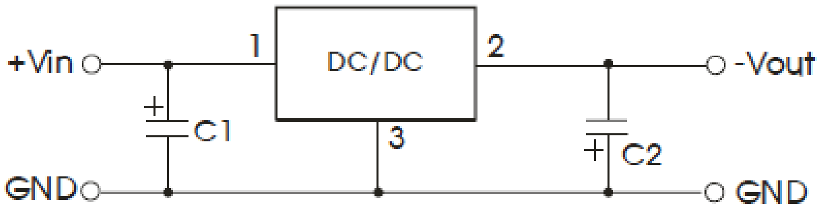

Diagram 3-2 Negative output application

3.3. Positive and Negative Outputs Application

To achieve a positive and negative output in the same circuit two switching regulators will be required, as shown in Diagram 3-3.

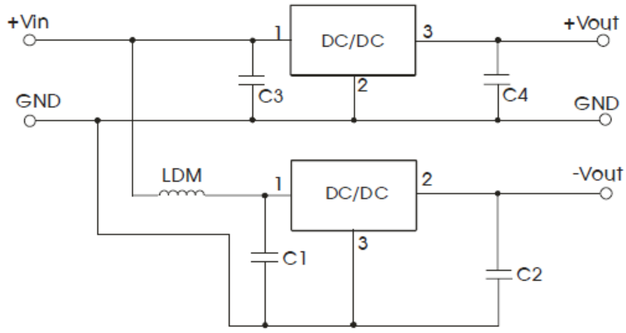

Diagram 3-3 Positive and negative outputs application

It should be noted that start-up current is higher for a negative output configuration as the topology is BUCKBOOST rather than BUCK.

At the same time, in the case of same input voltage, some modules can offer both positive and negative voltage output while some ones cannot. For example, it's hard to produce ±15V from a same input voltage. The most important reason is that the circuit structure, BUCK or BUCKBOOST, determines switching voltage differences of internal MOSFET in practical application. The MOSFET, however, is difficult to meet the two circuit structure simultaneously. For more detail please refer to the appropriate datasheet.

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3.4. Input Reverse Polarity Protection

If there is a possibility that a reverse input may be connected in the application it is recommended that reverse polarity protection is added. The simplest way is to connect a diode in series, as shown in Diagram 3-4.

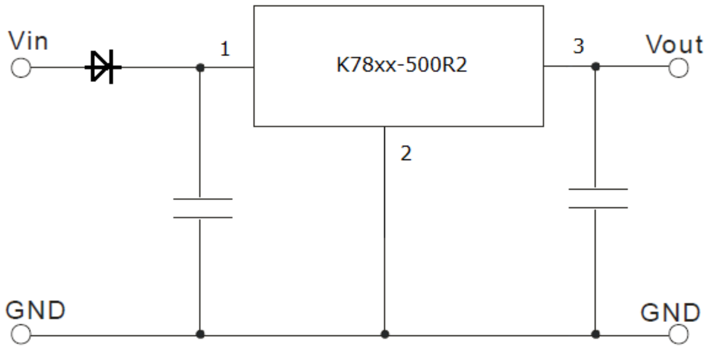

Diagram 3-4 Input reverse polarity protection circuit

In the application it is important to ensure that the diodes voltage drop is taken into consideration with reference to the input voltage requirements of the switching regulator. The diode must also be selected on the basis that its maximum current rating is adequate for the circuit.

3.5. Input and Output Filtering Circuit

Filters are usually connected at the input and output terminals of the converters to reduce ripple and noise in applications which are sensitive. A recommended circuit is as shown in Diagram 3-5.

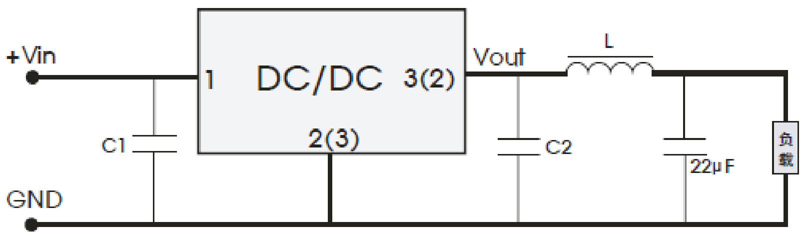

Diagram 3-5 Recommended circuit reducing ripple & noise

C1 and C2 are suggested to refer to datasheet before selecting. Inductance L should be 10uH-47uH.

3.6. Electromagnetic Interference and Electromagnetic Compatibility

3.6.1. Electromagnetic Interference (EMI)

EMI is the pollution of the environment by electromagnetic phenomenon through either

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conducted or radiated means. It cannot be completely eliminated may be reduced to acceptable levels through the application of various filter, layout and shielding techniques. Effective ways to suppress EMI include,

(1) Shielding EMI radiation: by using converters that have metal packages or by using additional shielding to reduce EMI radiation;

(2) Grounding techniques;

(3) Selection of suitable filters or filter networks to reduce the transmission of EMI;

(4) PCB layouts that separate switching circuits from small signal circuits to prevent induced noise.

3.6.2. Electromagnetic Compatibility (EMC)

EMC is the ability of electronic equipment and power supply to work stably and reliably in environments where electromagnetic interference is present. It is also the ability of electronic equipment and power supply to limit their own electromagnetic interference and avoid interference with other electronic equipment.

1) Improving EMC is available from the following three aspects,

- ■Reducing the radiation from sources of EMC interference;
- ■Shielding EMC interference transmissions;
- ■Improve anti-electromagnetic capabilities of circuits.

2)Transmission of EMC interference is divided into,

- ■Conducted interference. This is noise generated by the system into the DC input line or signal line. The frequency range of interest is 150KHz-30MHz. Conducted interference is seen as either common or differential mode. An LC network is often used to suppress the conducted interference;
- ■Radiated interference. This is noise generated as electromagnetic waves, the frequency range of interest is 30MHz-1GHz. Radiation interference can be suppressed by metal shielding.

3.6.3. EMC Solution-recommended Circuit

As DC/DC convertors are secondary power supplies, in order to pass EMS test, they usually

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connect external protection circuit at the DC/DC port or signal port. The protection circuit is as shown in Diagram 3-6.

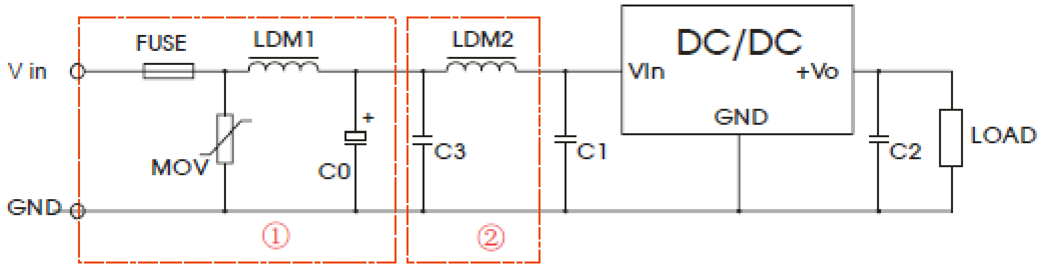

Diagram 3-6 EMC Solution-recommended Circuit

The circuit marked ① is a peripheral circuit for EMS and the circuit marked ② is used for EMI filtering. These circuits can be selected and applied as required and may depend on other circuit elements that may assist or adversely affect the operation on the overall system to EMS and EMI. For more details please refer to the appropriate datasheet.

3.7. Capacitive Load

For the general switching mode power, it's recommended to connect electrolytic capacitors at the output terminal to meet the requirements for the maximum capacitive load. But it should be noted that too large a capacitance or low ESR (equivalent series resistance) may cause the module to work in an unstable mode or may result in start-up issues. For more details please refer to the appropriate datasheet.

3.8. Pin-out

3.8.1. TRIM

K78xxT-500R3 and K78xxT-1000R3 offer output voltage trimming function. External resistor connection method is as shown in Diagram 3-7.

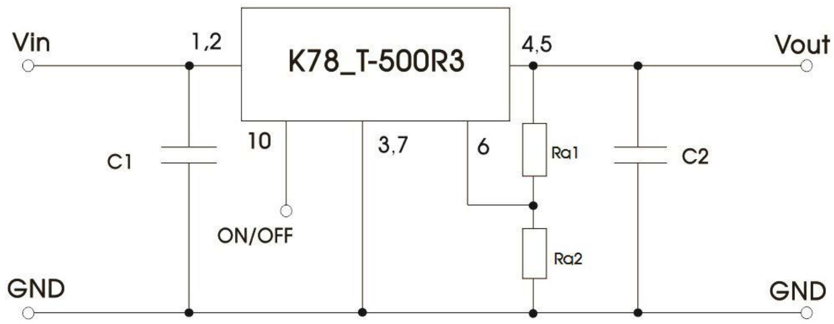

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Diagram 3-4 Connection of output voltage trimming with an external resistor

To adjust to a higher output voltage, increase the value of Ra1 and decrease the value of Ra2. To adjust to a lower output voltage the inverse applies. If the TRIM is not required the associated pins should be left disconnected.

For K12T series products, the output voltage is determined by the Trim pin, and the use of this pin is shown in diagram 3-8,

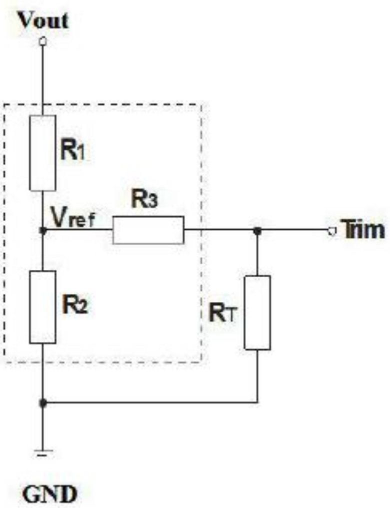

Diagram 3-8 application of trim pin

The calculation formula for resistance： $R_T = \frac{7200}{V_o - 0.7525} - 1000$

3.8.2. Switch control

Switch control is provided in K78xxT-500R3 and K78xxT-1000R3 products. Switch control refers to the module’s output voltage operation of "ON" (enabled) and "OFF" (disabled), as pin10 shown in the Diagram 3-7.

When the voltage Vc of control pin is between 3.2-8VDC or when there is no connection, the module normally works. When Vc is at a low level (0~0.8V), the module powers off.

The functions of the Ctrl pin of the K12T series are divided into positive logic and negative logic. The related logic, on and off are shown in the following table,

Power	Type	Ctrl State
ON	K12T-xx-P	Ctrl: no connection or at high level（Vin-2.5~Vin）
	K12T-xx-N	Ctrl: grounding or at low level（0~0.5VDC）

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OFF	K12T-xx-P	Ctrl: grounding or at low level（0~0.5VDC）
	K12T-xx-N	Ctrl: no connection or at high level（Vin-2.5~Vin）

3.8.3. Remote Compensation Sense

When the module is powered from a long distance, in order to meet the voltage requirements of the load for normal operation, the remote voltage compensation method is generally used to increase the voltage of the load. The SENSE remote voltage compensation pin of the module compensates the voltage of the remote load to meet the application requirements, and customers can use wires for remote connection.

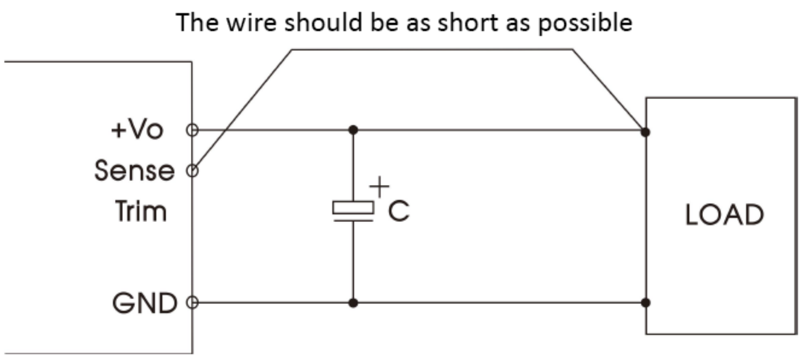

Diagram 3-9 Sense pin remote compensation application

3.8.4. Use of adjustable input starting (under-voltage) voltage

KUB48xxQB-10A products also provide the adjustment function of input voltage. The input voltage range of KUB4824QB-10A is 30-75VDC, and the input voltage range of KUB4812QB-10A is 16-75VDC. If there is an application that needs to adjust the voltage start point, increasing the under-voltage point of the product can make it power off quickly. For example, in battery-powered situations, a relatively low voltage cut-off point will reduce battery life. The method of connecting an external resistor to CTRL and VIN or GND is shown in diagram 3-10,

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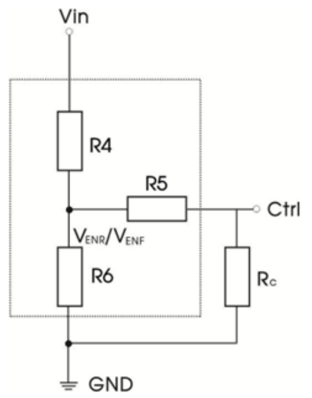
The circuit of adjustable input starting (under-voltage) voltage
(inner part of the product in the dotted frame)



Calculation formula of the resistance of adjustable input starting (under-voltage) voltage,

$$R_C=\frac{bR_5}{R_5-b}-R_6 \qquad b=\frac{V_{EN}}{Vin-V_{EN}}\cdot R_4$$

*Rc : resistance of adjustable input starting (under-voltage) voltage
*b: self-defined parameter with no actual meaning
*when the VEN value is VENR, Vin is the actually needed starting voltage
*when the VEN value is VENF, Vin is the actually needed input under-voltage

Diagram 3-10 Adjustable input starting (under-voltage) voltage usage and resistance calculation formula

4. FAQs

4.1. Do MORNSUN’s switching regulators support hot-plug?

"Hot-plug", simply refers to the plugging or unplugging of converters into the system while the circuit is live.

The switching regulators **MUST NOT** be used in this way as it may result in excessive current flow, voltage spikes or internal damage to the converter.

4.2. Can MORNSUN’s switching regulators be used at no-load or light-load?

The switching regulators can be used at no-load or light-load applications unless specified. Under such conditions, the conversion efficiency of the converters is relatively low and the converter’s control loop may be unstable and produce oscillation. Also, certain parameters may not meet the requirements of datasheet. From the view of reliability it is recommended that the minimum output current is 10%. For best operation it is recommended that the switching regulator is used in a load range of 30-80% of maximum load.

4.3. Reasons cause failures of MORNSUN’s switching regulators?

Reason 1: Exceeding the maximum capacitive load value stated in the datasheet. Capacitive loads outside of specification may require a larger starting current, this may cause failure of the converters. That reducing the output capacitance at the output terminal

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or connecting buffer circuit are good choices to increase the capacity of the converters;

Reason 2: The input power supply is not capable of providing the initial start-up current of the switching regulator circuit, this may have a large instantaneous current requirement. In such circumstances it is recommended that a small resistance or NTC is added to the circuit at the input terminal of the switching regulator to reduce the start-up current;

Reason 3: When driving an inductive load (usually motor coil) the circuit resistance seen is very low, usually mΩ ~ Ω level. According to $I = \frac{V}{r}$, the output current required will be in excess of the over the over-current protection value of the converter and as a result the converter will protect the output. To overcome this issue it is recommended that a small resistor is added in series with the output to present a load that will ensure the over-current protection is not triggered, alternatively a switching regulator with a larger output current capability may be selected;

Reason 4: The input voltage is lower than the product's operating voltage, resulting in unstable output.

4.4. Reasons damaging MORNSUN's switching regulators?

Five things that may result in damage to the switching regulators, written in *Wide Input Non-Isolated Regulated Output Series Product*.

Reason 1: reverse polarity connection;

Reason 2: the input voltage is much higher than the maximal input voltage, refer to the appropriate datasheet for confirmation on this;

Reason 3: hot-plug produces a larger voltage spike, or input power produces overshoot;

Reason 4: Extreme overload;

Reason 5: The GND is not connected securely, when under heavy load.

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