



SMT4004 QUAD TRACKING POWER SUPPLY MANAGER

ADVANCED CURRENT SENSING SCHEMES AND POWER MOSFET SELECTION

USING KELVIN SENSE CONNECTIONS FOR ACCURATE CURRENT MEASUREMENT

High current measurements using a series connected resistor can be very accurate, provided the resistor is Kelvin connected. A Kelvin connection is a simple 4-terminal connection, usually made to a 2-terminal device, separating the current path through the resistor from the voltage drop across the resistor. The 4-wire connection improves the measurement accuracy by directly sensing the voltage drop across the resistor. This eliminates inaccuracies caused by voltage drops across resistor leads and printed circuit board (PCB) traces. The sensed voltage is then applied to high-impedance circuitry.

Figure 1 illustrates the 4-wire Kelvin principle applied to a 2-terminal surface mount sense resistor.

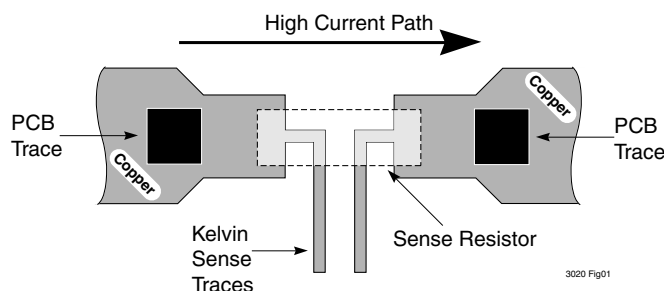


Figure 1. Kelvin Sensing.

Current sense resistors are available from a number of manufacturers in two basic styles: open air and resistor chips. Open-air resistors are metal strips and are available in both leaded and surface mount packages. Resistor chips are surface mount packages and offer excellent thermal characteristics. Both styles are available in resistance ranges from $<1\text{m}\Omega$ to 1Ω . True 4-terminal sense resistors are available, but are generally more expensive. Unless extreme precision is required, the 2-terminal resistor is the economical choice with PCB traces added to provide the 4-terminal connection.

Figure 2 illustrates the 4-wire principle as applied to the SMT4004 power supply controller. For optimal performance, maintain equal length PCB sense traces and locate the sense resistor(s) as close to the SMT4004 as possible. Since the highest level of the four voltages the SMT4004 controls is used to power the device itself, this sense (VI1) trace must be

capable of handling 3mA maximum without dropping additional voltage. The highest level input can be any one of the VIx pins. The remaining three sense resistors should have identical Kelvin sense trace widths and lengths. A typical layout example is shown in Figure 3.

Recommended sense resistor vendor: IRC — International Resistive Co., Inc. (<http://www.ircct.com/>). A list of other vendors is shown in Table 1.

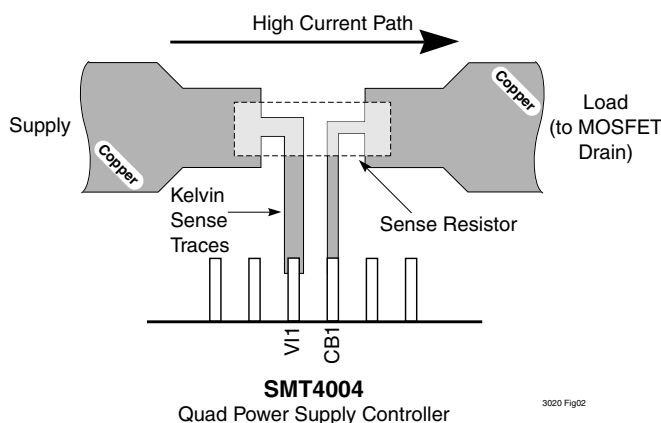


Figure 2. Kelvin Sense Connections on the SMT4004.

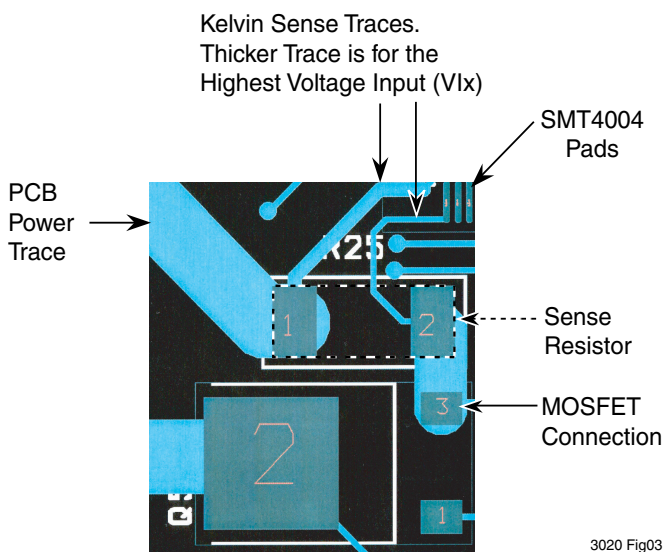


Figure 3. Typical Layout Example.



Figure 4. Current Sense Resistor Types.

Mfgr	Model	Resistance Range	No. Of Terminals	Surface or ThruHole	70°C Max. Power Rating
Vishay	WSL3637	3mΩ to 10mΩ	4	Surface	3.0W
Vishay	WSL	1mΩ to 5mΩ	2	Surface	1.0W
Vishay	WSR	1mΩ to 5mΩ	2	Surface	3.0W
IRC/Welwyn	*CSC	1mΩ to 5mΩ	4	Surface	5.0W
IRC/Welwyn	CSL	0.25mΩ to 2.5mΩ	4	Thruhole	5.0W
IRC/Welwyn	LRC	3mΩ to 10mΩ	2	Surface	2.0W
IRC/Welwyn	LRK	3mΩ to 10mΩ	4	Surface	2.0W
IRC/Welwyn	LRF3W	3mΩ to 10mΩ	2	Surface	3.0W
IRC/Welwyn	OARS	3mΩ to 50mΩ	2	Surface	1.0W
ISOTEK	**BVS	0.3mΩ to 1mΩ	2	Surface	3.0W
ISOTEK	PMA / PMD	2mΩ to 500mΩ	4	Surface	3.0W / 2.0W
ISOTEK	PMB / PMU	1mΩ to 20mΩ	4	Surface	20.0W / 5.0W

3020 Table01

Table 1. Suggested Sense Resistors for Use with the SMT4004.

* Ceramic substrate - .714" W x .275" L x .118" H. Power rating good to 50 Amp max.

** .2" W x .4" L, low ohms and good power rating.



SELECTING SENSE RESISTOR VALUES AND POWER MOSFETS

Selection of MOSFET switches for the SMT4004 Trakker is a compromise between load regulation, board area, and MOSFET cost.

To obtain good load regulation with low supply voltages the MOSFET must have a very low ON resistance ($R_{DS(ON)}$). For example, a 1.8V supply with a 10A maximum load current is equivalent to 180m Ω load resistance. If the total resistance of the sense resistor plus MOSFET ON resistance is 9m Ω , the load regulation is approximately 5% for a load change from 0A to 10A. Great care must be taken in choosing the MOSFET and ensuring the PCB trace resistance does not degrade circuit performance.

If the circuit breaker trip voltage is programmed to 25mV on the SMT4004, and if the voltage drop across the MOSFET is kept below 25mV at maximum current, then the total drop of 50mV yields a load regulation of less than 3% with a 1.8V supply, and 1% with a 5V supply.

Choosing a suitable MOSFET is simply a matter of applying Ohm's law once the supply voltage, load current, and load regulation requirements are known. Returning to the 1.8V supply example with a maximum current of 10A — first choose the current sense resistor, then set the trip current higher than the operating current. Choosing 12.5A yields 25% over-current and allows for the tolerances of the resistor and trip voltage. With a nominal trip voltage of 25mV and a trip current of 12.5A, the current sense resistor is 2m Ω . Therefore, the MOSFET $R_{DS(ON)}$ must be below 7m Ω . A list of recommended MOSFETs is shown in Table 2.

Part Number	Manufacturer	$V_{(BR)DSS}$	$R_{DS(ON)} @ V_{GS} = 10V$	$I_D @ 100^\circ C$	Package
IRF3703	International Rectifier	30V	2.5m Ω max.	180A	Super D2
IRAF1404S	International Rectifier	40V	4m Ω max.	115A	D2PAK
IRF6603	International Rectifier	30V	3.9m Ω max.	22A	DirectFET™
HUF76145S3S	Fairchild Semiconductor	30V	4.5m Ω max.	75A	D2PAK
HUF76145S3S	Fairchild Semiconductor	30V	5.5m Ω max.	75A	D2PAK
*STV160NF03L	ST Microelectronics	30V	2.8m Ω max.	113A	Power SO-10
STB80NF03L-04	ST Microelectronics	30V	4m Ω max.	56A	D2PAK
SUB75N03-04	Vishay Siliconix	30V	4m Ω max.	75A	TO-263
SUB75N04-05L	Vishay Siliconix	40V	5.5m Ω max.	55A	TO-263

3020 Table02

Table 2. Suggested Low $R_{DS(ON)}$ N-Channel MOSFET Switches for Use with the SMT4004.

* The V_{GS} maximum for the ST Microelectronics devices is 15V. The VGATE output from the SMT4004 is typically 14V, but the data sheet maximum is 16V. In order to protect the MOSFET four 13V zener diodes (1N5243B) can be added from each VGATE pin to ground. Alternately, a single 15V zener diode (1N5245B) can be added from the VGG_CAP pin to ground to clamp all VGATE outputs.



PARALLELING MOSFETS REDUCES VOLTAGE DROPS AND POWER DISSIPATION

When supply regulation is unacceptable due to high $R_{DS(ON)}$, two or more MOSFETs may be wired in parallel to lower the $R_{DS(ON)}$. For example, a 1V supply delivering 15A of load current will have its load regulation improved by using two or more MOSFETs in parallel (see Figure 5). The $R_{DS(ON)}$ is halved when two identical MOSFETs with identical gate resistors (RGx) are connected as in the Figure. The SMT4004 has been demonstrated to drive as many as 6 high current MOSFETs connected in parallel from any of the VGATE outputs.

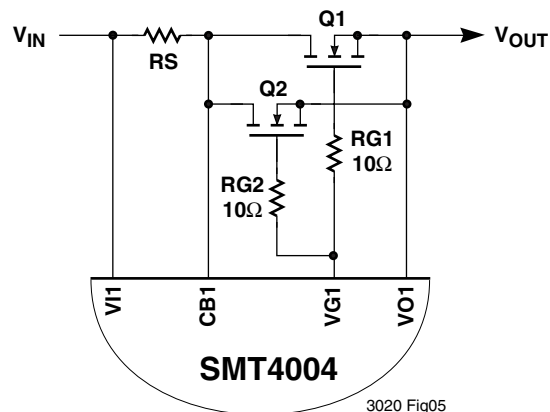


Figure 5. Paralleling MOSFETs to achieve lower $R_{DS(ON)}$ (up to 6 in parallel).

ADVANCED CURRENT-SENSING TECHNIQUES REDUCE LOSSES, IMPROVE RELIABILITY

SMT4004: Typical Current-Sensing

The SMT4004 provides over-current protection by sensing the voltage drop across an external resistor. Voltage trip levels are user-programmable to 25mV or 50mV. The voltage dropped across the resistor and the MOSFET reduces the available output voltage (Figure 6). This drop becomes substantial when low input voltage high current supplies are employed.

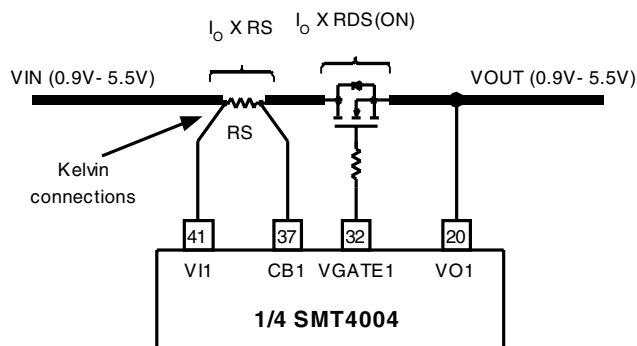


Figure 6: SMT4004 Typical Current-Sensing Scheme.

Output voltage regulation also suffers as the power supply voltage is regulated on the input-side of the circuit. The output voltage varies according to:

$$\text{Eq 1: } V_{OUT} = V_{IN} - I_O(R_S + R_{DS(ON)})$$

Reducing the voltage drop across the sense resistor without compromising fault protection is desirable for improved efficiency and output voltage regulation.

REDUCE THE IR DROP: ADD AN OFFSET VOLTAGE

Adding a simple resistive divider significantly reduces the required sense resistor voltage needed to trip the SMT4004 Circuit Breaker while maintaining fault protection (Figure 7).

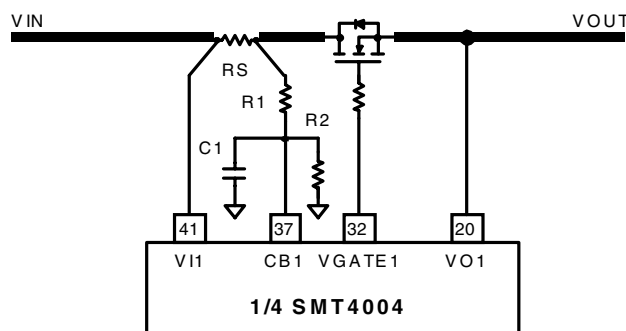


Figure 7: Simple Divider Reduces Voltage Drop.



The resistor values are calculated according to the maximum desired voltage drop across R_s to trigger a fault:

$$\text{Eq 2: } \frac{R_1}{R_2} = \frac{V_{IN}}{V_{IN} - (V_{SET} - V_{TRIP})} - 1$$

Where:

V_{SET} = SMT4004 OC Trip Point (25mV or 50mV)

V_{TRIP} = Desired Trip Voltage (across R_s).

Given:

$V_{IN} = 2.5V$, $V_{SET} = 25mV$, $V_{TRIP} = 10mV$

$$\text{Eq 3: } \frac{R_1}{R_2} = \frac{2.5V}{2.5V - (0.025V - 0.010V)} - 1 = 0.00603$$

Using 1% resistors the closest values are:

$R_1 = 56.2\Omega$, $R_2 = 9.31K\Omega$

Note: Adding a small valued capacitor (C1) is suggested to prevent nuisance tripping. The value is chosen for a cutoff point (3dB) of $1/10^{th}$ the switching frequency of V_{IN} . Assuming $f_{sw} = 100kHz$:

$$\text{Eq 4: } C_1 = \frac{10}{2 \times \pi \times f_{sw} \left(\frac{R_1 \times R_2}{R_1 + R_2} \right)} = 2.8 \times 10^{-7}$$

Use 0.33uF.

IMPROVED REGULATION: CORRECT VOLTAGE-SENSING

Nearly all power supplies make available 'Sense' terminals for remote regulation of the output voltage. Figure 8 displays the correct Sense terminal connection.

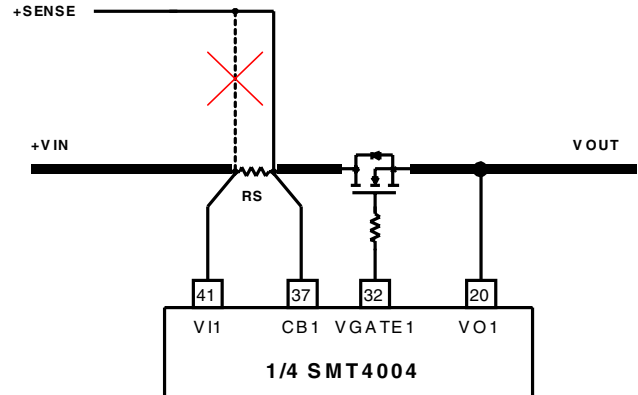
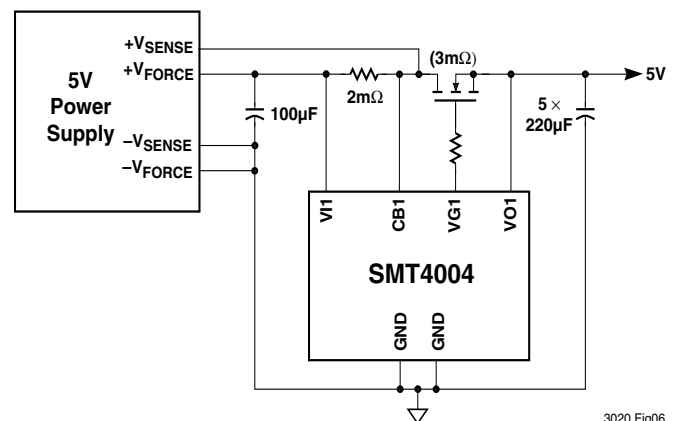


Figure 8: Improved Power Supply Sensing

This technique can be used with power supplies that have Sense inputs. Remote sensing eliminates the effect of the current sense resistor voltage drop. With this arrangement (Figure 9) only the MOSFET $R_{DS(ON)}$ must be considered and a wider selection of devices can be used.



3020 Fig06

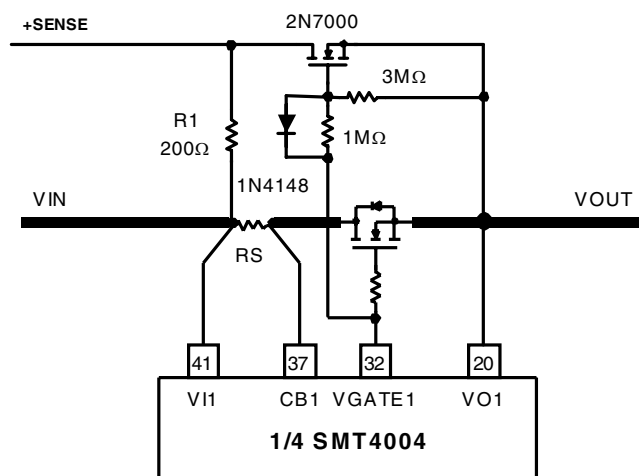
Figure 9. Remote Sensing Using a Four Terminal DC/DC Brick.

The Sense lead is applied to the output side of the current sense resistor, thereby eliminating this voltage drop as a factor in output voltage regulation.



ULTIMATE REGULATION: INTELLIGENT VOLTAGE-SENSING

Ideally, the Sense connections should be made to the load side (Card-Side) to obtain the best possible voltage regulation. Unfortunately, such a connection could lead to a Bus-Side overvoltage during the time the MOSFET is being turned-on (or turned off). An intelligent voltage-sensing scheme overcomes this dilemma (Figure 10).



The gate drive voltage (VGATE1) is used to turn on the 2N7000 small signal MOSFET thereby connecting the +Sense lead to the Card-Side after the power MOSFET is fully enhanced. The 1N4148 is used to quickly shut-off the 2N7000 when a fault occurs. Without it, the 2N7000 may remain enhanced long enough for the power supply to cause an overvoltage on the Bus-Side.

Note: This example of switching the +Sense lead was tested using a 5V supply. When used with lower voltage supplies, the resistor values must be altered to prevent the 2N7000 from turning on before the power MOSFET is fully enhanced. Increase the 1MΩ resistor according to this ratio:

$$\text{Eq 5: } \frac{5}{V_{IN}} \times 1\text{M}\Omega$$

For example, when using a 3.3V supply, the 1MΩ is replaced with a 1.5MΩ resistor.

Figure 10: Intelligent Power Supply Sensing.

NOTICE

SUMMIT Microelectronics, Inc. reserves the right to make changes to the products contained in this publication in order to improve design, performance or reliability. SUMMIT Microelectronics, Inc. assumes no responsibility for the use of any circuits described herein, conveys no license under any patent or other right, and makes no representation that the circuits are free of patent infringement. Charts and schedules contained herein reflect representative operating parameters, and may vary depending upon a user's specific application. While the information in this publication has been carefully checked, SUMMIT Microelectronics, Inc. shall not be liable for any damages arising as a result of any error or omission.

SUMMIT Microelectronics, Inc. does not recommend the use of any of its products in life support or aviation applications where the failure or malfunction of the product can reasonably be expected to cause any failure of either system or to significantly affect their safety or effectiveness. Products are not authorized for use in such applications unless SUMMIT Microelectronics, Inc. receives written assurances, to its satisfaction, that: (a) the risk of injury or damage has been minimized; (b) the user assumes all such risks; and (c) potential liability of SUMMIT Microelectronics, Inc. is adequately protected under the circumstances.

Revision 2.0 - This document supersedes all previous versions.

© Copyright 2002 SUMMIT MICROELECTRONICS, Inc. **Power Management for Communications™**

I²C is a trademark of Philips Corporation.