SK6018C 2μA IQ, 600mA Low-Dropout Linear Regulator

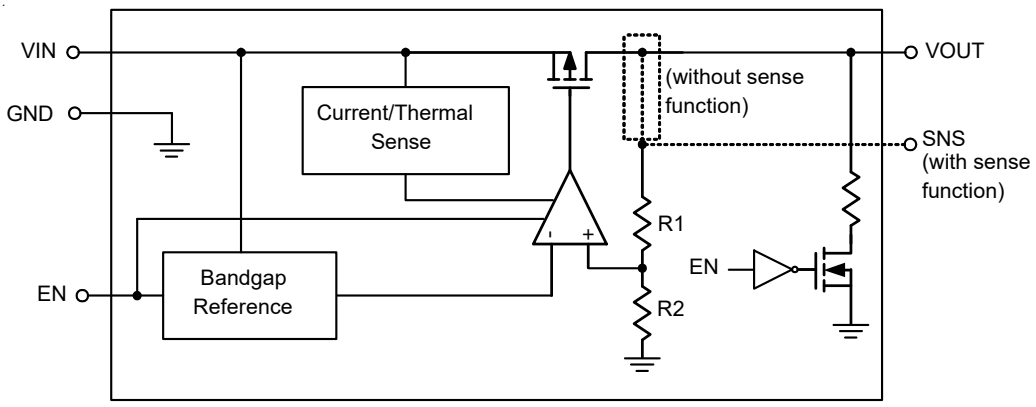
Features

- 2μA Ground Current at no Load
- PSRR = 75dB at 1kHz
- Adjustable Output Voltage Available by Specific Application
- ±2% Output Accuracy
- 600mA (V_{IN} ≥2.3V) Output Current with EN
- Low (0.1μA) Disable Current
- 1.2V to 5.5V Operating Input Voltage
- Dropout Voltage : 0.31V at 600mA when V_{OUT}≥3V
- Support Fixed Output Voltage 0.8V to 3.3V
- Stable with Ceramic or Tantalum Capacitor
- Current-Limit Protection

Applications

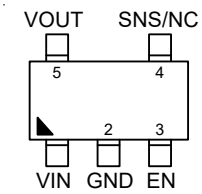
- Portable, Battery Powered Equipment
- Ultra Low Power Microcontrollers
- Notebook Computers

Block Diagram

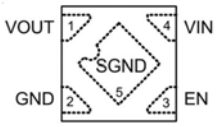


Pin Configurations

SOT23-5



DFN1x1-4



Pin Description

Pin No.		Pin Name	Pin Function
SOT23-5	DFN1x1-4		
1	4	VIN	Supply voltage input.
2	2	GND	Ground.
3	3	EN	Enable control input.
4	--	SNS	Output voltage sense. (SK6018CNS5 only)
		NC	No internal connection.
5	1	VOUT	Output of the regulator.
--	5 (Exposed Pad)	SGND	Substrate of chip. Leave floating or tie to GND.

Ordering Information

Part Number	Package	SNS	Quantity
SK6018CS5-XX	SOT23-5	NO	3000
SK6018CNS5-XX	SOT23-5	YES	3000
SK6018CD4-XX	DFN1x1-4	N/A	10000

Operation

Basic Operation

The SK6018C is a low quiescent current linear regulator designed especially for low external components system. The input voltage range is from 1.2V to 5.5V.

The minimum required output capacitance for stable operation is 1μF effective capacitance after consideration of the temperature and voltage coefficient of the capacitor.

Output Transistor

The SK6018C builds in a P-MOSFET output transistor which provides a low switch-on resistance for low dropout voltage applications.

Error Amplifier

The Error Amplifier compares the internal reference voltage with the output feedback voltage from the internal divider, and controls the Gate voltage of P-MOSFET to support good line regulation and load regulation at output voltage.

Enable

The SK6018C delivers the output power when it is set to enable state. When it works in disable state, there is no output power and the operation quiescent current is almost zero.

Current-Limit Protection

The SK6018C provides current limit function to prevent the device from damages during over-load or shorted-circuit condition. This current is detected by an internal sensing transistor.

Over-Temperature Protection

The over-temperature protection function will turn off the P-MOSFET when the junction temperature exceeds 150°C (typ.), and the output current exceeds 80mA. Once the junction temperature cools down by approximately 20°C, the regulator will automatically resume operation.

Absolute Maximum Ratings (Note 1)

- VIN, VOUT, SNS, EN to GND ---------- –0.3V to 6.5V
- VOUT to VIN ---------- –6.5V to 0.3V
- Power Dissipation, P_D @ T_A = 25°C
  SOT23-5 ---------- 0.43W
  DFN1x1-4 ---------- 0.44W
- Package Thermal Resistance (Note 2)
  SOT23-5, θ_{JA} ---------- 230.6°C/W
  SOT23-5, θ_{JC} ---------- 21.8°C/W
- DFN1x1-4 , θ_{JA} ---------- 226°C/W
- DFN1x1-4 , θ_{JC} ---------- 43°C/W
- Lead Temperature (Soldering, 10 sec.) ---------- 260°C
- Junction Temperature ---------- 150°C
- Storage Temperature Range ---------- –65°C to 150°C
- ESD Susceptibility (Note 3)
  HBM (Human Body Model) ---------- 2kV

Recommended Operating Conditions (Note 4)

- Input Voltage, VIN ---------- 1.2V to 5.5V
- Junction Temperature Range ---------- –40°C to 125°C
- Ambient Temperature Range ---------- –40°C to 85°C

Electrical Characteristics

(V_{OUT} + 1 < V_{IN} < 5.5V, T_A = 25°C, unless otherwise specified)

Parameter	Symbol	Test Conditions	Min	Typ	Max	Unit
Output Voltage Range	V_{OUT}		0.8	-	3.3	
DC Output Accuracy		I_{LOAD} = 1mA	–2	--	2	%
Dropout Voltage (I_{LOAD} = 600mA) (Note 5)	V_{DROP}	0.8V ≤ V_{OUT} < 1.05V (SOT23-5)	--	1.05	1.33	V
		0.8V ≤ V_{OUT} < 1.05V (DFN1x1-4L)	--	1.05	1.63	
		1.05V ≤ V_{OUT} < 1.2V	--	0.8	1.13	
		1.2V ≤ V_{OUT} < 1.5V	--	0.71	1.03	
		1.5V ≤ V_{OUT} < 1.8V	--	0.57	0.93	
		1.8V ≤ V_{OUT} < 2.1V	--	0.57	0.83	
		2.1V ≤ V_{OUT} < 2.5V	--	0.41	0.73	
		2.5V ≤ V_{OUT} < 3V	--	0.36	0.63	
		3V ≤ V_{OUT}	--	0.31	0.53	
V_{CC} Consumption Current	I_Q	I_{LOAD} = 0mA, V_{OUT} ≤ 5.5V V_{IN} ≥ V_{OUT} + V_{DROP}	--		4	μA
Shutdown GND Current (Note 6)		V_{EN} = 0V	--	0.1	0.5	μA
Shutdown Leakage Current (Note 6)		V_{EN} = 0V, V_{OUT} = 0V	--	0.1	0.5	μA

Parameter	Symbol	Test Conditions		Min	Typ	Max	Unit
EN Input Current	I_{EN}	V_{EN} = 5.5V		--	--	0.1	μA
Line Regulation	ΔLINE	I_{LOAD} = 1mA	1.2V ≤ V_{IN} < 1.5V	--	0.3	0.6	%
			1.5V ≤ V_{IN} < 1.8V	--	0.15	0.3	
			1.8V ≤ V_{IN} < 5.5V	--	0.13	0.35	
Load Regulation	ΔLOAD	1mA < I_{LOAD} < 600mA		--	0.5	1	%
Power Supply Rejection Ratio	PSRR	V_{IN} = 3V, I_{LOAD} = 50mA, C_{OUT} = 1μF, V_{OUT} = 2.5V, f = 1kHz		--	75	--	dB
Output Voltage Noise		C_{OUT} = 1μF, I_{LOAD} = 150mA, BW = 10Hz to 100kHz, V_{IN} = V_{OUT} + 1V	V_{OUT} = 0.8V	--	26	--	$μV_{RMS}$
			V_{OUT} = 1.2V	--	37	--	
			V_{OUT} = 1.8V	--	39	--	
			V_{OUT} = 3.3V	--	42	--	
Output Current Limit	I_{LIM}	V_{OUT} = 90%$V_{OUT(Normal)}$		610	1100	--	mA
Enable Input Voltage Logic-High	V_{IH}	V_{IN} = 5V		0.9	--	--	V
Enable Input Voltage Logic-Low	IL	V_{IN} = 5V		--	--	0.4	
Thermal Shutdown Temperature	T_{SD}	I_{LOAD} = 30mA, V_{IN} ≥ 1.5V		--	150	--	°C
Thermal Shutdown Hysteresis	$ΔT_{SD}$			--	20	--	°C
Discharge Resistance		EN = 0V, V_{OUT} = 0.1V		--	80	--	Ω

Note 1. Stresses beyond those listed under "Absolute Maximum Ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions may affect device reliability.

Note 2. $θ_{JA}$ is measured in the natural convection at T_A = 25°C on a two-layer Richtek Evaluation Board for DFN1x1-4L

$θ_{JA}$ is measured at T_A = 25°C on a high effective thermal conductivity four-layer test board per JEDEC 51-7 for SOT23-5 Package.

Note 3. Devices are ESD sensitive. Handling precaution is recommended.

Note 4. The device is not guaranteed to function outside its operating conditions.

Note 5. The dropout voltage is defined as V_{IN} – V_{OUT}, when V_{OUT} is 98% of the normal value of V_{OUT}.

Note 6. The specification is tested at wafer stage and guarantee by design after assembly.

Typical Application Circuit

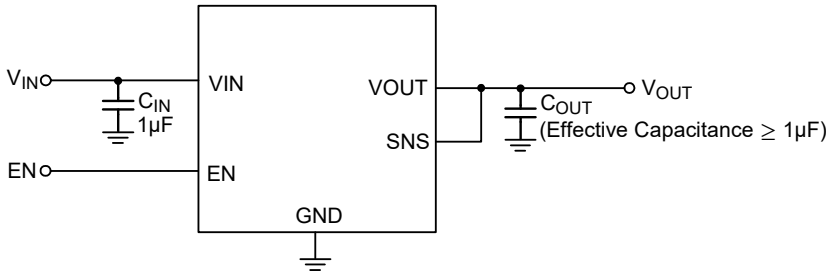


Figure 1. Application with Sense Function

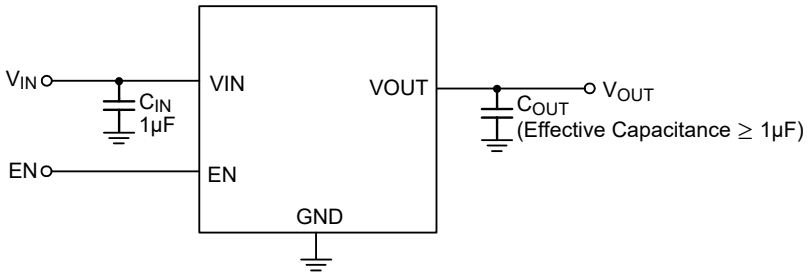


Figure 2. Application without Sense Function

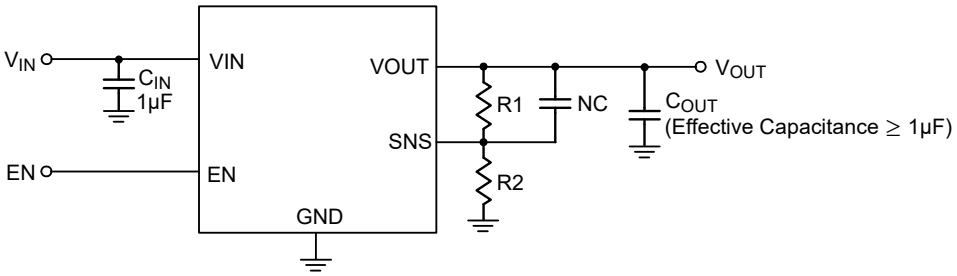
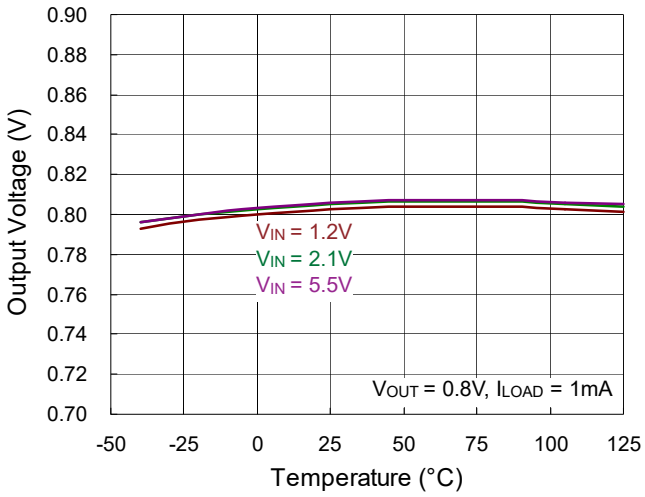
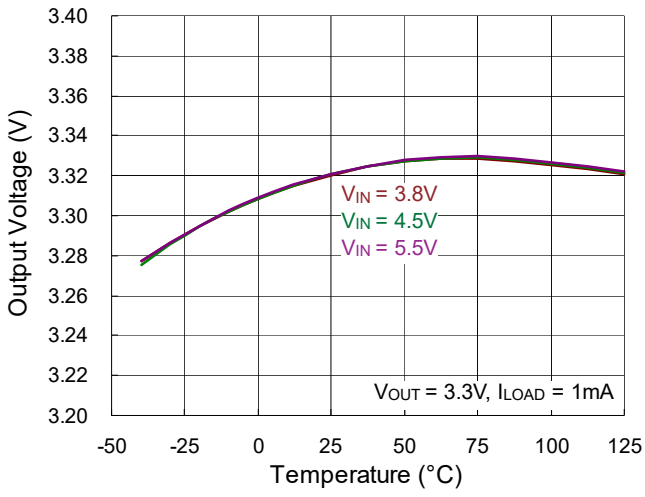


Figure 3. Adjustable Output Voltage Application Circuit

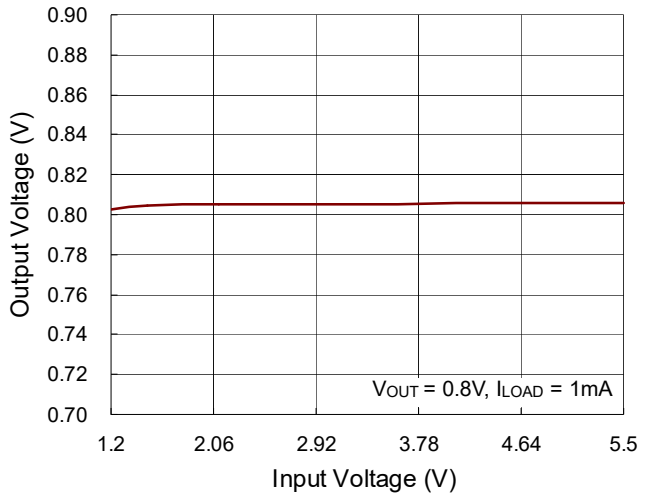
Output Voltage vs. Temperature



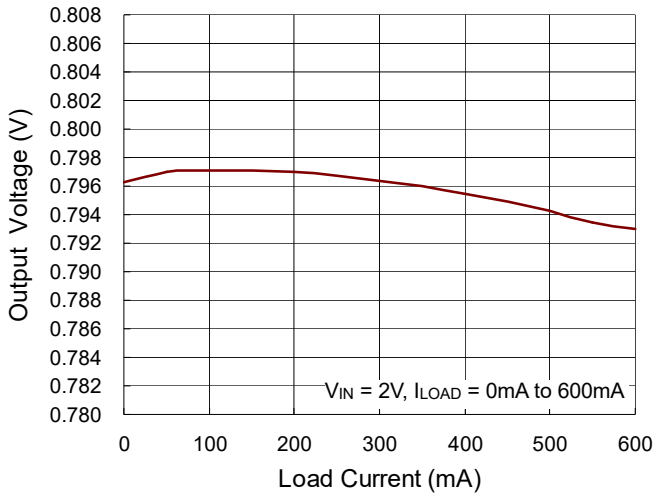
Output Voltage vs. Temperature



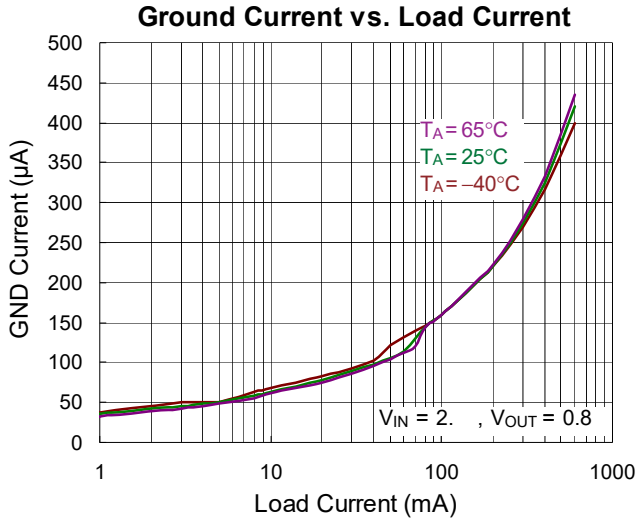
Output Voltage vs. Input Voltage



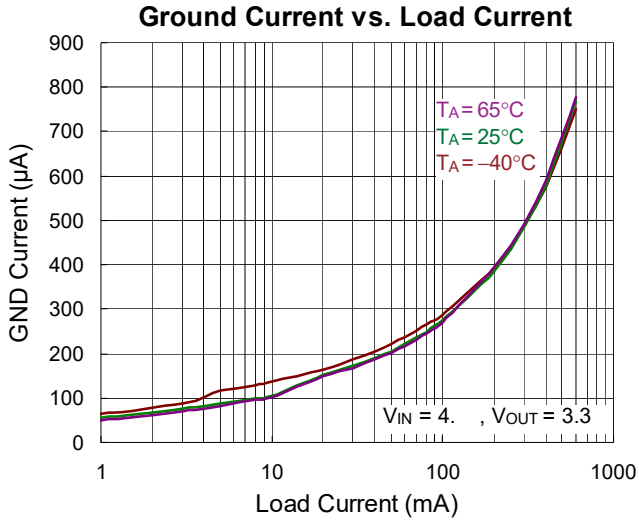
Output Voltage vs. Load Current



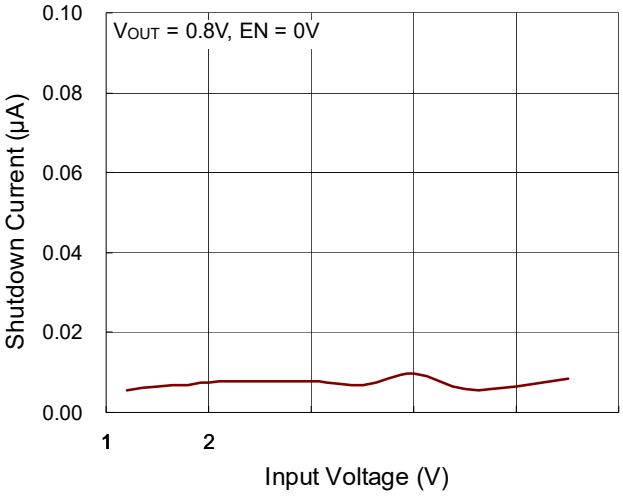
Ground Current vs. Load Current



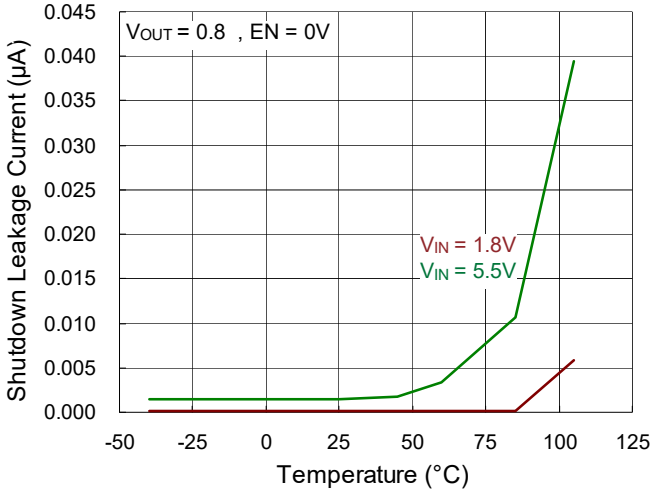
Ground Current vs. Load Current



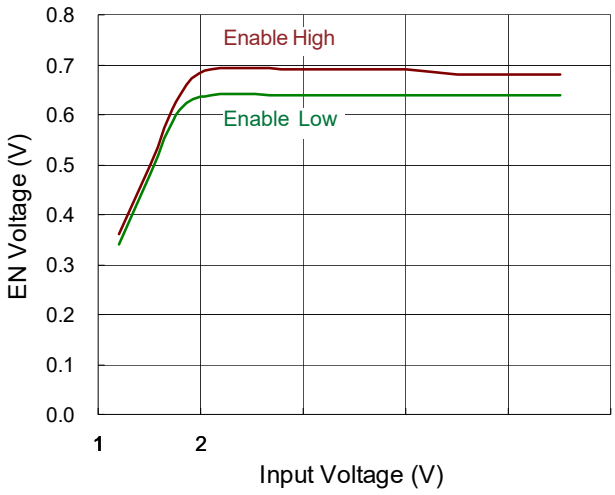
Shutdown Current vs. Input Voltage



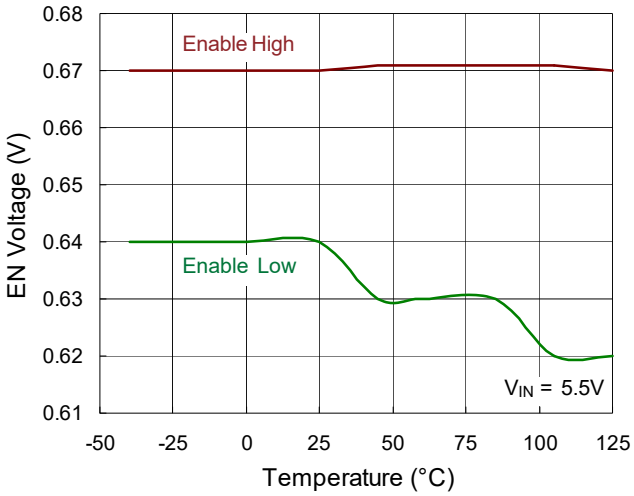
Shutdown Leakage Current vs. Temperature



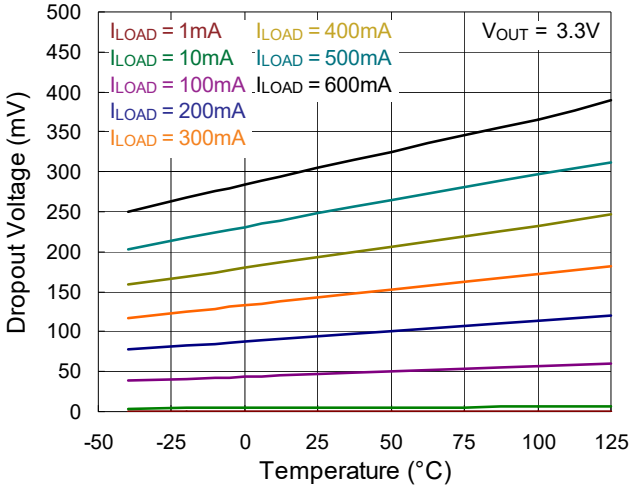
Enable Threshold vs. Input Voltage



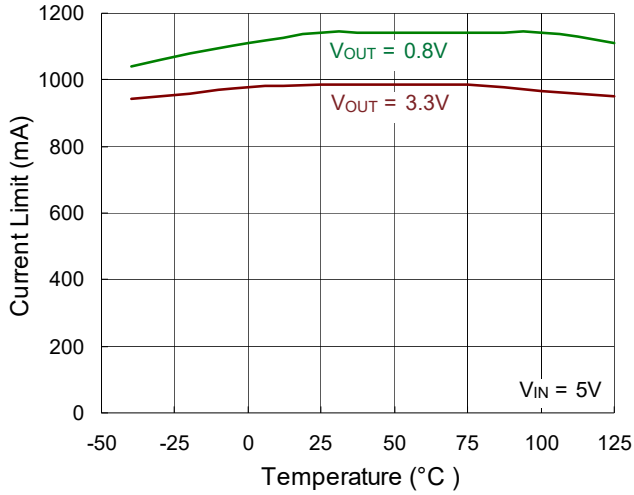
Enable Threshold vs. Temperature



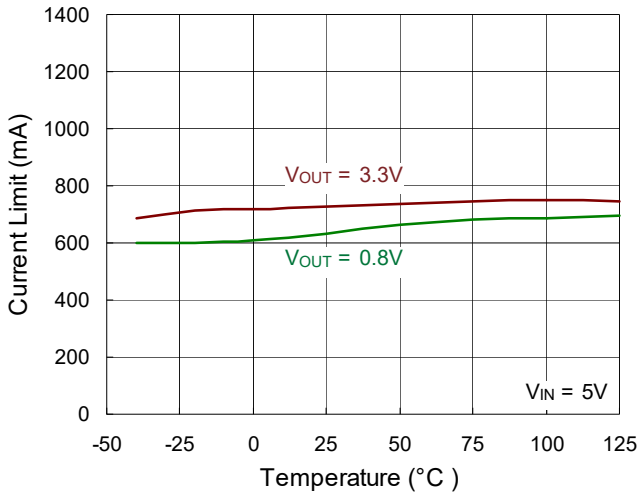
Dropout Voltage vs. Temperature



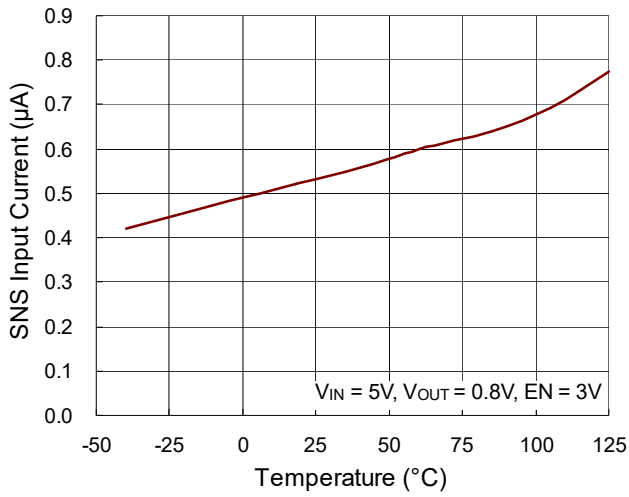
Current Limit vs. Temperature



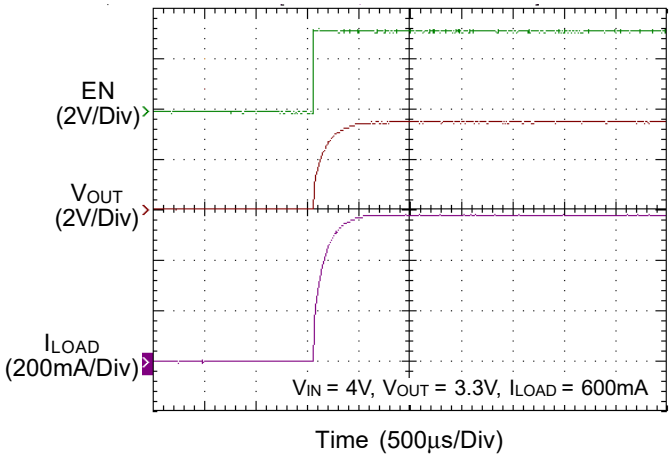
Fold-Back Current Limit vs. Temperature



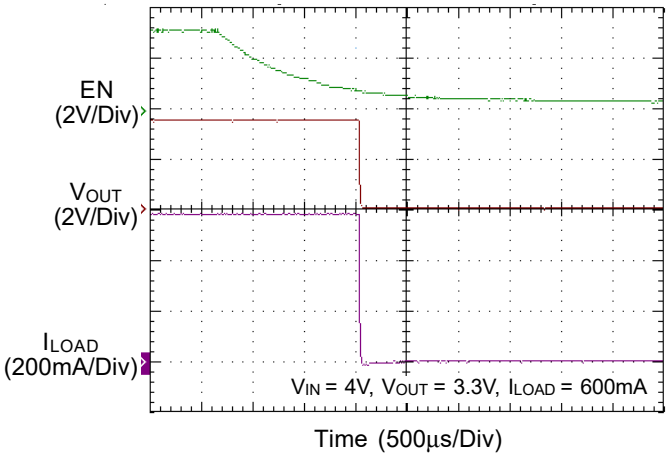
SNS Input Current vs. Temperature



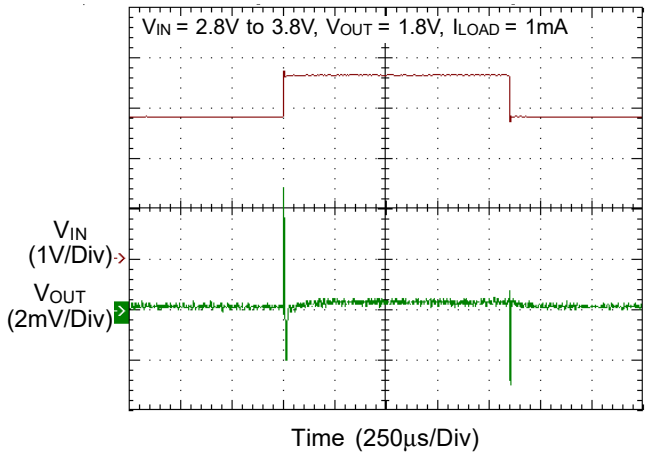
Power On from EN



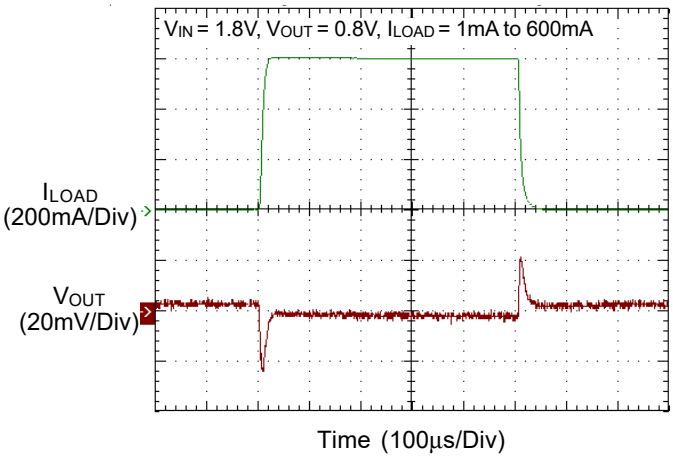
Power Off from EN

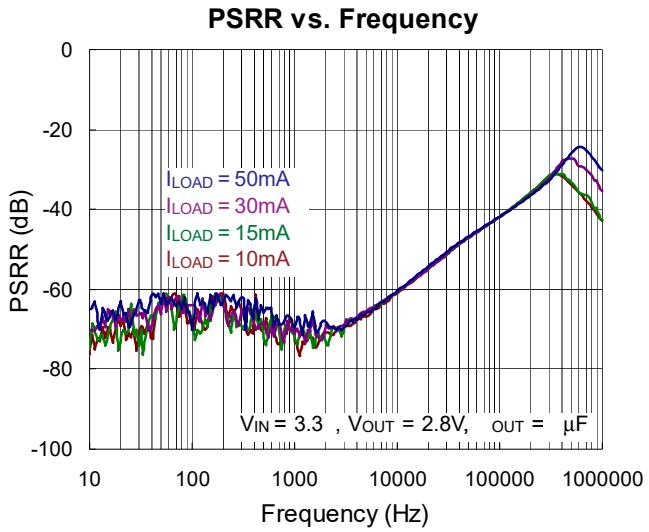


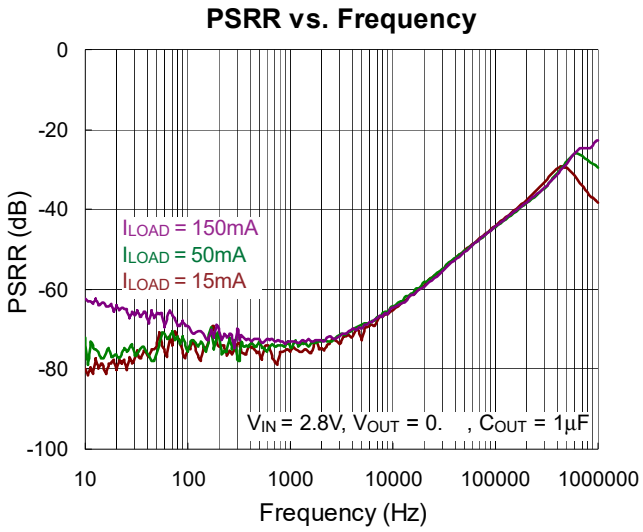
Line Transient

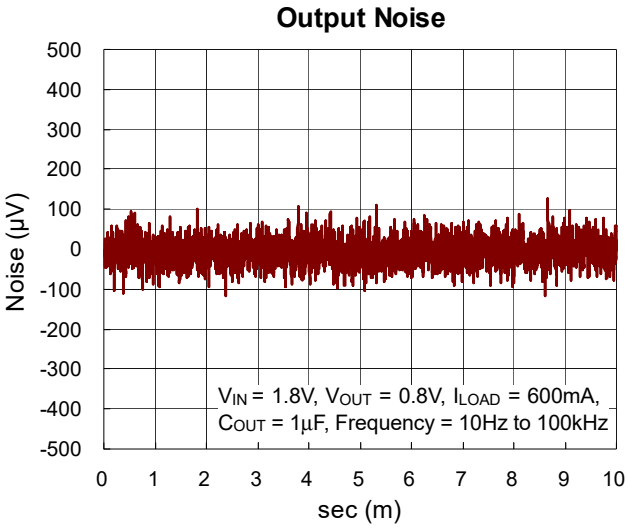


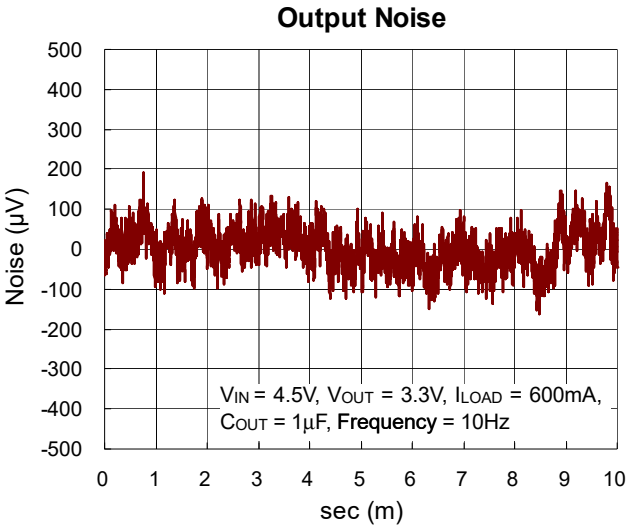
Load Transient




PSRR vs. Frequency
PSRR (dB)
0
-20
-40
-60
-80
-100
ILOAD = 50mA
ILOAD = 30mA
ILOAD = 15mA
ILOAD = 10mA
VIN = 3.3 , VOUT = 2.8V, OUT = µF
10
100
1000
10000
100000
1000000
Frequency (Hz)


PSRR vs. Frequency
PSRR (dB)
0
-20
-40
-60
-80
-100
ILOAD = 150mA
ILOAD = 50mA
ILOAD = 15mA
VIN = 2.8V, VOUT = 0. , COUT = 1µF
10
100
1000
10000
100000
1000000
Frequency (Hz)


Output Noise
Noise (µV)
500
400
300
200
100
0
-100
-200
-300
-400
-500
VIN = 1.8V, VOUT = 0.8V, ILOAD = 600mA,
COUT = 1µF, Frequency = 10Hz to 100kHz
0
1
2
3
4
5
6
7
8
9
10
sec (m)


Output Noise
Noise (µV)
500
400
300
200
100
0
-100
-200
-300
-400
-500
VIN = 4.5V, VOUT = 3.3V, ILOAD = 600mA,
COUT = 1µF, Frequency = 10Hz
0
1
2
3
4
5
6
7
8
9
10
sec (m)

Application Information

Like any low dropout linear regulator, the SK6018C's external input and output capacitors must be properly selected for stability and performance. Use a 1μF or larger input capacitor and place it close to the IC's VIN and GND pins. Any output capacitor meeting the minimum 1mΩ ESR (Equivalent Series Resistance) and effective capacitance larger than 1μF requirement may be used. Place the output capacitor close to the IC's VOUT and GND pins. Increasing capacitance and decreasing ESR can improve the circuit's PSRR and line transient response.

Enable

The SK6018C has an EN pin to turn on or turn off the regulator, When the EN pin is in logic high, the regulator will be turned on. The shutdown current is almost 0μA typical. The EN pin may be directly tied to V_{IN} to keep the part on. The Enable input is CMOS logic and cannot be left floating.

Adjustable Output Voltage Setting

Because of the small input current at the SNS pin, the SK6018CNS5 with SNS pin also can work as an adjustable output voltage LDO. Figure 3 gives the connections for the adjustable output voltage application. The resistor divider from VOUT to SNS sets the output voltage when in regulation.

The voltage on the SNS pin sets the output voltage and is determined by the values of R1 and R2. In order to keep a good temperature coefficient of output voltage, the values of R1 and R2 should be selected carefully to ignore the temperature coefficient of input current at the SNS pin. A current greater than 50μA in the resistor divider is recommended to meet the above requirement. The adjustable output voltage can be calculated using the formula given in equation 1 :

$$V_{OUT} = \frac{R1 + R2}{R2} \times V_{SNS} \quad (1)$$

where V_{SNS} is determined by the output voltage selections in the ordering information of the SK6018CNS5. The maximum adjustable output voltage can be as high as input voltage deducted by the dropout voltage.

When we choose 51kΩ and 16kΩ as R1 and R2 respectively, and select a 0.8V output at SNS pin, the adjustable output voltage will be set to around 3.35V. Its temperature coefficient in Figure 4 is still perfect in such kind of application.

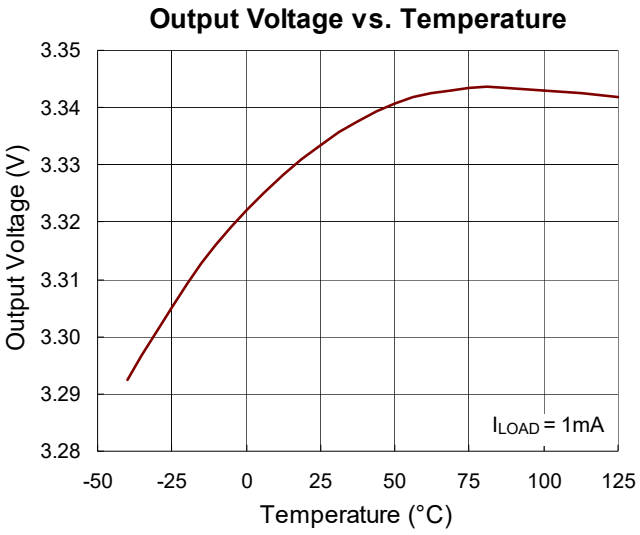


Figure 4. Temperature Coefficient of Adjustable Output Voltage

The minimum recommended 50μA in the resistor divider makes the application no longer an ultra low quiescent LDO. Figure 5 is another fine adjustable output voltage application can keep the LDO still operating in low power consumption. The fine tune range is recommended to be less than 50mV (R1 ≤ 91kΩ) in order to keep a good temperature coefficient of the output voltage.

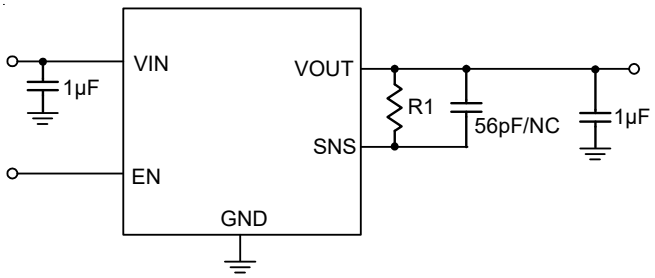


Figure 5. Fine Adjustable Output Voltage Application Circuit

There isn't extra current consumption in the above application. But the temperature coefficient of output voltage will be degraded by the input current at SNS pin. If the tuning range is larger than 50mV, a compensation capacitor (56pF) is required to keep the stability of output voltage. The fine adjustable output voltage is calculated using the formula given in equation2 :

$$V_{OUT} = V_{SNS} + I_{SNS} \times R1 \quad (2)$$

where I_{SNS} is the input Current at SNS pin (typical 550nA at room temperature) and VSNS is determined by the output voltage selections in the ordering information of the SK6018CNS5.

Current Limit

The SK6018C contains an independent current limiter, which monitors and controls the pass transistor's gate voltage, limiting the output current to 1.1A (typ.). The current limiting level is reduced to around 0.6A named fold-back current limit when the output voltage is further decreased. The output can be shorted to ground indefinitely without damaging the part.

Thermal Considerations

For continuous operation, do not exceed absolute maximum junction temperature. The maximum power dissipation depends on the thermal resistance of the IC package, PCB layout, rate of surrounding airflow, and difference between junction and ambient temperature. The maximum power dissipation can be calculated by the following formula :

$P_{D(MAX)} = (T_{J(MAX)} - T_A) / \theta_{JA}$

where $T_{J(MAX)}$ is the maximum junction temperature, T_A is the ambient temperature, and θ_{JA} is the junction to ambient thermal resistance.

For recommended operating condition specifications the maximum junction temperature is 125°C and T_A is the ambient temperature. The junction to ambient thermal resistance, θ_{JA}, is layout dependent. For SOT23-5 package, the thermal resistance, θ_{JA}, is 230.6°C/W on a standard JEDEC 51-7 four-layer thermal test board. For DFN1x1-4 package, the thermal resistance, θ_{JA}, is 226°C/W on a two-layer Richtek evaluation board. The maximum power dissipation at T_A = 25°C can be calculated by the following formula :

$P_{D(MAX)} = (125°C - 25°C) / (230.6°C/W) = 0.43W$ for SOT23-5 package

$P_{D(MAX)} = (125°C - 25°C) / (226°C/W) = 0.44W$ for DFN1x1-4 package

The maximum power dissipation depends on the operating ambient temperature for fixed $T_{J(MAX)}$ and thermal resistance, θ_{JA}. The derating curve in Figure 6 allows the designer to see the effect of rising ambient temperature on the maximum power dissipation.

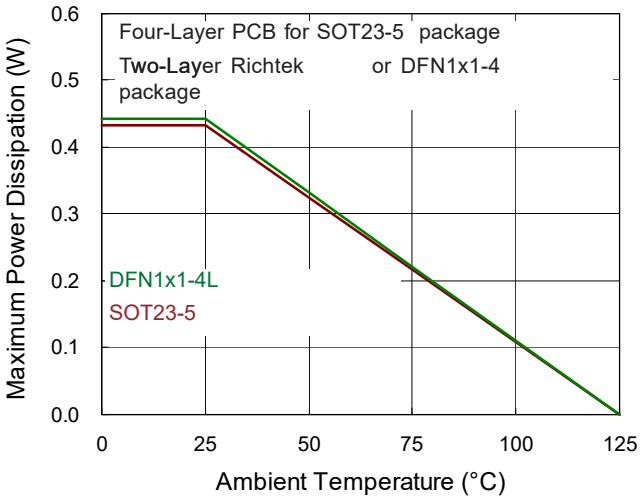
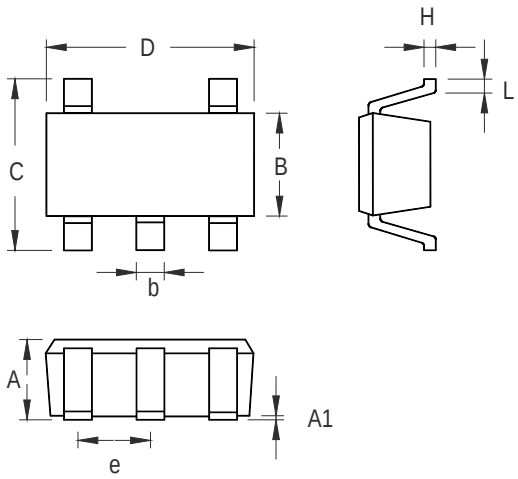


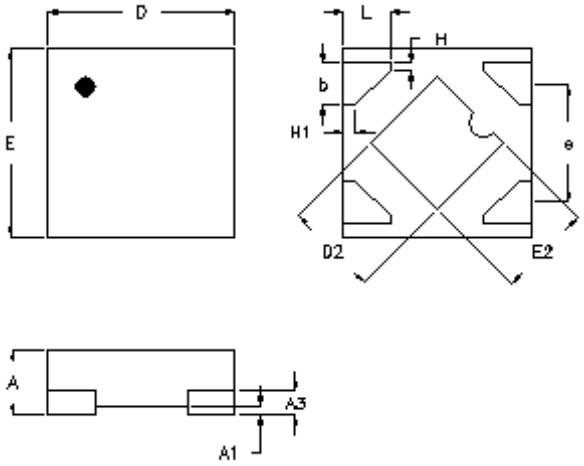
Figure 6. Derating Curve of Maximum Power Dissipation

Package Information: SOT23-5



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A	0.700	1.000	0.0 8	0.0 9
A1	0.000	0.100	0.0 0	0.0 4
B	1.397	1.803	0.0 5	0.0 1
b	0.300	0.559	0.0 2	0.0 2
C	2.591	3.000	0.102	0.118
D	2.692	3.099	0.1 6	0.1 2
e	0.838	1.041	0.0 3	0.0 1
H	0.080	0.254	0.0 3	0.0 0
L	0.300	0.610	0.0 2	0.0 4

Package Information: DFN1x1-4



Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min.	Max.	Min.	Max.
A	0.300	0.400	0.012	0.016
A1	0.000	0.050	0.000	0.002
A3	0.117	0.162	0.005	0.006
b	0.175	0.275	0.007	0.011
D	0.900	1.100	0.035	0.043
D2	0.450	0.550	0.018	0.022
E	0.900	1.100	0.035	0.043
E2	0.450	0.550	0.018	0.022
e	0.625		0.025	
L	0.200	0.300	0.008	0.012
H	0.039		0.002	
H1	0.064		0.003	