Unregulated 60mA Charge Pump Voltage Inverter

1 FEATURES

- **Inverts Input Supply Voltage**
- **Up to 60mA Output Current**
- **Only Three Small 3.3µF Ceramic Capacitors Needed**
- **Input Voltage Range From 1.5 V to 5.5 V**
- **Device Quiescent Current Typical 110µA**
- **Integrated Active Schottky-Diode for Start-up Into Load**
- **Package: SOT23-5**

2 APPLICATIONS

- **LCD Bias**
- **GaAs Bias for RF Power Amps**
- **Sensor Supply in Portable Instruments**
- **Bipolar Amplifier Supply**
- **Medical Instruments**
- **Battery-Operated Equipment**

3 DESCRIPTIONS

The RS6903 generates an unregulated negative output voltage from an input voltage ranging from 1.5V to 5.5V. Only three external capacitors are required to build a complete DC/DC charge pump inverter. Additional board area and component count reduction is achieved by replacing the Schottky diode that is typically needed for start-up into load by integrated circuitry. The RS6903 can deliver a maximum output current of 60mA with a typical conversion efficiency of greater than 85% over a wide output current range. The fixed switching frequency is 50kHz.

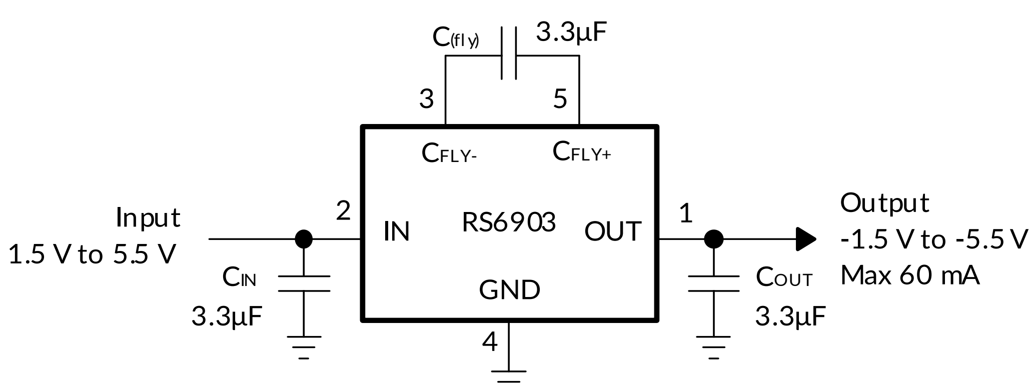
The RS6903 is available in SOT23-5 package. It operates over an ambient temperature range of -40℃ to +85℃.

Device Information (1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
RS6903	SOT23-5	2.92mm×1.60mm

(1) For all available packages, see the orderable addendum at the end of the data sheet.

4 Typical Application Circuit



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5 Revision History

Note: Page numbers for previous revisions may different from page numbers in the current version.

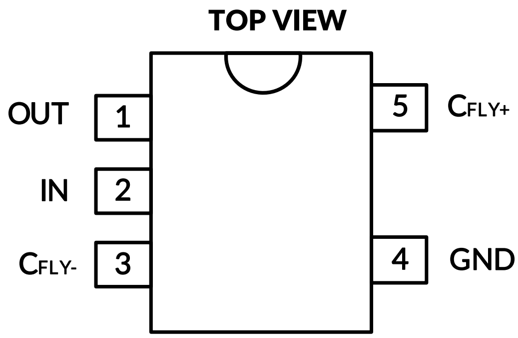
VERSION	Change Date	Change Item
A.0	2023/08/29	Preliminary version completed
A.1	2024/02/01	Initial version completed

6 PACKAGE/ORDERING INFORMATION [1]

PRODUCT	ORDERING NUMBER	TEMPERATURE RANGE	PACKAGE LEAD	PACKAGE MARKING [2]	MSL[3]	PACKAGE OPTION
RS6903	RS6903YF5	-40°C ~+85°C	SOT23-5	6903	MSL3	Tape and Reel,3000

NOTE:
(1) This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the right-hand navigation.
(2) There may be additional marking, which relates to the lot trace code information (data code and vendor code), the logo or the environmental category on the device.
(3) MSL, The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications.

7 PIN CONFIGURATIONS



SOT23-5

PIN DESCRIPTION

PIN SOT23-5	NAME	I/O (1)	FUNCTION
1	OUT	O	Power Output with V_{OUT} = -V_{IN}. Bypass OUT to GND with the output filter capacitor C_{OUT}
2	IN	I	Supply Input. Bypass IN to GND with a capacitor that has the same value as the flying capacitor.
3	C_{FLY-}	-	Negative Terminal of the Flying Capacitor C_{FLY}.
4	GND	G	Ground
5	C_{FLY+}	-	Positive Terminal of the Flying Capacitor C_{FLY}.

(1) I=input, O=output, P=power, G=Ground.

8 SPECIFICATIONS

8.1 Absolute Maximum Ratings

Over operating free-air temperature range (unless otherwise noted) [1]

SYMBOL	PARAMETER		MIN	MAX	UNIT
	Input Voltage Range on SW, VOUT, VCC, FB, EN		-0.3	5.5	V
θ_{JA}	Package thermal impedance [2]	SOT23-5		230	°C/W
T_J	Operating virtual junction temperature range [3]		-40	150	°C
T_{stg}	Storage Temperature		-55	150	°C
	Lead Temperature (Soldering, 10s)			260	°C

(1) Stresses beyond those listed under Absolute Maximum Ratings may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under Recommended Operating Conditions. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) The package thermal impedance is calculated in accordance with JESD-51.
(3) The maximum power dissipation is a function of $T_{J(MAX)}$, $R_{\theta JA}$, and T_A. The maximum allowable power dissipation at any ambient temperature is $P_D = (T_{J(MAX)} - T_A) / R_{\theta JA}$. All numbers apply for packages soldered directly onto a PCB.

8.2 ESD Ratings

The following ESD information is provided for handling of ESD-sensitive devices in an ESD protected area only.

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), MIL-STD-883K METHOD 3015.9	±1000	V
		Charged-device model (CDM), ANSI/ESDA/JEDEC JS-002-2018	±1000	

ESD SENSITIVITY CAUTION

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

8.3 Recommended Operating Conditions

SYMBOL	PARAMETER	MIN	MAX	UNIT
V_{IN}	Input supply voltage	1.5	5.5	V
I_{OUT}	Output current	0	60	mA
C_{IN}	Capacitor of V_{IN} pin	3.3	$C_{(FLY)}$	µF
C_{FLY}	Flying capacitor	3.3		µF
C_{OUT}	Capacitor of V_{OUT} pin	3.3	47	µF
ESR	Equivalent series resistance	5	100	mΩ
T_A	Operating temperature	-40	85	°C

8.4 ELECTRICAL CHARACTERISTICS

(C_{IN} = C_{OUT} =C_{fly} = 3.3µF, V_{IN}=5.0V, Full = -40°C to +85°C, typical values are at T_A = +25°C, unless otherwise noted.)

PARAMETER	SYMBOL	TEST CONDITIONS	TEMP	MIN(1)	TYP(2)	MAX(1)	UNIT
Input Voltage	V_{IN}		FULL	1.5		5.5	V
Output Voltage	V_O		+25°C		$-V_{IN}$		V
Static power consumption	I_Q	I_{OUT} = 0mA; V_{IN}=5.0V	+25°C		110	135	µA
			FULL			160	
Output Current			FULL	60			mA
Output Voltage ripple	V_{PP}	I_{OUT}= 5mA C(fly) = C_O = 3.3 µF (3)	+25°C		25		mV_{PP}
Internal Switching Frequency	f_{OSC}		FULL	43	50	57	kHZ
Impedance		V_{IN}=5V	+25°C		9	12	Ω
Thermal shutdown temperature	T_{SD}	T_J Increasing	-		145		°C
Thermal shutdown hysteresis	T_{SD_HY}		-		30		°C

(1) Limits are 100% production tested at 25°C. Limits over the operating temperature range are ensured through correlations using statistical quality control (SQC) method.

(2) Typical values represent the most likely parametric norm as determined at the time of characterization. Actual typical values may vary over time and will also depend on the application and configuration.

(3) Capacitor: TDK, CGA4J1X7R1E335KT0Y0E.

8.5 TYPICAL CHARACTERISTICS

NOTE: The graphs and tables provided following this note are a statistical summary based on a limited number of samples and are provided for informational purposes only.

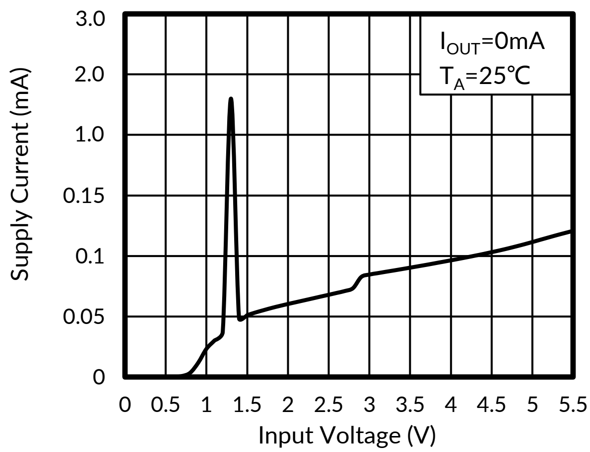


Figure 1. Supply Current vs Input Voltage

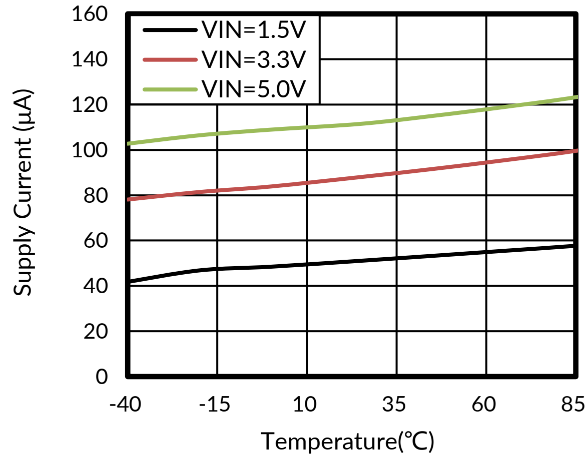


Figure 2. Supply Current vs Temperature

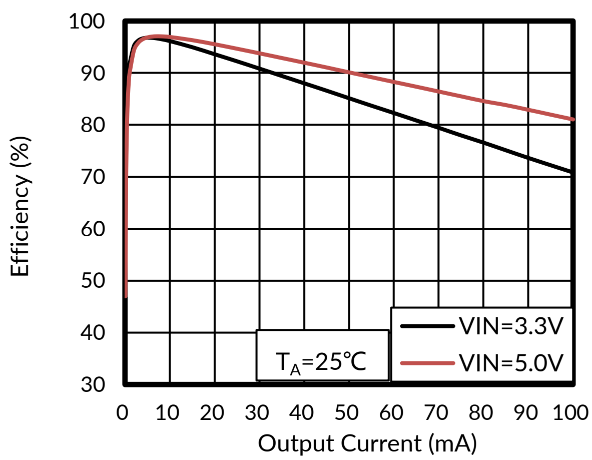


Figure 3. Efficiency vs Output Current

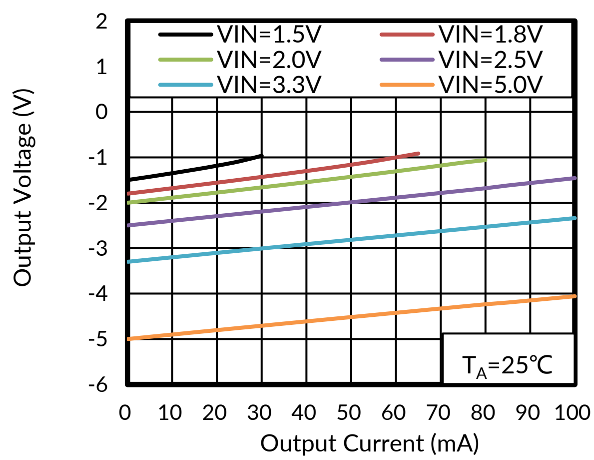


Figure 4. Output Voltage vs Output Current

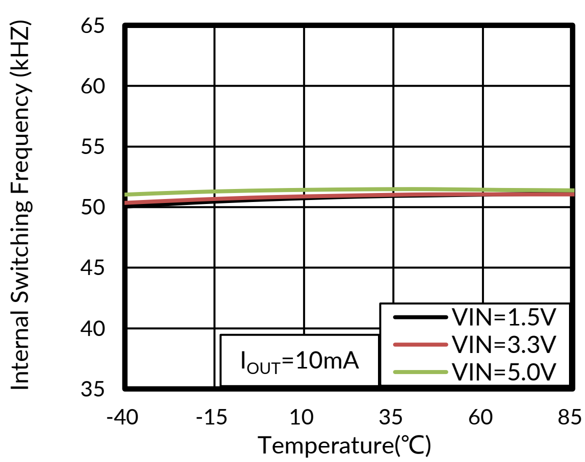


Figure 5. Internal Switching Frequency vs Temperature

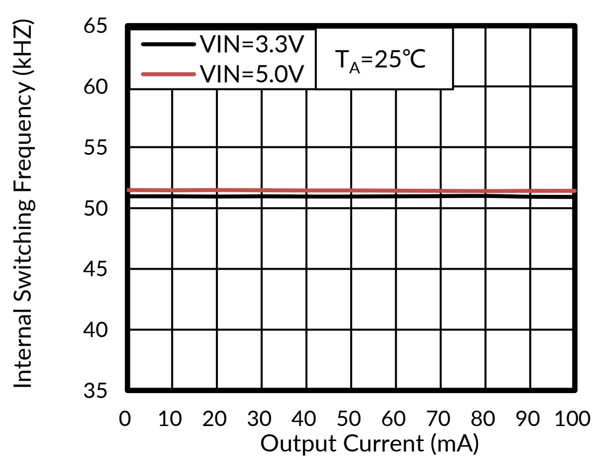


Figure 6. Internal Switching Frequency vs Output Current

TYPICAL CHARACTERISTICS

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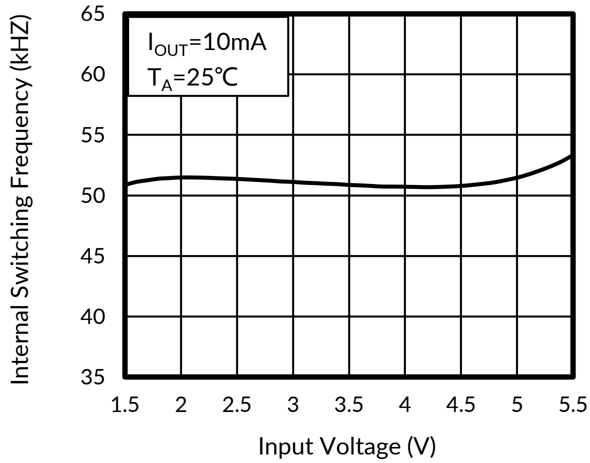


Figure 7. Internal Switching Frequency vs Input Voltage

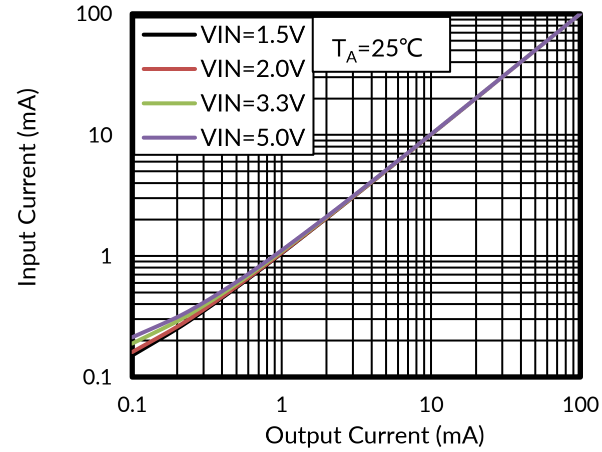


Figure 8. Input Current vs Output Current

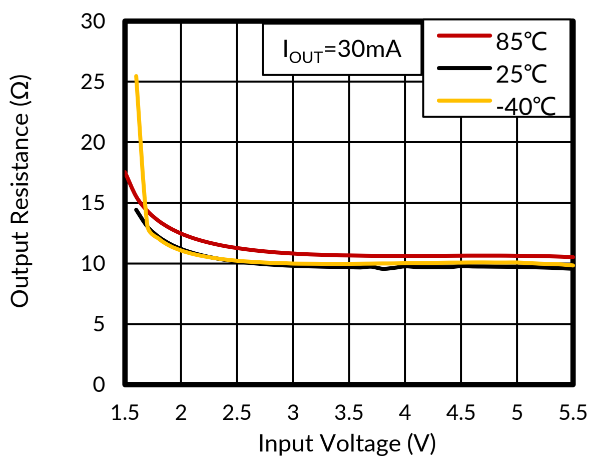


Figure 9. Output Resistance vs Input Voltage

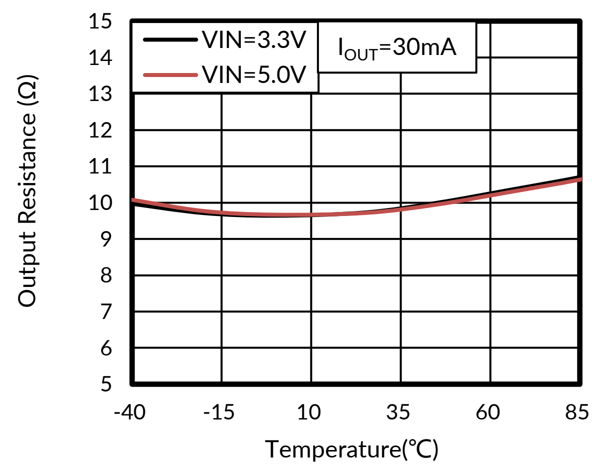


Figure 10. Output Resistance vs Temperature

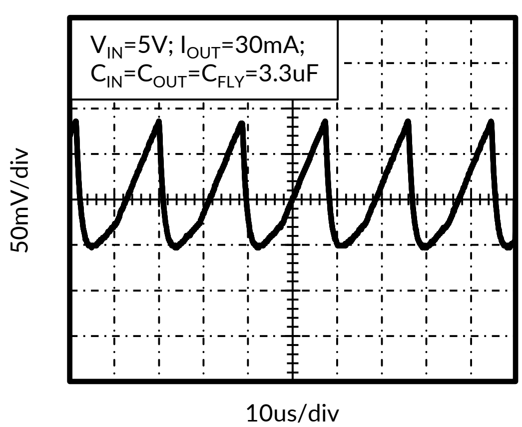


Figure 11. Output Voltage vs Time

9 DETAILED DESCRIPTION

9.1 Operating Principle

The RS6903 charge pump inverts the voltage applied to the input. For the best performance, use low equivalent series resistance (ESR) capacitors (e.g., ceramic). During the first half-cycle, switches S2 and S4 open, switches S1 and S3 close, and capacitor C_{FLY} charges to the voltage at V_{IN}. During the second half-cycle, S1 and S3 open and S2 and S4 close. This connects the positive terminal of C_{FLY} to GND and the negative to V_{OUT}. By connecting C_{FLY} in parallel, C_{OUT} is charged negative. The actual voltage at the output is more positive than $-V_{IN}$, since switches S1 - S4 have resistance and the load drains charge from C_{OUT}.

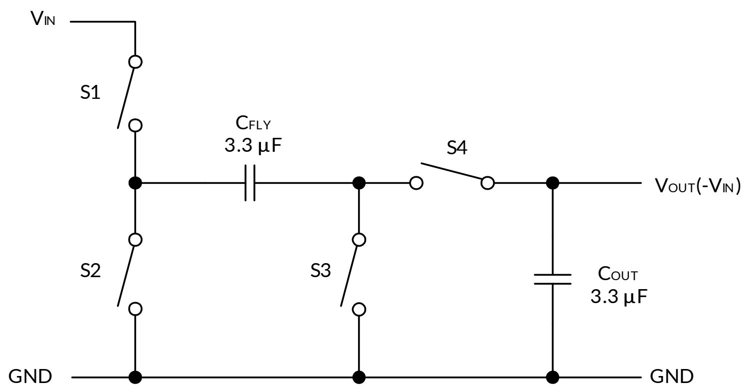


Figure 12. Operating Principle

9.2 Charge Pump Output Resistance

The RS6903 device is not voltage regulator. The charge pump output source resistance is approximately 9Ω at room temperature (with V_{IN} = 5V), and V_{OUT} approaches 5V when lightly loaded. V_{OUT} will droop toward GND as load current increases.

$$V_{OUT} = -(V_{IN} - R_{OUT} \times I_{OUT})$$

$$R_{OUT} \approx \frac{1}{f_{OSC} \times C_{FLY}} + 4(2R_{SWITCH} + ESR_{CFLY}) + ESR_{COUT}$$

Where:
R_{OUT} = output resistance of the converter
R_{SWITCH} = resistance of a single MOSFET-switch inside the converter
f_{OSC} = oscillator frequency

9.3 Efficiency Considerations

The power efficiency of a switched-capacitor voltage converter is affected by three factors: the internal losses in the converter IC, the resistive losses of the capacitors, and the conversion losses during charge transfer between the capacitors. The internal losses are associated with the IC's internal functions, such as driving the switches, oscillator, etc. These losses are affected by operating conditions such as input voltage, temperature, and frequency. The next two losses are associated with the voltage converter circuit's output resistance. Switch losses occur because of the on-resistance of the MOSFET switches in the IC. Charge pump capacitor losses occur because of their ESR. The relationship between these losses and the output resistance is as follows:

$$P_{CAPACITOR\ LOSSES} + P_{CONVERSION\ LOSSES} = I_{OUT}^2 \times R_{OUT}$$

The first term is the effective resistance from an ideal switched-capacitor circuit. Conversion losses occur during the charge transfer between C_{FLY} and C_{OUT} when there is a voltage difference between them. The power loss is:

$$P_{CONVERSION\ LOSS} = [\,1/2 \times C_{FLY}(V_{IN}^2 - V_{OUT}^2) + 1/2 C_{OUT}(V_{RIPPLE}^2 - 2V_{OUT}V_{RIPPLE})] \times f_{OSC}$$

The efficiency of the RS6903 is dominated by their quiescent supply current at low output current and by their output impedance at higher current.

$$\eta \cong \frac{I_{OUT}}{I_{OUT} + I_Q} \left(1 - \frac{I_{OUT} \times R_{OUT}}{V_{IN}}\right)$$

where, I_Q = quiescent current.

9.4 Input Capacitor (C_{IN})

Bypass the incoming supply to reduce its AC impedance and the impact of the RS6903 switching noise. The recommended bypassing depends on the circuit configuration and where the load is connected. When the inverter is loaded from OUT to GND, current from the supply switches between 2 × I_{OUT} and zero. Therefore, use a large bypass capacitor (e.g., equal to the value of C_{FLY}) if the supply has high AC impedance. When the inverter is loaded from IN to OUT, the circuit draws 2 × I_{OUT} constantly, except for short switching spikes. A 0.1μF bypass capacitor is sufficient.

9.5 Output Capacitor (C_{OUT})

Increasing the output capacitor's size reduces the output ripple voltage. Decreasing its ESR reduces both output resistance and ripple. Smaller capacitance values can be used with light loads if higher output ripple can be tolerated. Use the following equation to calculate the peak-to-peak ripple.

$$V_{OUT\ RIPPLE} = \frac{I_{OUT}}{f_{OSC} \times C_{OUT}} + 2 \times I_{OUT} \times ESR_{COUT}$$

9.6 Flying Capacitor (C_{FLY})

Increasing the flying capacitor's size reduces the output resistance. Small values increase the output resistance. Above a certain point, increasing C_{FLY}'s capacitance has a negligible effect, because the output resistance becomes dominated by the internal switch resistance and capacitor ESR.

9.7 Capacitor Selection

To maintain the lowest output resistance, use capacitors with low ESR (see Table 1). The charge pump output resistance is a function of C_{FLY}'s and C_{OUT}'s ESR. Therefore, minimizing the charge pump capacitor's ESR minimizes the total output resistance. The capacitor values are closely linked to the required output current and the output noise and ripple requirements. It is possible to only use 3.3μF capacitors of the same type.

Table 1. Recommended Capacitor Values

V_{IN} (V)	C_{IN} (μF)	C_{FLY} (μF)	C_{OUT} (μF)
1.5 to 5.5	3.3	3.3	3.3

9.8 Thermal Shutdown

Thermal shutdown is employed to protect device and load from damage. It shuts off the RS6903, if the die temperature exceeds 145°C until the die temperature drops to 115°C.

10 Power Supply Recommendations

The RS6903 device family has no special requirements for its power supply. The power supply output needs to be rated according to the supply voltage, output voltage and output current of the RS6903.

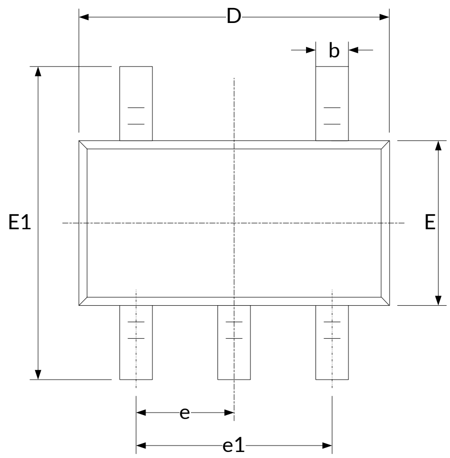
11 Layout

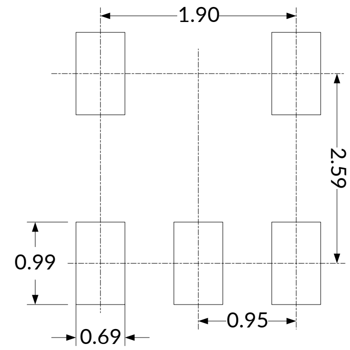
11.1 Layout Guidelines

All capacitors should be soldered as close as possible to the IC. Care has been taken to connect all capacitors as close as possible to the circuit to achieve optimized output voltage ripple performance.

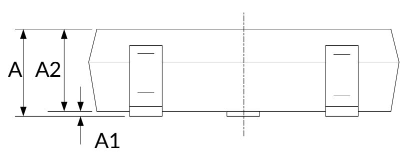
12 PACKAGE OUTLINE DIMENSIONS

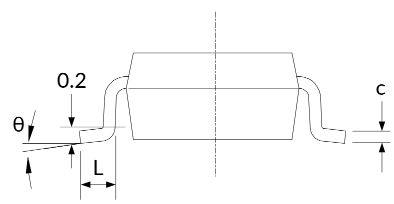
SOT23-5 (3)





RECOMMENDED LAND PATTERN (Unit: mm)





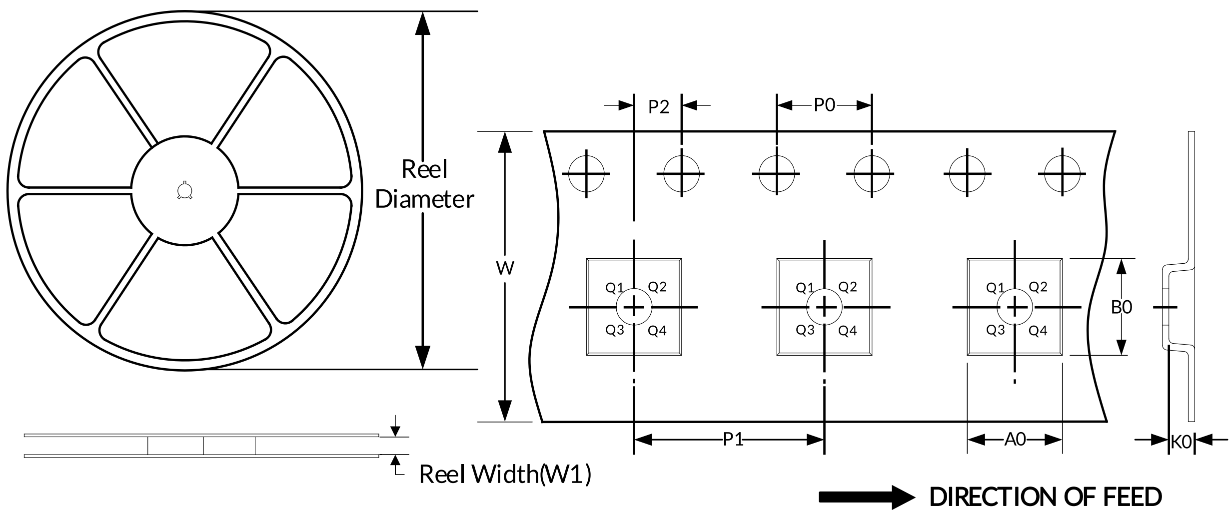
Symbol	Dimensions In Millimeters		Dimensions In Inches	
	Min	Max	Min	Max
A (1)	1.050	1.250	0.041	0.049
A1	0.000	0.100	0.000	0.004
A2	1.050	1.150	0.041	0.045
b	0.300	0.500	0.012	0.020
c	0.100	0.200	0.004	0.008
D (1)	2.820	3.020	0.111	0.119
E (1)	1.500	1.700	0.059	0.067
E1	2.650	2.950	0.104	0.116
e	0.950(BSC) (2)		0.037(BSC) (2)	
e1	1.800	2.000	0.071	0.079
L	0.300	0.600	0.012	0.024
θ	0°	8°	0°	8°

NOTE:

1. Plastic or metal protrusions of 0.15mm maximum per side are not included.
2. BSC (Basic Spacing between Centers), "Basic" spacing is nominal.
3. This drawing is subject to change without notice.

13 TAPE AND REEL INFORMATION

REEL DIMENSIONS **TAPE DIMENSION**



NOTE: The picture is only for reference. Please make the object as the standard.

KEY PARAMETER LIST OF TAPE AND REEL

Package Type	Reel Diameter	Reel Width (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P0 (mm)	P1 (mm)	P2 (mm)	W (mm)	Pin1 Quadrant
SOT23-5	7''	9.5	3.20	3.20	1.40	4.0	4.0	2.0	8.0	Q3

NOTE:
1. All dimensions are nominal.
2. Plastic or metal protrusions of 0.15mm maximum per side are not included.

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