Power Multiplexer for USB High Side Switch

❖ GENERAL DESCRIPTION

The AX8701 is a current limited power multiplexer acting as a high side switch for USB applications where heavy capacitive loads and short-circuits is likely to be encountered. It switches output voltage to 5VSB at S3/S4/S5 states with 200mΩ switch and 500mA capacity; to 5VCC at S0/S1/S2 states with 80mΩ switch and 1.5A capacity.

This device features an active-high enable control input. Soft start function limits the inrush current from supply input when enabled. Disabling the device reduces its standby current down to less than 1uA.

Optimal switch logic according to S3# and 5VCC status ensures seamless output voltage transition.

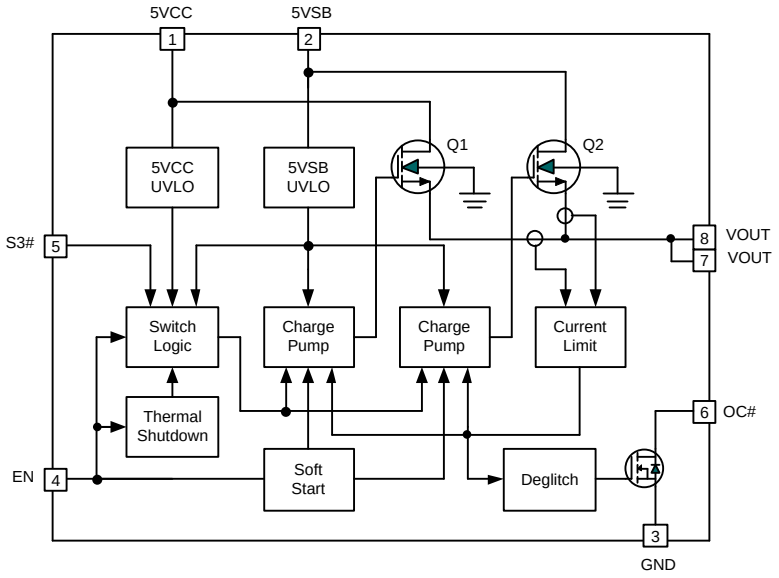
When the output load exceeds the current-limit threshold or a short is present, the AX8701 asserts overcurrent protection and limits the output current to a safe level by driving the power switches into saturation mode.

Other features include soft-start to limit inrush current during plug-in, thermal shutdown to prevent catastrophic switch failure from high-current loads, under-voltage lockout (U_{VLO}) to ensure that the device remains off unless there is a valid input voltage present. The AX8701 is available in SOT-23-8L and SOP-8L packages.

❖ FEATURES

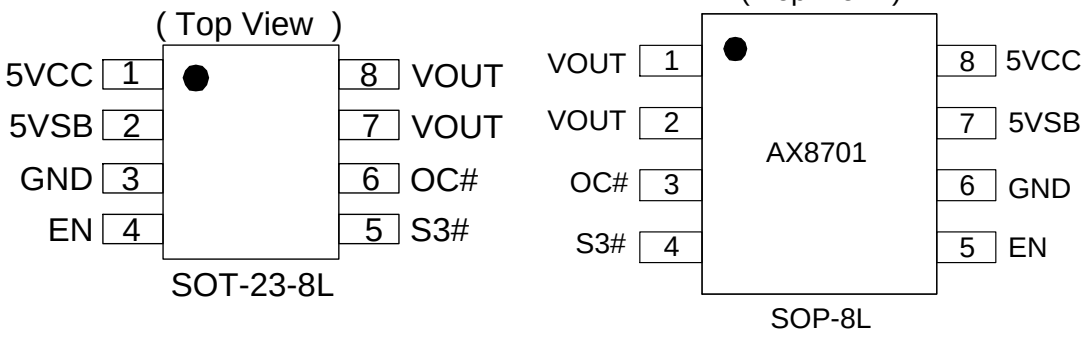
- Compliant to USB Specifications
- Operating Range: 4.5 V to 5.5 V
- Output Voltage Switch to 5VSB at S3/S4/S5
- 500mA Continuous Load Current
- 200mΩ High Side Switch
- Output Voltage Switch to $5V_{CC}$ at S0/S1/S2
- 1.5A Continuous Load Current
- 80mΩ High Side Switch
- Low Quiescent Current: 50uA Typical
- Low Standby Current: Less Than 1uA
- Slow Turn On and Fast Turn Off
- Enable Active-High
- RoHS Compliant and Halogen Free
- UL Approved-E353665

❖ BLOCK DIAGRAM



❖ PIN ASSIGNMENT

The packages of AX8701 are SOT-23-8L and SOP-8L; the pin assignment is given by:



Name	Description
5VCC	Supply Input from $5V_{CC}$. This pin is the N-Channel MOSFET Drain that supplies output current at S0/S1/S2 states and should be connected to 5VCC. Bypass this pin with a minimum 1uF capacitor to ground.
5VSB	Supply Input. This pin is the N-Channel MOSFET Drain that supplies output current at S3/S4/S5 states and should be connected to 5VSB. This pin also supplies operating current for the device. Bypass this pin with a minimum 1μF capacitor to ground.
GND	Ground.
EN	Enable Input. This is the enable input to turn on/off the power switch. Pulling low this pin shuts down the device.
S3#	Sleep State Control Pin. This pin along with the $5V_{CC}$ status controls the switching configuration.
OC#	Fault Flag. This is an active-low, open-drain fault flag output for the power switch. The AX8701 asserts this pin low when fault occurs with typical 8ms deglitch delay.
VOUT	Output Voltage. These pins are output from N-Channel MOSFET Sources. Bypass these pins with a minimum 10uF capacitor to ground.

❖ ORDER/MARKING INFORMATION

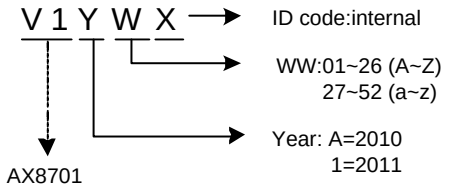
Order Information

AX8701 X X

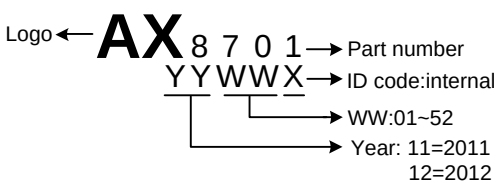
Package Type
L: SOT-23-8L
S: SOP-8L

Packing
Blank: Tube
A : Taping

Top Marking (SOT-23-8L)



Top Marking (SOP-8L)



❖ ABSOLUTE MAXIMUM RATINGS (at T_A=25°C)

Characteristics		Symbol	Rating	Unit
Supply Input Voltage		$5V_{SB}$	-0.3 to +5.7	V
Other Pins			-0.3 to +5.7	V
Junction Temperature			150	°C
Storage Temperature Range		T_S	-65 to +150	°C
Lead Temperature (Soldering, 10 sec)			260	°C
ESD Rating (Note 2)	HBM(Human Body Mode)		2	kV
	MM (Machine Mode)		200	V
Package Power Dissipation		P_D	Internally limited	mW
Operating Junction Temperature Range (Note 4)			-40 to +125	°C
Operating Ambient Temperature Range			-40 to +85	°C
UL evaluated the device with a storage temperature			-30 to +70	°C
Thermal Resistance from Junction to case	SOT-23-8L	θ_{JC}	125	°C/W
	SOT-8L		60	
Thermal Resistance from Junction to ambient	SOT-23-8L	θ_{JA}	250	°C/W
	SOT-8L		160	

❖ ELECTRICAL CHARACTERISTICS

($5V_{SB}$=5V, T_A=25°C, unless otherwise noted)

Characteristics	Symbol	Conditions	Min	Typ	Max	Units
Supply Input 5VSB						
Supply Input Voltage Range			4.5	-	5.5	V
Under Voltage Lockout	V_{UVLO}	$5V_{SB}$ rising	-	4.3	4.5	V
UVLO Hysteresis			-	80	-	mV
Shutdown Current	I_{SD}	No load on V_{OUT}, Disabled	-	0.01	1	μA
Quiescent Current	I_Q	No load on V_{OUT}, Enabled, S3# = 0, $5V_{CC}$ = 0V	-	50	70	μA
Supply Input 5VCC						
Supply Input Voltage Range			4.5	-	5.5	V
Under Voltage Lockout	V_{UVLO}	$5V_{CC}$ rising	-	4.3	4.5	
UVLO Hysteresis			-	80	-	mV
Enable Control						
High Level Threshold			1.0	0.7	-	V
Low Level Threshold			-	0.7	0.4	V
Enable Pin Input Current			-1	-	1	μA
Enable Delay	T_{D_EN}	Enable threshold to V_{OUT} starting to ramp up	-	0.15	1	ms
Power Switch for 5VSB (Q2)						
N-MOSFET ON Resistance	$R_{DS(ON)}$	I_{OUT} = 100mA	-	200	300	mΩ
Leakage Current		V_{OUT} connected to GND, Disabled	-	-	1	μA
Reverse Leakage Current		V_{OUT} = 5.5V, 5VSB = 0V	-	-	1	μA
Power Switch for 5VCC (Q1)						
N-MOSFET ON Resistance	$R_{DS(ON)}$	I_{OUT} = 1A @ 25°C	-	80	105	mΩ
Leakage Current		$5V_{CC}$ = 5.5V, V_{OUT} = 0V, Disabled	-	-	1	μA
Reverse Leakage Current			-	-	1	μA
Current Limit						
Current Limit Threshold for Q2			1.0	1.5	3.0	A
Current Limit Threshold for Q1			1.2	2.3	4.6	A
OC# Output Low Voltage		$I_{OC\#}$ = 5mA	-	-	0.4	V
Off State Current		V_{OC} # = 5.5V	-	-	1	μA
OC# Deglitch		OC# assertion	4	8	15	ms
		OC# de-assertion	150	250	500	μs
Soft start						
Output Voltage Ramp Up Time		S3# = 0V, C_{OUT} = 10uF, No Load	-	1.3	-	ms
		S3# = $5V_{CC}$ = 5V, C_{OUT} = 10uF, No Load	-	1.3	-	ms

❖ ELECTRICAL CHARACTERISTICS (CONTINUOUTS)

Over Temperature Protection						
Thermal Shutdown Threshold Level		By Design	-	135	-	°C
Thermal Shutdown Hysteresis		By Design	-	30	-	°C

Note1: Stresses beyond those listed as the above Absolute Maximum Ratings may cause permanent damage to the device. These are for stress ratings only. Functional operation of the device at these or any other conditions beyond those indicated in the Recommended Operation Condition section of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may remain possibility to affect device reliability.

Note2: Devices are ESD sensitive. Handling precaution recommended.

Note3: θ_{JA} is measured in the natural convection at T_A = 25°C on a low effective thermal conductivity test board of JEDEC 51-3 thermal measurement standard.

Note4: The device is not guaranteed to function outside its operating conditions.

Note5: These items are not tested in production, specified by design.

❖ FUNCTIONAL DESCRIPTION

Power Switches

The AX8701 is a current limited power multiplexer acting as a high side switch for USB applications where heavy capacitive loads and short-circuits is likely to be encountered. It contains two N-Channel MOSFETs Q1 and Q2 as power switches that supply output current to V_{OUT} pins. The sources of Q1 and Q2 are connected together to the V_{OUT} pins, the drain of Q1 is connected to $5V_{CC}$ pin and the drain of Q2 is connected to 5VSB pin. The MOSFETs are without body diode and prevent current flows when turned off.

Q2 is a 200mΩ MOSFET with 500mA capacity and Q1 is an 80mΩ MOSFET with 1.5A capacity. The power switches are driven by internal charge pumps and controlled by S3# and enable status. The AX8701 switches the output voltage to 5VSB through Q2 at S3/S4/S5 states, to $5V_{CC}$ through Q1 at S0/S1/S2 states.

Charge Pumps and Drivers

An internal charge pump supplies power to the driver circuit and provides the necessary voltage to pull the gate of the MOSFET above the source. The driver controls the gate voltage of the power switch. To limit large current surges and reduce the associated electromagnetic interference (EMI) produced, the driver incorporates circuitry that controls the rise times and fall times of the output voltage.

Chip Enable

The EN pin receives a TTL or CMOS compatible input to enable/disable the AX8701. Logic low disables the power switch, charge pump, gate driver and other circuitry and reduces the supply current down to less than 1uA. Logic high restores bias to the drive and control circuits and turns the switch on.

Soft Start

The AX8701 features soft start function to eliminate the inrush current into downstream and voltage drop of upstream when hot-plug-in with capacitive loads. The soft start interval is 1.3ms typically. The input current to charge up the load capacitor is proportional to its capacitance. The AX8701 current limit function may be active during the plug-in of extreme large capacitive load.

Over Current Limit

The AX8701 continuous monitors the output current for overcurrent protection to protect the system power, the power switch, and the load from damage during output short circuit or soft start interval. When an overload or short circuit is encountered, the current-sense circuitry sends a control signal to the driver. The driver in turn reduces the gate voltage and drives the power FET into its saturation region, which switches the output into a constant-current mode and holds the current constant while varying the voltage on the load. The current limit level is typical 2.3A when the power switch operates in linear region and is typical 1.5A in saturation region.

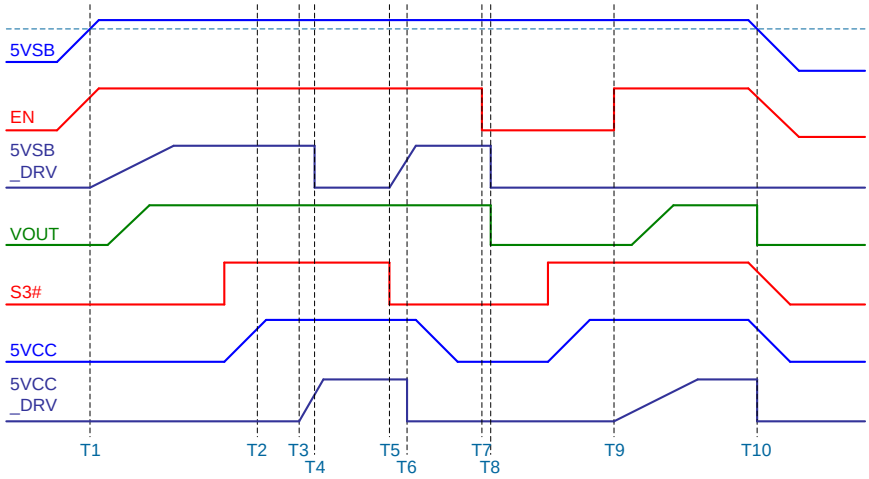
The AX8701 asserts fault condition and pulls low OC# when overcurrent, over temperature, input under voltage lockout condition is encountered. The output remains asserted until the overcurrent or over temperature condition is removed. A 8ms deglitch circuit prevents the OC# signal from oscillation or false triggering. If an over temperature shutdown occurs, the OC# is asserted instantaneously.

Under voltage Lockout

A voltage sense circuit monitors the input voltage. When the input voltage is below approximately 4.2V, a control signal turns off the power switch.

Over temperature Protection

The AX8701 continuously monitors the operating temperature of the power switch for over temperature protection. The AX8701 asserts over temperature and turns off the power switch to prevent the device from damage if the junction temperature rises to approximately 135°C due overcurrent or short-circuit conditions. Hysteresis is built into the thermal sense; the switch will not turns back on until the device has cooled approximately 20 degrees. The open-drain false reporting output (OC#) is asserted (active low) when an over temperature shutdown or overcurrent occurs. If the fault condition is not removed, the switch will pulse on and off as the temperature cycles between these limits.



❖ APPLICATION INFORMATION

The AX8701 is a current limited power multiplexer acting as a high side switch for USB applications where heavy capacitive loads and short-circuits is likely to be countered.
It switches output voltage to $5V_{SB}$ at S3/S4/S5 states with 200mΩ switch and 500mA capability; to $5V_{CC}$ at S0/ S1/S2 states with 80mΩ switch and 1.5A capability.

This device features an active-high enable control input. Soft start function limits the inrush current from supply input when enabled. Disabling the device reduces its standby current down to less than 1uA. Optimal switch logic according to S3# and 5VCC status ensures seamless output voltage transition. When the output load exceeds the current-limit threshold or a short is present, the AX8701 asserts overcurrent protection and limits the output current to a safe level by driving the power switches into saturation mode.

Other features include soft-start to limit inrush current during plug-in, thermal shutdown to prevent catastrophic switch failure from high-current loads, under-voltage lockout (U_{VLO}) to ensure that the device remains off unless there is a valid input voltage present. The AX8701 is available in SOT-23-8L package.

Input and output capacitors

Bypass the supply input pins with a single 1μF capacitor as close as possible to the AX8701. A 10μF output capacitor at the output pin is recommended even much larger output capacitors are already available at the output of the AX8701, especially if the output capacitors are more than 2 inches away on the PCB. The inrush current to charge the output capacitors is calculated as:

$$I_{IN} = C_{OUT} \times \frac{V_{OUT}}{T_{SS}} (A)$$

Special care should be paid to large output capacitor applications. Take C_{OUT} = 1000uF as example, the inrush current is I_{IN} = 1000uF x 5V / 1.3ms = 3.8A. This is higher than the current limit threshold of Q1 and Q2. In this case, the output voltage ramp up time is controlled by the current limit function of Q1 and Q2. Fault indication function may be false triggered and pull low the OC# as shown in Figure 1.

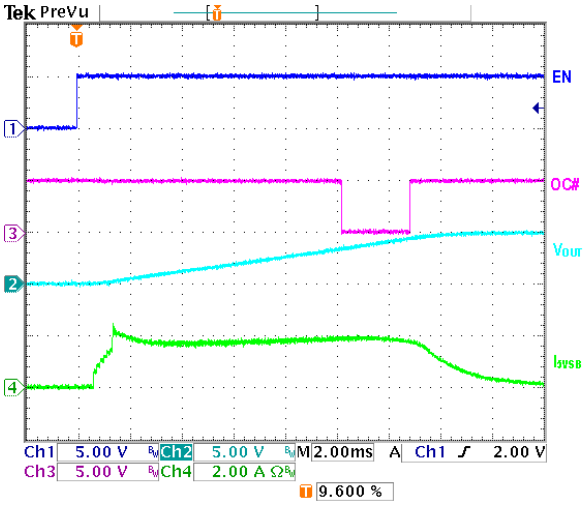


Figure1. Turn on into $5V_{SB}$ with 5000μF output capacitor.

Hot Plug Application

The output voltage undergoes an abrupt drop when a device with large input capacitors is hot plugged into the output of AX8701 as shown in Figure 2, where a device with 2000μF is hot plugged into AX8701 output with 470μF output capacitor. The output voltage ramp up time is controlled by the current limit level.

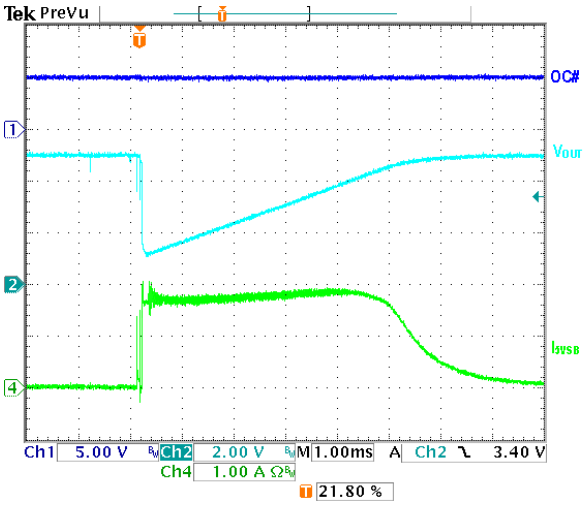
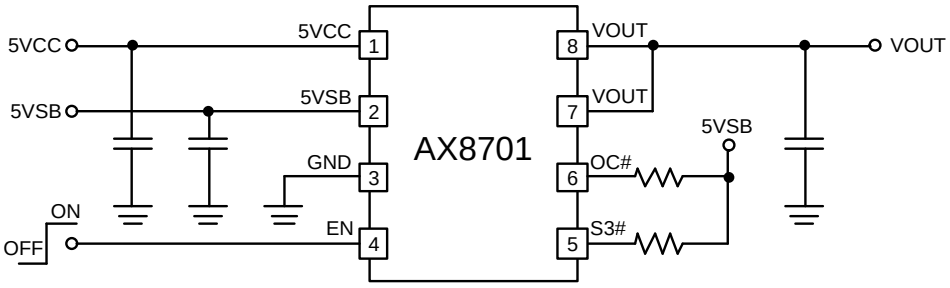


Figure2. Hot plug application with S3# = 0V.

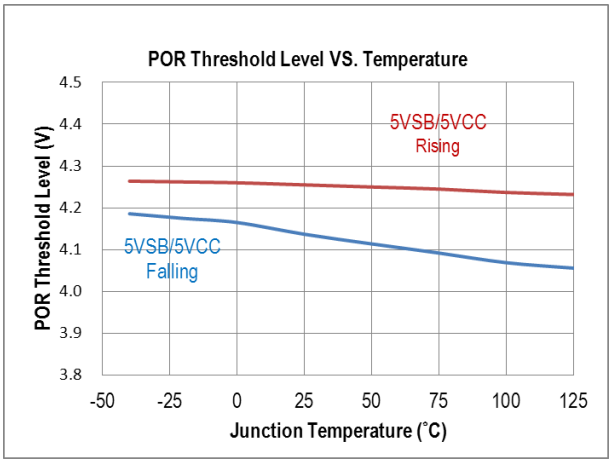
Thermal Consideration

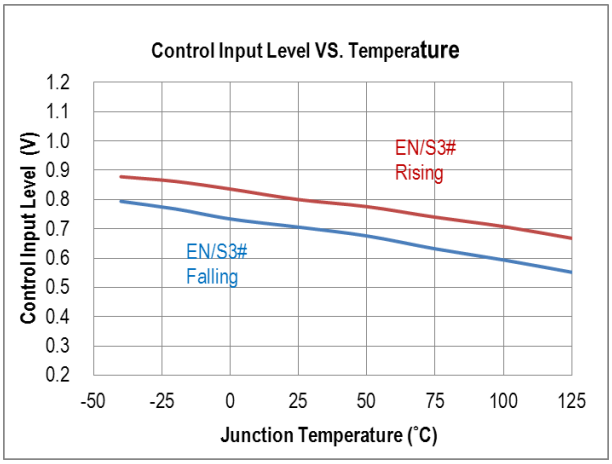
Temperature effect should be well considered when dealing with voltage drop and power dissipation. The maximum $R_{DS(ON)}$ of the power switch is 80mΩ of Q1 under 25°C junction temperature. If the device is expected to operate at 125°C junction temperature, the $R_{DS(ON)}$ of Q1 will become 80mΩ * (1 + (125°C - 25°C) * 0.5%/°C) = 120mΩ
where 0.5%/°C is the approximated temperature coefficient of the $R_{DS(ON)}$.
If the maximum load current is expected to be 1.2A, the maximum voltage will become
1.2A * 100mΩ = 120mV
This in turn will cause power dissipation as
1.2A * 120mV = 144mW
The temperature raise is calculated as
144mW * 250°C/W = 36°C
The junction temperature is calculated as TA + 36°C, where
T_A is the expected maximum ambient temperature. A few iterations are required until get final solutions.

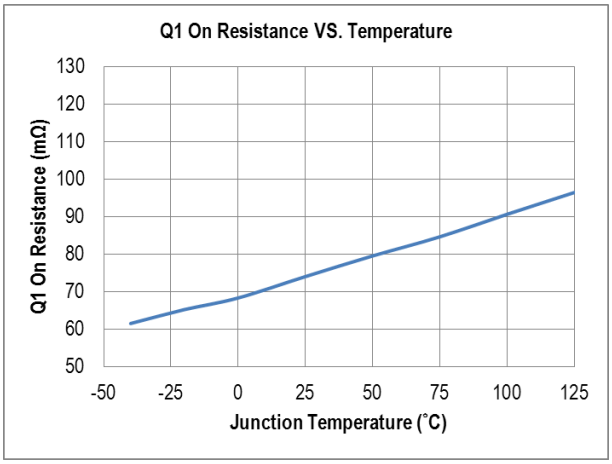
❖ APPLICATION CIRCUIT

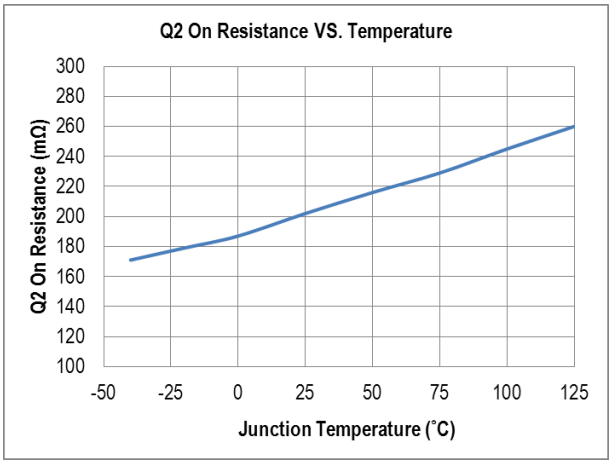


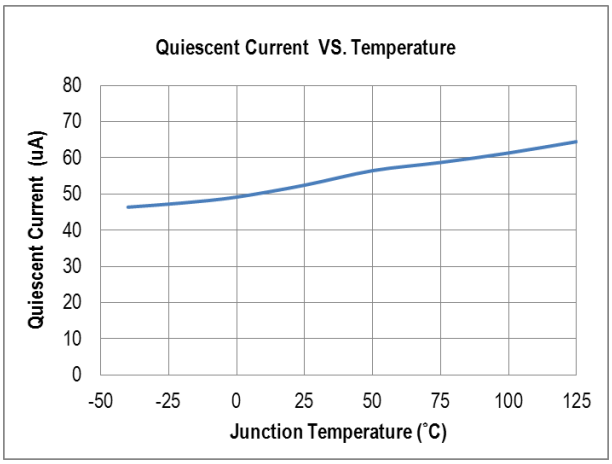
❖ TYPICAL CHARACTERISTICS





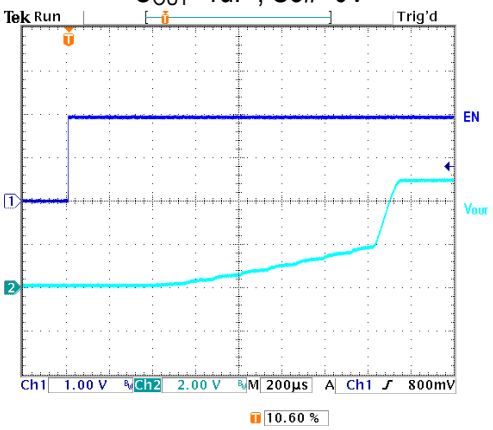




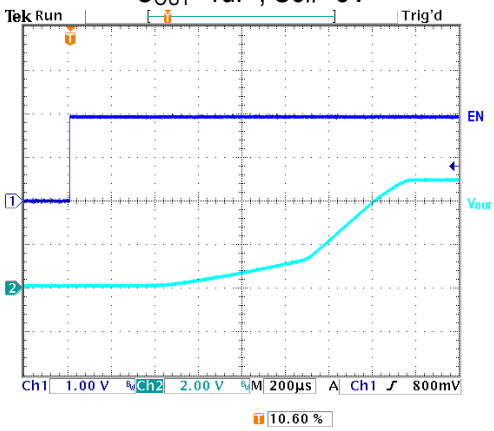


❖ TYPICAL CHARACTERISTICS (CONTINUES)

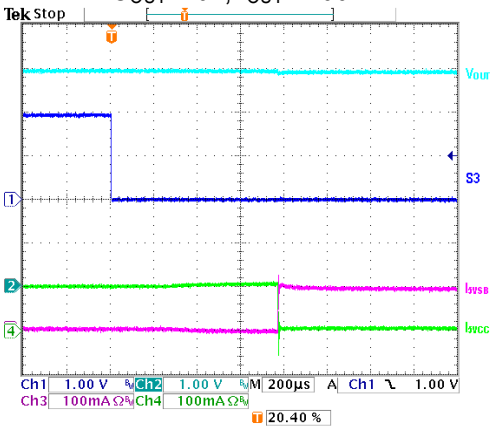
Turn On into 5VSB
C_{OUT}=1uF , S3#=0V



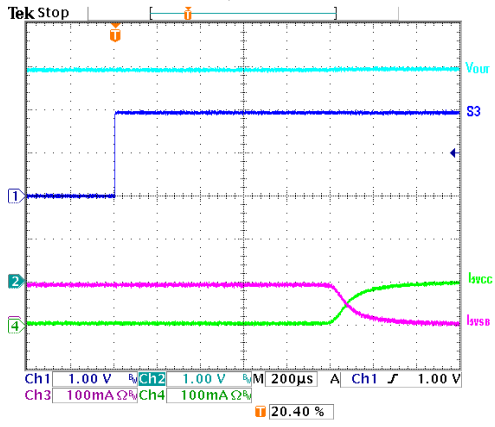
Turn On into 5VCC
C_{OUT}=1uF , S3#=5V



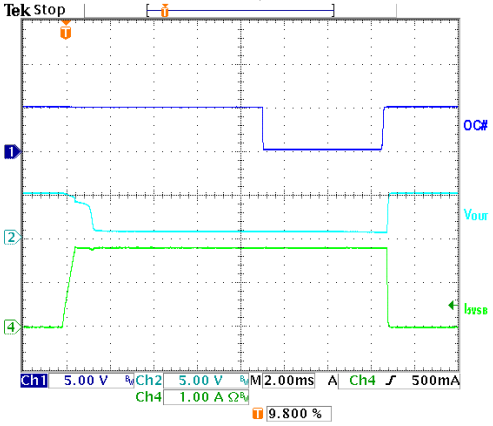
S3# High to Low
C_{OUT}=1uF, I_{OUT} =100mA



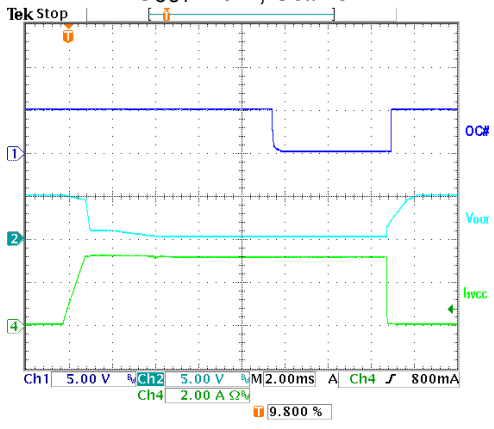
S3# Low to High
C_{OUT}=1uF, I_{OUT} =100mA



OCP for 5VSB
C_{OUT}=1uF , S3#=0V

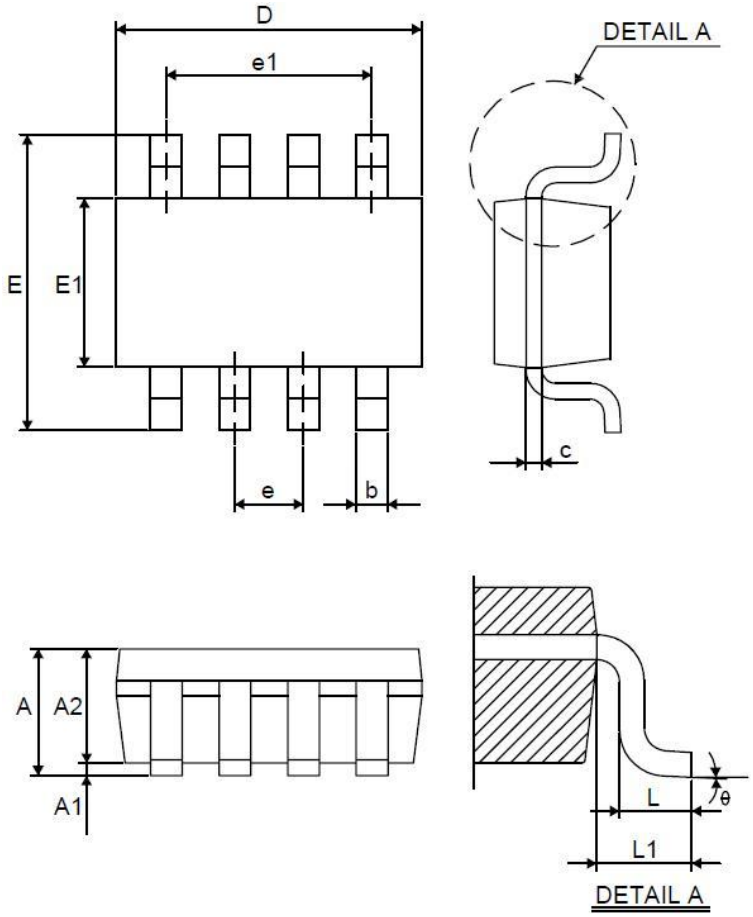


OCP for 5VCC
C_{OUT}=1uF , S3#=5V



❖ PACKAGE OUTLINES

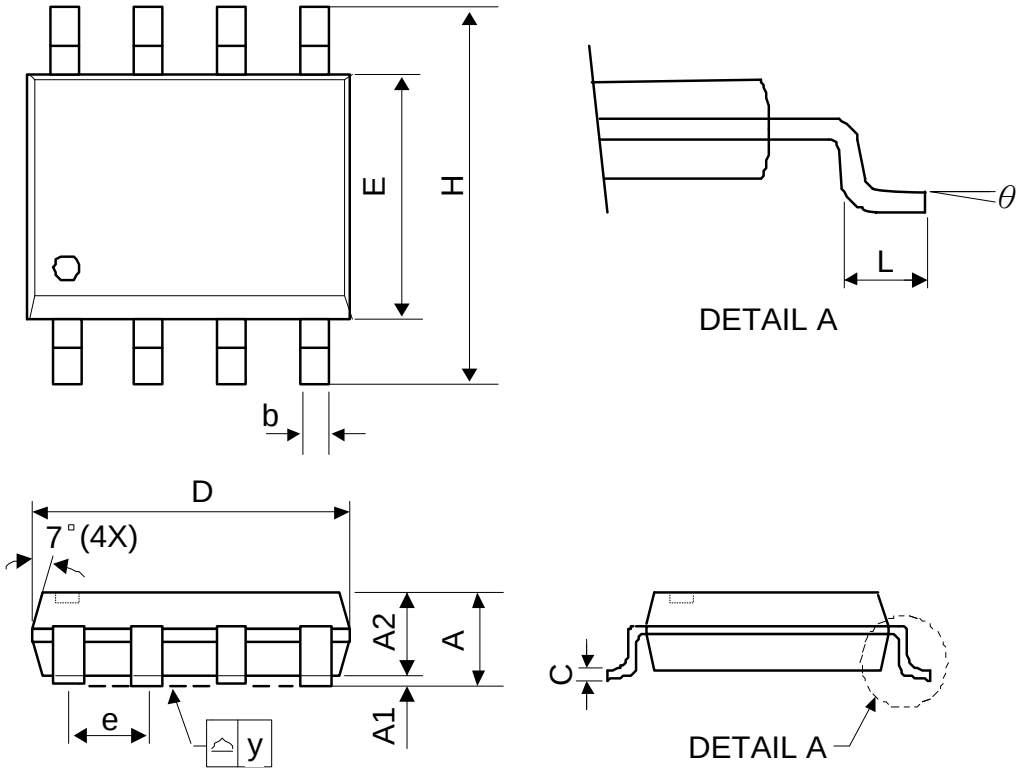
(1) SOT-23-8L



Symbol	Dimensions in Millimeters			Dimensions in Inches		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	-	-	1.45	-	-	0.057
A1	0.00	-	0.15	0	0.003	0.006
A2	0.90	1.10	1.30	0.035	0.043	0.051
b	0.22	0.30	0.38	0.012	0.016	0.020
C	0.08	-	0.22	0.003	0.006	0.009
D	2.70	2.90	3.10	0.106	0.114	0.122
E1	1.40	1.60	1.80	0.055	0.063	0.071
E	2.60	2.80	3.00	0.102	0.110	0.118
L	0.30	0.45	0.60	0.012	0.018	0.024
L1	0.50	0.60	0.70	0.020	0.024	0.028
e1	1.95 BSC			0.075 BSC		
e	0.65 BSC			0.037 BSC		
θ	0°	4°	8°	0°	4°	8°

JEDEC outline: MO-178 BA

(2) SOP-8L



Symbol	Dimensions in Millimeters			Dimensions in Inches		
	Min.	Nom.	Max.	Min.	Nom.	Max.
A	-	-	1.75	-	-	0.069
A1	0.1	-	0.25	0.04	-	0.1
A2	1.25	-	-	0.049	-	-
C	0.1	0.2	0.25	0.0075	0.008	0.01
D	4.7	4.9	5.1	0.185	0.193	0.2
E	3.7	3.9	4.1	0.146	0.154	0.161
H	5.8	6	6.2	0.228	0.236	0.244
L	0.4	-	1.27	0.015	-	0.05
b	0.31	0.41	0.51	0.012	0.016	0.02
e	1.27 BSC			0.050 BSC		
y	-	-	0.1	-	-	0.004
θ	0°	-	8°	0°	-	8°

Mold flash shall not exceed 0.25mm per side
JEDEC outline: MS-012 AA