Touch Screen Controller

FEATURES

- Pin compatible with SS7643
- Serial interface
- Interface for 4-wire touch-screen
- Embedded touch-screen drivers
- Internal 2.5V reference
- Direct battery measurement (0V to 6V)
- Touch-pressure measurement
- One auxiliary analog input
- On-chip temperature sensor
- Supply voltage from 2.2V to 5.5V
- 12-bit analog-to-digital converter
- Programmable 8- or 12-bit resolution
- Conversion rate up to 125kHz
- Full power-down control
- 16 pin SSOP package

APPLICATIONS

- Touch-screen Monitors
- Personal Digital Assistants
- Point-of-Sale Terminals
- Pagers
- High-Speed Data Acquisition
- Portable Instruments
- Low-power Instruments

DESCRIPTION

The SS7646 touch-screen controller IC is an advanced version of the previous controller, the SS7643.

The SS7646 is a 12-biit SAR analog-to-digital converter (ADC) with SPI serial interface and low-on resistance drivers for 4-wire resistive touch screens. The SS7646 is fully pin-compatible with the SS7643.

The SS7646 is a highly-integrated controller for portable applications using 4-wire resistive touch screens, such as PDAs, portable instruments, cell phones, etc. The SS7646 contains all the analog and digital circuitry necessary to complete a pen request, and features temperature, battery monitor and touch-pressure measurements.

The SS7646 also features an internal 2.5V reference that can be turned ON or OFF independently of the ADC.

The SS7646 consumes only 405 µW (with the internal reference OFF) at a sample rate of 125kHz with a 2.7V supply and consumes less than 2.7 µW in the shutdown mode. The SS7646 will operate with a supply down to 2.2V.

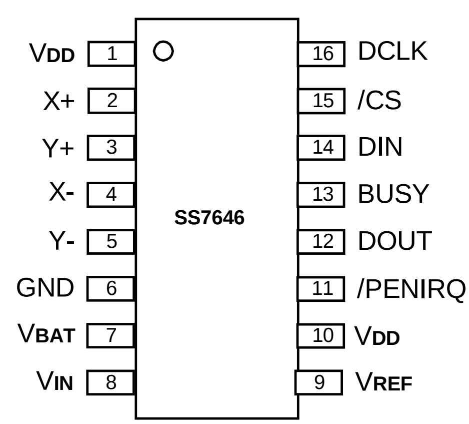
The SS7646 is supplied in a very small 16-lead SSOP package and is guaranteed over the temperature range.

ORDERING INFORMATION

SS7646TR

SS7646 in SSOP-16 shipped on tape and reel

PIN CONFIGURATION



SSOP-16

ABSOLUTE MAXIMUM RATINGS

VDD to GND………………………………………..……… -0.3V to +6V
Analog Input to GND………………………….... -0.3V to VDD +0.3V
Digital Input to GND……………………….…. -0.3V to VDD +0.3V
Operating Temperature Range………………. -40°C to +85°C
Maximum Junction Temperature………………………… +150°C
Storage Temperature Range…………………….. -60°C to +150°C
Lead Temperature (Soldering, 10s)…………………..…… +300°C

CAUTION: Stresses above those listed in "Absolute Maximum Ratings" may cause permanent damage to the device. This is a stress only rating and operation of the device at these or any other conditions above those indicated in the operational sections of this specification is not implied.

Electrostatic Discharge Sensitivity

This device can be damaged by ESD. Silicon Standard recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage. ESD damage can range from subtle performance degradation to complete device failure.

PIN DESCRIPTIONS

Pin	Name	Description
1	V_{DD}	Power Supply, 2.2V to 5.5V.
2	X+	X+ Input; ADC Input Channel 1.
3	Y+	Y+ Input; ADC Input Channel 2.
4	X-	X- Input.
5	Y-	Y- Input; ADC Input Channel 3.
6	GND	Ground.
7	V_{BAT}	Battery Monitor Input; ADC Input Channel 4.
8	V_{IN}	Auxiliary Input; ADC Input Channel 5.
9	V_{REF}	Reference Voltage Input / Output.
10	V_{DD}	Power Supply, 2.2V to 5.5V.
11	/PENIRQ	Pen Interrupt. Requires 10kΩ to 100kΩ external pull-up resistor.
12	DOUT	Serial Data Output. This output pin is high impedance when /CS is high.
13	BUSY	Busy Output. This output pin is high impedance when /CS is high.
14	DIN	Serial Data Input.
15	/CS	Chip Select Input. This input is active low.
16	DCLK	External Clock Input.

BLOCK DIAGRAM

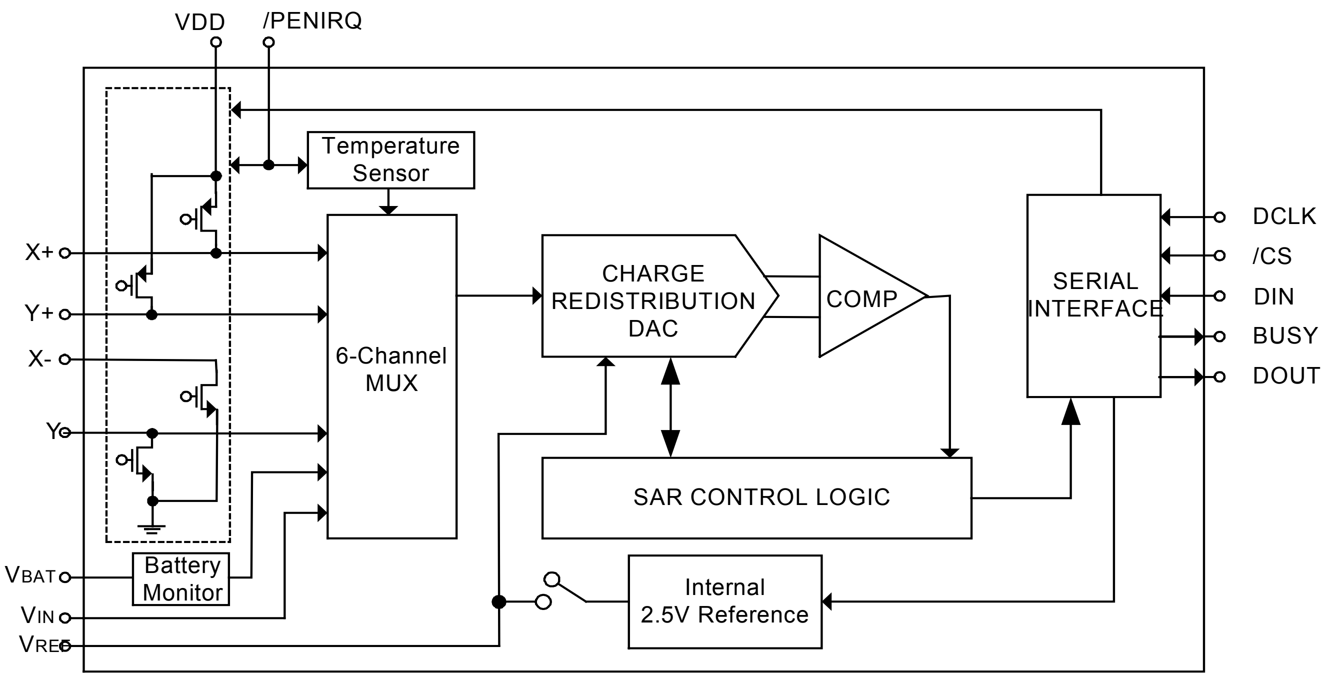


Figure 1. Block Diagram of SS7646

Electrical Specifications

(T_A = -40°C to +85°C, V_{DD}=+2.7V, V_{REF}=+2.7V, f_{Sample}=125KHz, f_{CLK}=24*f_{Sample}, 12-bit mode, Digital Inputs= GND or +V_{DD}. Typical values are at T_A = +25°C, unless otherwise noted.)

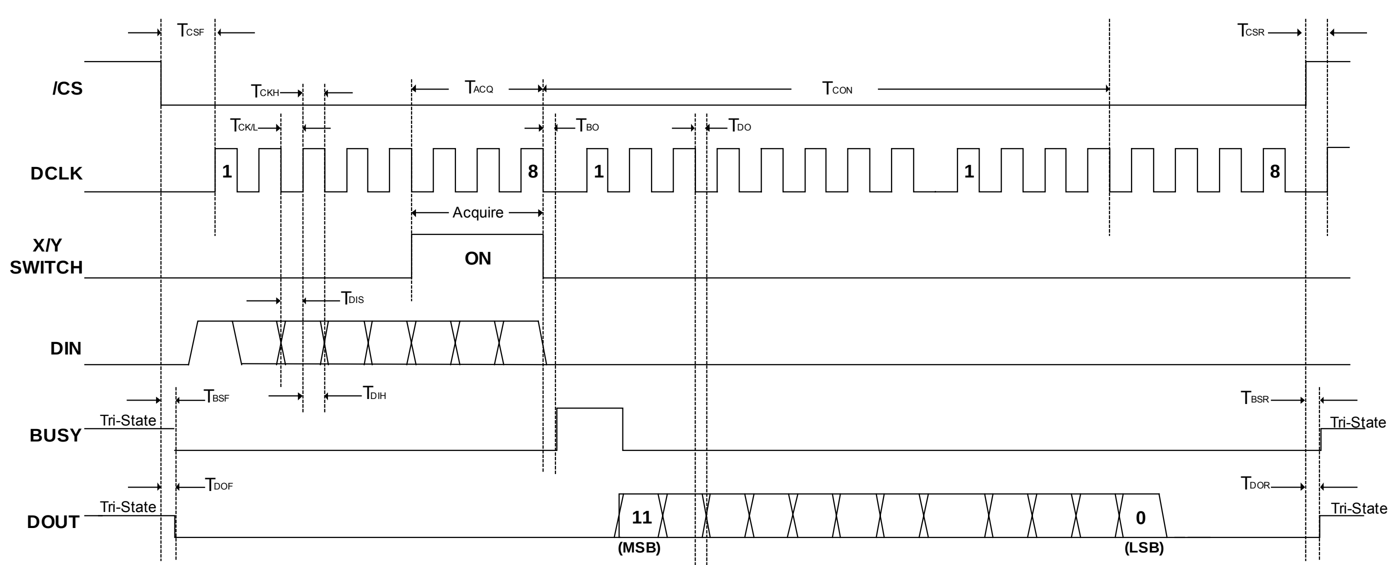
PARAMETER	TEST CONDITIONS	MIN.	TYP.	MAX.	UNITS
Power Supply Requirement					
V_{DD}	Specified Performance	2.7		3.6	V
	Functional Operating Range	2.2		5.5	V
Quiescent Current	Internal Reference OFF		150		μA
	Internal Reference ON		600		μA
	Shut Down Mode			1	μA
Power Dissipation	Internal Reference OFF		0.40		mW
	Internal Reference ON		1.62		mW
	Shut Down Mode			2.7	μW
System Performance					
Resolution			12		Bits
INL			±2		LSB
DNL			±1		LSB
Gain Error			±4		LSB
Offset Error			±6		LSB
Digital Input/Output					
Logic Family	CMOS Logic				
V_{OH}		V_{DD}*0.8			V
V_{OL}				0.4	V
V_{IH}		V_{DD}*0.7		V_{DD} + 0.3	V
V_{IL}		-0.3		0.8	V
/PENIRQ	100kΩ Pull-Up				
V_{OL}			0. 6		V
Analog Input					
Input Span		0		V_{REF}	V
Input Range		-0.2		V_{DD} + 0.2	V
Capacitance			25		pF
Reference Output	Internal Reference ON (PD1="1")				
Internal Reference Voltage	(Functional from 2.7V to 5.5V V_{DD})	2.45	2.50	2.55	V
Internal Reference Thermal Drift			15		ppm/°C
Quiescent Current			500		μA
Reference Input	Internal Reference OFF (PD1="0")				
Input Range		1		V_{DD}	V
Input Current			15		μA
X / Y Switches					
X+, Y+	Switch On-Resistance		5		Ω
X -, Y -	Switch On-Resistance		5		Ω
Battery Monitor					
Input Voltage Range		0.5		6.0	V
Accuracy	Internal Reference	-3		+3	%
Temperature Measurement					
Operating Temperature Range		-40		+85	°C
Resolution	Differential Method (TEMP1-TEMP0)		1.5		°C
	Single Conversion (TEMP0)		0.3		°C
Accuracy	Differential Method (TEMP1-TEMP0)		±2		°C
	Single Conversion (TEMP0)		±3		°C

Timing Specifications:

(T_A = -40°C to +85°C, $V_{DD} \geqq$ +2.7V, C_{LOAD}=50pF. Typical values are at T_A = +25°C, unless otherwise noted.)

SYMBOL	DESCRIPTION	MIN	TYP	MAX	UNITS
T_{ACQ}	ADC acquisition time	500			ns
T_{CON}	ADC conversion time	6.5			μs
T_{CSF}	/CS falling to first DCLK rising	100			ns
T_{CSR}	/CS rising to DCLK ignored	0			ns
T_{DOF}	/CS falling to DOUT enable			200	ns
T_{DOR}	/CS rising to DOUT disable			200	ns
T_{BSF}	/CS falling to BUSY enable			200	ns
T_{BSR}	/CS rising to BUSY disable			200	ns
T_{CKH}	DCLK High Period	200			ns
T_{CKL}	DCLK LOW Period	200			ns
T_{DIS}	DIN valid before DCLK rising	100			ns
T_{DIH}	DIN hold time after DCLK going high	15			ns
T_{DO}	DCLK falling to DOUT valid			200	ns
T_{BO}	DCLK falling to BUSY rising			200	ns

Timing Diagram:



FUNCTIONAL DESCRIPTION

OVERVIEW

The SS7646 is a 12-bit switched-capacitor SAR Analog-to-Digital converter (ADC). The converter is fabricated using a 0.6µm CMOS process and packaged in the very small 16-pin SSOP package.

The typical operation of the SS7646 is shown in Figure 12. The SS7646 operates on a single supply ranging from +2.2V to +5.5V. The SS7646 features an internal 2.5V reference and an external clock. The reference voltage directly sets the input range of the converter. The internal 2.5V reference can be turned ON or OFF independently of the ADC.

The SS7646 contains six channel inputs, a serial interface and low on-resistance switches for the touch screen (see Block Diagram). The input to the converter is selected via the six-channel multiplexer as shown in Figure 5.

SERIAL INTERFACE

The typical operation of the SS7646 serial interface (/CS, DCLK, DIN and DOUT) is shown in Figure 2. The SS7646 communicates with microprocessors or digital signal processors via a synchronous serial interface. One complete conversion can be accomplished with three serial communications for a total 24 clock cycles on the DCLK input.

Operation of 24-Clocks

The operation is initiated by a falling signal on Chip Select (/CS) input. After /CS falls, the SS7646 looks for a start bit on the DIN input. The first eight clock cycles are used to provide the control byte. At the end of the operation the /CS pin should be brought high. Bringing /CS high after the conversion also minimizes supply current if DCLK is left running.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
Start	A2	A1	A0	Mode1	Mode0	PD1	PD0

Table I. Control Bits in the Control Byte

BIT	NAME	DESCRIPTION
7	Start	Start Bit.
6, 5, 4	A2, A1, A0	Input Channel Select Bits.
3, 2	Mode1, Mode0	12-Bit / 8-Bit Resolution and Int. Reference Configuration Bits
1, 0	PD1, PD0	Power Down Control Bits

Table II. Description of the Control Bits

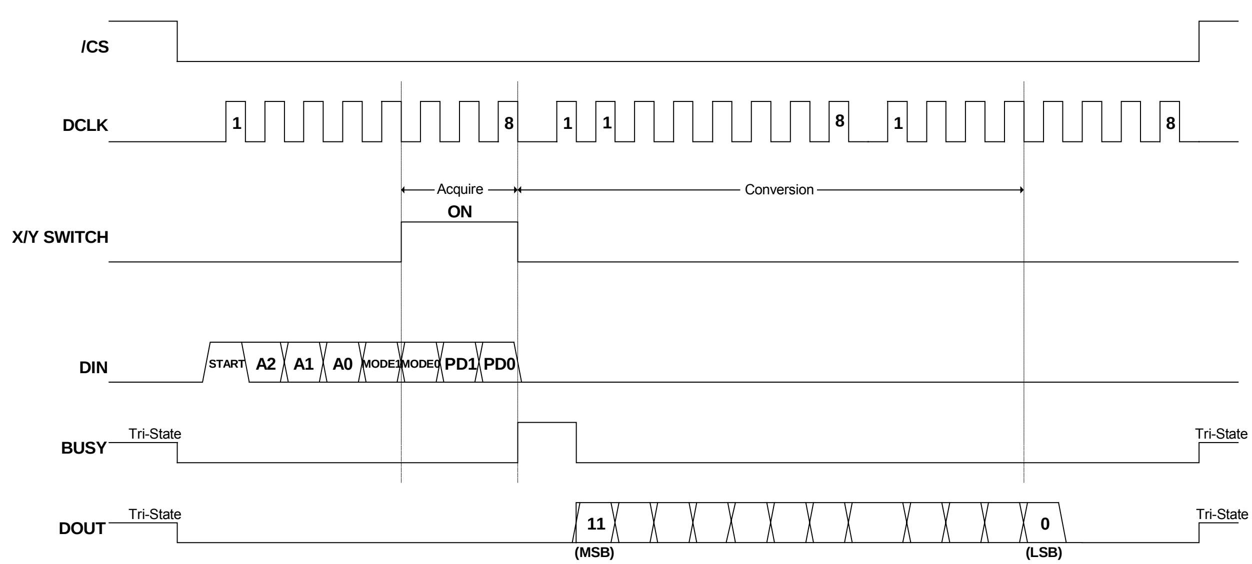


Figure 2. Serial Interface of SS7646

The Control Byte :

Table I and Table II show detailed information of the control byte (on DIN). The control byte provides the start operation, addressing, resolution, reference and power down information to the SS7646.

Start Bit – Initiate Start

The control byte starts with the first high bit on DIN. The first bit must always be HIGH (1) to initiate the start of the conversion. The SS7646 will ignore any inputs on the DIN until the start bit is detected.

Addressing Bits – Input Channel Selection

The next three bits on control byte (A2, A1, A0) select the active input channel of the input multiplexer (see Table III, and Figure 5), and touch screen drivers.

Mode Bits – Resolution and Reference Configuration

The Mode bits (Mode1, Mode0) set the resolution of the analog-to-digital (ADC) converter. With the Mode1 bit LOW (0) the following conversion will have 12 bits of resolution. With the Mode1 bit HIGH (1) the following conversion will have 8 bits of resolution. The MODE0 bit set the reference input of the ADC (see Reference Input section and Figure 5). Table IV shows detailed information of the Mode Bits.

PD0 and PD1 Bits - Power Down Control

The last two bits (PD1, PD0) control the power-down mode and pen interrupt request of the SS7646. If both bits are HIGH (1), the ADC is always powered up and pen interrupt will be disabled. If both bits are LOW (0), the ADC enters a power-down mode between conversions. The internal 2.5V voltage reference can be turned ON or OFF independently of the ADC with the PD1 bit. See Table V for more information.

A2	A1	A0	Measure	Input Channel	X Switch	Y Switch
0	0	1	Y-POSITION	X+	OFF	ON
1	0	1	X-POSITION	Y+	ON	OFF
0	1	1	Z1-POSITION	X+	X- ON	Y+ ON
1	0	0	Z2-POSITION	Y-	X- ON	Y+ ON
0	1	0	Battery	V_{BAT}	OFF	OFF
1	1	0	Auxiliary	V_{IN}	OFF	OFF
0	0	0	TEMP0	-	OFF	OFF
1	1	1	TEMP1	-	OFF	OFF

Table III. Input Channel Configuration

Operation of 16-Clocks

The typical operation of the SS7646 is 24-clocks (three control bytes) per conversion. However the control bits for the next conversion can be overlapped with current conversion for a faster conversion. Figure 3 shows the timing of 16-Clocks per conversion.

Operation of 15-Clocks

The fastest operation (15-clocks per conversion) of SS7646 is shown on Figure 4. This operation will not work with the serial interface of most microcontrollers and digital signal processors, as they are not capable of providing 15 clocks cycles per serial transfer.

MODE1	MODE0	Resolution	ADC Reference
0	1	12bits	V_{REF}
0	0	12bits	V_{DD}*
1	1	8bits	V_{REF}
1	0	8bits	V_{DD}*

Table IV. Resolution and Reference Configuration

* When measuring Y(001), X(101), Z1(011) and Z2(100) positions, otherwise Invalid configuration

PD1	PD0	/PENIRQ	DESCRIPTION
0	0	Enable	The reference is switching OFF and the ADC will power down between conversions. Y- switch is on while in power-down.
0	1	Enable	The reference is switching OFF and the ADC is ON permanently. No power down between conversions.
1	0	Enable	The reference is ON and the ADC will power down between conversions.
1	1	Disable	The reference and the ADC are ON. No power down between conversions, the ADC always power up. The pen interrupt functionality will be disabled.

Table V. Power-Down and Pen Interrupt Selection

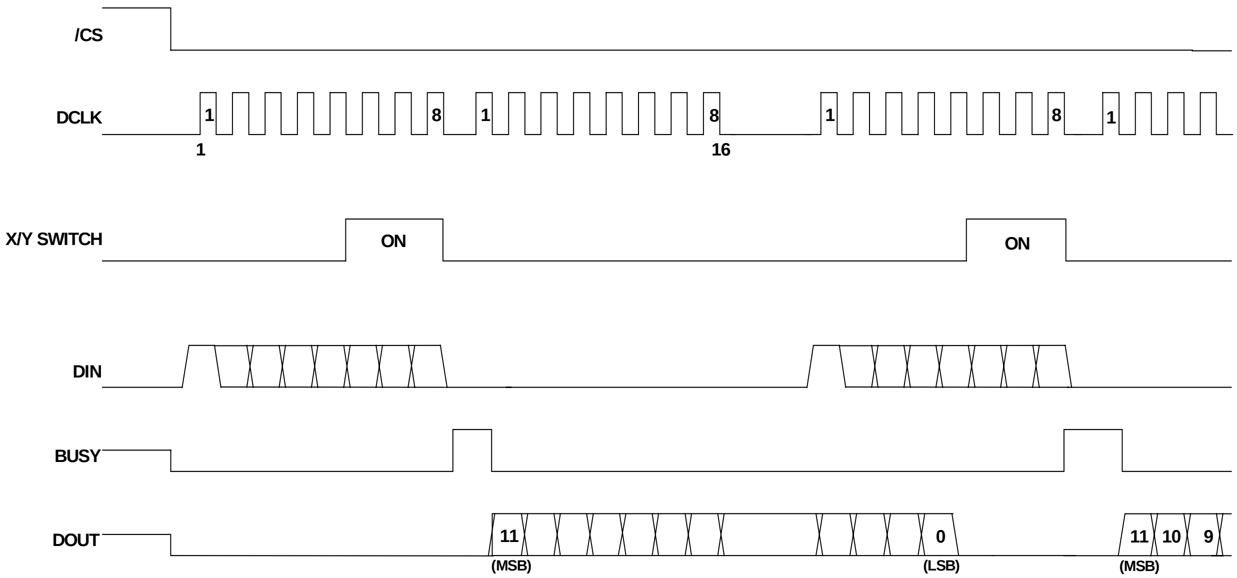


Figure 3. Timing of 16-clocks per Conversion

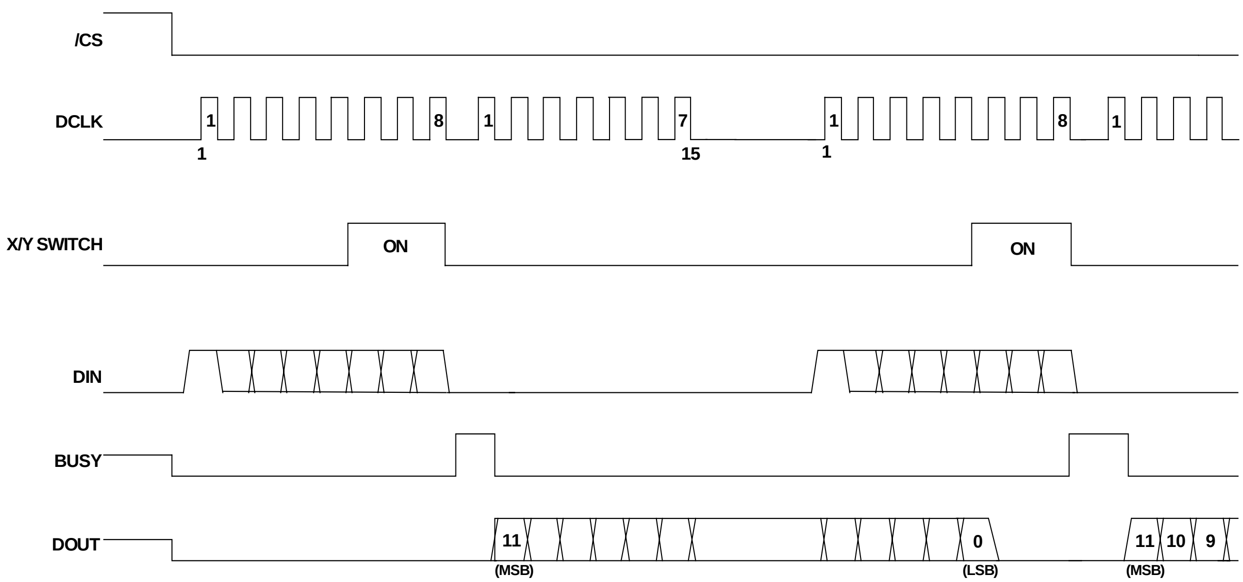


Figure 4. Timing of 15-clocks per Conversion

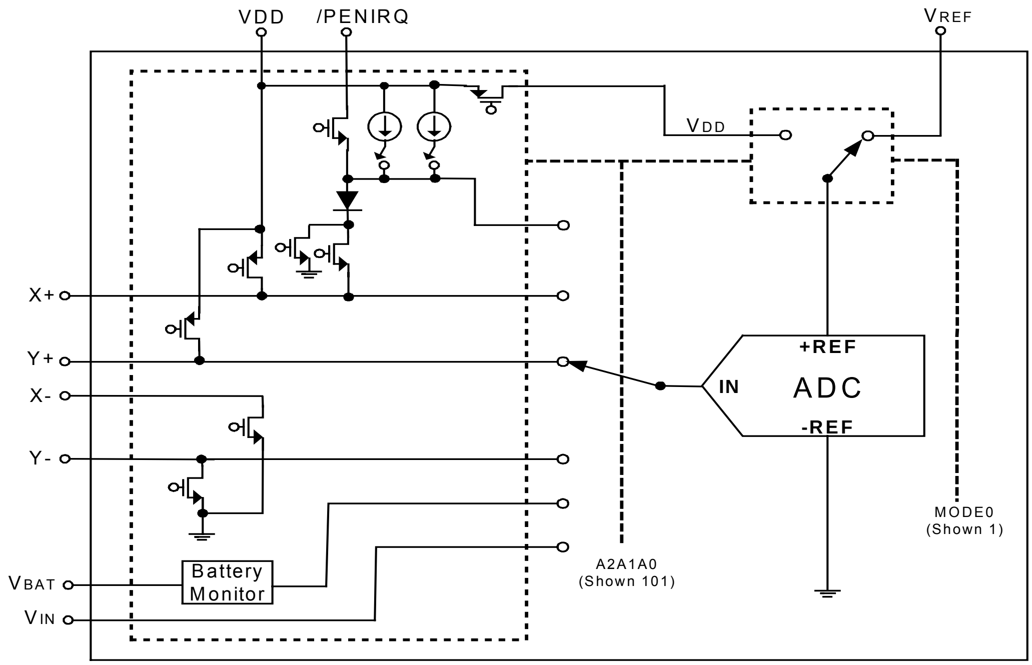


Figure 5. Diagram of Input Channel and Reference Input

ANALOG INPUT MEASUREMENT

The SS7646 contains 6 channel inputs. X+, Y+ and Y- inputs are for touch screen measurement, 2 auxiliary inputs are V_{BAT} and V_{IN}. The diode input (internal node) is for temperature measurement. Figure 5 shows a diagram of the analog input channel and reference input. The input to the A/D converter is selected via the six-channel multiplexer. (see Block Diagram and Figure 5.)

Input Channel

Table III shown the input channel configuration of the SS7646. The control bits are set via the DIN pin. (see Control Byte section). The selected channel is for A/D converter input. Please refer to Figure 5 for detailed input channel multiplexer. For measuring X+ (Y-position) and Y+ (X-position), Y switches and X switches are turned on respectively.

Internal Reference

The SS7646 has an internal 2.5V voltage reference that can be turned ON with the power-down address bit, PD1="1", at the configuration byte (See Table V and Figure 1). The internal reference voltage of SS7646 should be turned OFF (PD1="0") in order to be compatible with the SS7643. If the internal reference is turned OFF and the reference is taken from the power supply directly, special care must be taken to avoid noise from the power supply.

While the ADC can be powered up or down instantly, the internal reference requires settling time to settle to the final value. The power-up time of V_{REF} is typically 30µs without a load. The internal reference voltage can be turned ON or OFF independently of the ADC. This allows extra time for the reference voltage to be settled before a conversion. Although /CS="1" will put the SS7646 into a power-down mode immediately, the internal reference does not turn OFF with /CS going HIGH. An additional pattern with PD1="0" is required before /CS goes HIGH.

Reference Input

The voltage difference between +REF and –REF (shown V_{REF} in Figure 5), in the range of 1V to + V_{DD}, sets the Analog-to-Digital converter (ADC) input range. The full-scale analog input range of the SS7646 is therefore from 0 to V_{REF}.

Typically the reference input is an external precise voltage source V_{REF} (MODE0=1, see Table IV) for touch screen and auxiliary inputs measurement. Figure 6 shows the configuration for a Y coordinate measurement with MODE0=1. When utilizing the panel measurement, the V_{REF} must equal V_{DD} as input range is from 0 to V_{DD}. If the reference input is from the power supply directly, as Figure 12 shows for example, special care must be taken to avoid noise from the power supply.

When making touch screen measurements only, the reference input can be set from V_{DD} directly (MODE0=0) and discard the V_{REF} input. Figure 7 shows the configuration for a Y coordinate measurement with MODE0=0.

Examples of DIN Configuration

Table VI shows DIN configurations for specified applications.

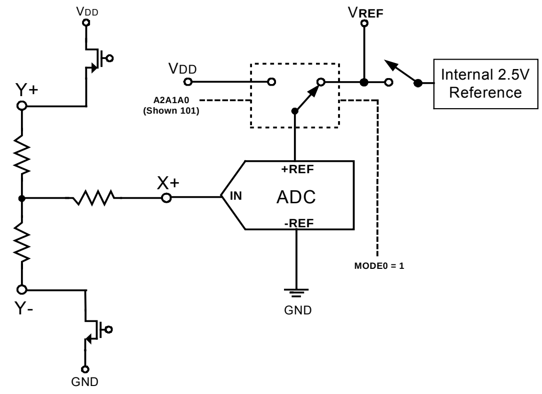


Figure 6. Touch Screen Measurement with MODE0=1

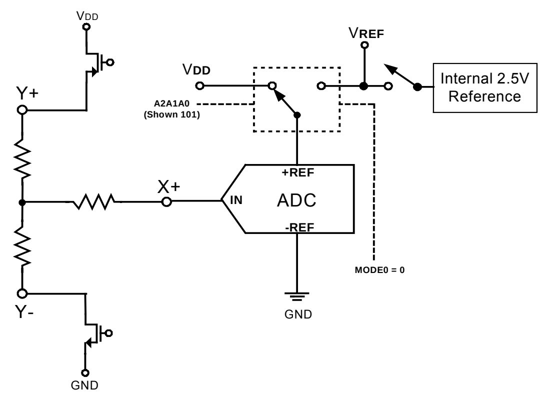


Figure 7. Touch Screen Measurement with MODE0=0

Measurement	S	A2	A1	A0	MODE1	MODE0	PD1	PD0	+REF	X SWITCHES	Y SWITCHES
Touch Screen											
Y-Position (X+)	1	0	0	1	0	0 / 1	0	0	V_{DD} / V_{REF}	OFF	ON
X-Position (Y+)	1	1	0	1	0	0 / 1	0	0	V_{DD} / V_{REF}	ON	OFF
Z1-Position (X+)	1	0	1	1	0	0 / 1	0	0	V_{DD} / V_{REF}	X+ OFF, X- ON	Y+ ON , Y- OFF
Z2-Position (Y -)	1	1	0	0	0	0 / 1	0	0	V_{DD} / V_{REF}	X+ OFF, X- ON	Y+ ON , Y- OFF
Battery											
V_{BAT}	1	0	1	0	0	1	1	1	V_{REF}	OFF	OFF
-	1	0	1	0	*	0	*	*	Invalid Configuration		
Auxiliary In.											
V_{IN}	1	1	1	0	0	1	1	1	V_{REF}	OFF	OFF
-	1	1	1	0	*	0	*	*	Invalid Configuration		
Temperature											
TEMP1	1	1	1	1	0	1	1	1	V_{REF}	OFF	OFF
TEMP0	1	0	0	0	0	1	1	1	V_{REF}	OFF	OFF
-	1	1	1	1	*	0	*	*	Invalid Configuration		
-	1	0	0	0	*	0	*	*	Invalid Configuration		

Table VI. Examples of DIN Configuration

Temperature Measurement

The temperature measurement is based on an on-chip forward diode measurement. The forward diode voltage V_{BE} has a well-defined characteristic vs. temperature. There are two measurement options for the SS7646, a Single Conversion Mode and a Differential Conversion Mode.

(1) In the Single Conversion Mode, a diode voltage is first digitized at a fixed calibration temperature (25°C) during the final test of the end product and this value T1 is stored in the memory, then only a single reading T2 is required for the users to obtain the ambient temperature through extrapolation from the calibration temperature diode result.

$$T(°C) = [25 - (T2 - T1)x0.3]°C$$

This result assumes a diode temperature coefficient (TC) of approximately –2.1 mV/°C. This method provides a resolution of approximately 0.3°C and a predicted accuracy of ± 3°C.

$$1LSB = 2.5V/4096 = 0.61mV$$
$$Resolution = 0.3\ °C/LSB$$

This mode is achieved with an address setting of A2=0, A1=0, A0=0 (TEMP0). Please refer to Table III and Figure 8 for details.

(2) The Differential Conversion Mode requires two points measurement to eliminate the need for absolute temperature calibration. The first measurement TEMP0 (A2=0, A1=0, A0=0) is performed with a fixed bias current into a diode and the second measurement TEMP1 (A2=1, A1=1, A0=1) is performed with N times (N=120 for SS7646) of the bias current into the same diode. The voltage difference between first and second readings is proportional to absolute temperature and is given by the following formula:

$$\Delta V_{BE} = (kT/q)\ x\ \ln(N)$$

where V_{BE} represents the diode voltage, N is the bias current multiple, k is Boltzmann's constant and q is the electron charge.

Taking Boltzmann's constant $k=1.38054x10^{-23}$ electrons volts/degrees Kelvin, the electron charge $q=1.602189x10^{-19}$ Coulomb, then the ambient temperature T, in degrees centigrade, would be calculated as follows:

$$T(°K) = (q\ x\ \Delta V_{BE})/[k\ x\ \ln(120)]$$
$$T(°C) = 2.42\ x\ \Delta V_{BE}(mV) - 273$$

This method provides a much improved absolute measurement of temperature of ± 2°C, however resolution is reduced to approximately 1.5°C/LSB.

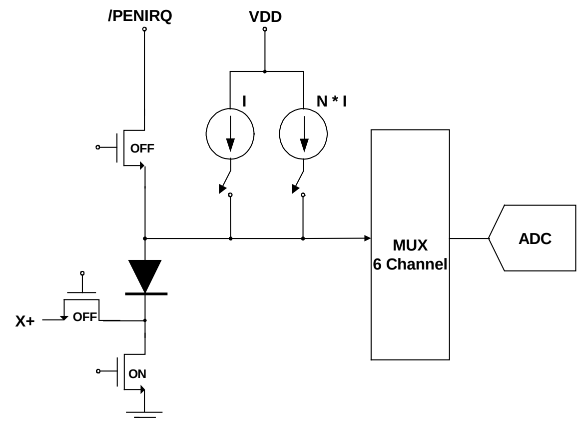


Figure 8. Block Diagram of Temperature Measurement Circuit

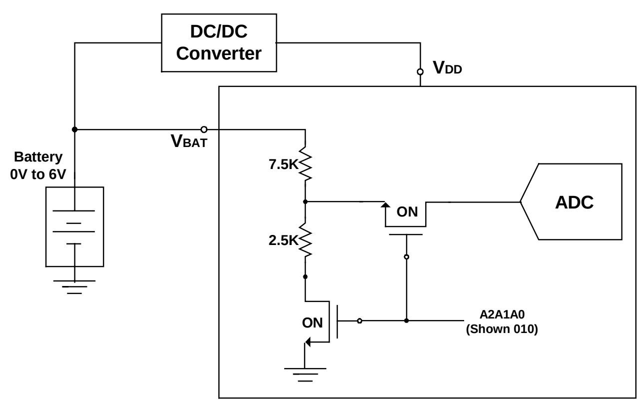


Figure 9. Block Diagram of Battery Measurement Circuit

Battery Measurement

Another feature of the SS7646 is the battery measurement ability. Figure 9 shows a block diagram of a battery voltage monitored by the SS7646. While the main power to the SS7646 via the DC/DC regulator is maintained at the desired voltage, the battery voltage can vary from 0.5V to 6V. The SS7646 is able to monitor this battery voltage through the V_{BAT} pin. The voltage on V_{BAT} pin is divided down by 4 so that the battery voltage of 6V becomes 1.5V to the ADC input. In order to minimize the power consumption, the divider is only on during the sampling phase of the ADC. See Table V for the control bit configurations required to perform this battery measurement.

Pressure Measurement

The SS7646 is also able to determine the pen or finger touch through the pressure measurement with some simple calculations. The pressure measurement is based on the contact resistance between the X and Y plates. Figure 10 shows a block diagram of the pressure measurement. There are two recommended methods to perform the measurement. Generally, the pressure measurement can be accomplished sufficiently with 8-bit resolution mode, but the following examples are shown with the 12-bit resolution mode.

(1) The first method requires the user knowing the X-plate resistance. Performing three touch screen conversions, X-Position, Z1-Position and Z2-position, then use the following equation to calculate the touch resistance:

$$R_{touch} = R_{xplate} \times (X_{position}/4096) \times [(Z_2/Z_1) - 1]$$

(2) The second method requires the user knowing both the X-plate and Y-plate resistance. Performing three touch screen conversions, X-Position, Y-Position and Z1-position, then use the following equation to calculate the touch resistance:

$$R_{touch} = (R_{xplate} \times X_{position})/4096 \times [(4096/Z_1) - 1] - (R_{yplate} \times Y_{position})/4096$$

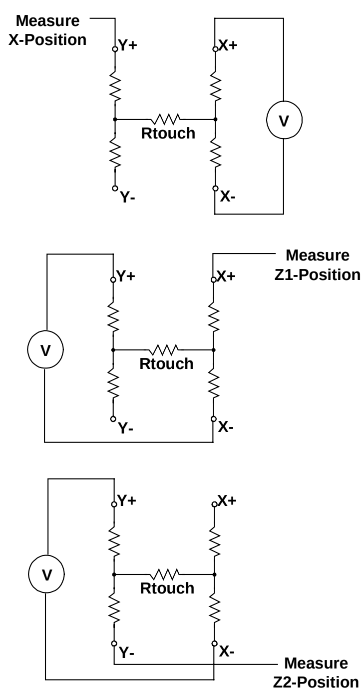


Figure 10. Block Diagram of Pressure Measurement

Pen Interrupt Request

The pen interrupt function is shown in Figure 11. Normally the /PENIRQ is HIGH by connecting a pull-up resistor (typically 100KΩ) to V_{DD}. If /PENIRQ has been enabled (See Table V), Y- driver is ON and connected to GND and /PENIRQ diode is connected to X+ input. When the touch screen connected to the SS7646 is touched, the X+ input is pulled to ground through the touch screen and /PENIRQ will go low, initiating an interrupt to the microprocessor. During the X and Y plates measurement cycles, the /PENIRQ diode will be internally connected to GND and X+ input disconnected from the diode to eliminate leakage current to the touch screen.

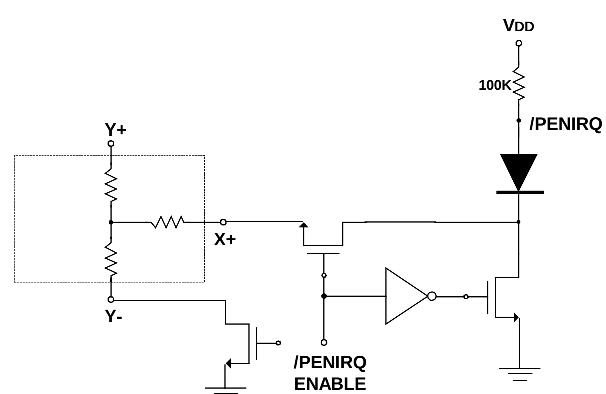


Figure 11. Block Diagram of Pen Interrupt Circuit

APPLICATION CONSIDERATIONS

Typical Operating Circuit

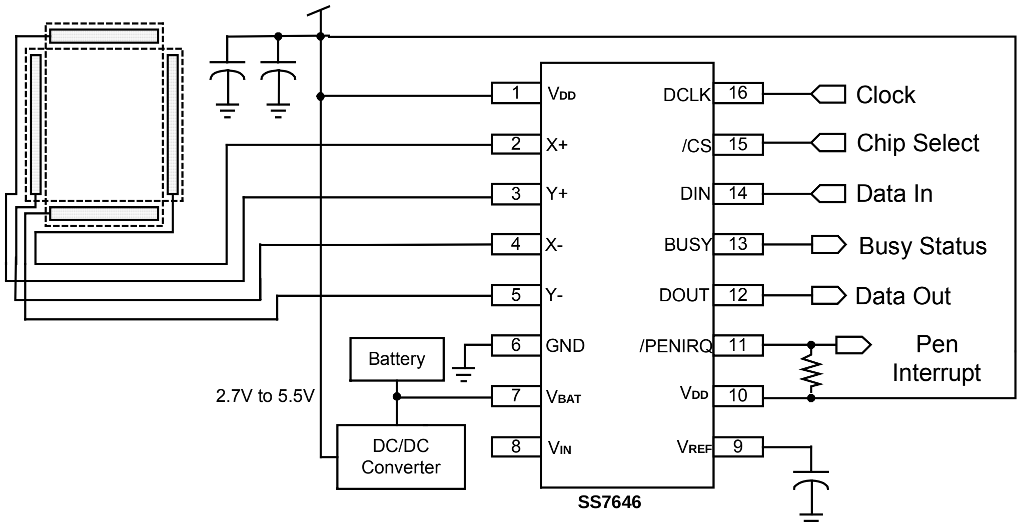


Figure 12. Typical Operation Circuit of the SS7646

Resistive Touch Screen (4-Wire)

The 4-wire resistive touch screen consists of 2 resistive plates that are separated by a small gap. Each of the plates has a resistance in the range from 200 to 2000 ohms.

The screen works by applying a voltage across the X plate or Y plate resistive networks. If a voltage is applied, for example, between X+ and X- then a voltage divider is formed on the X plate. When the Y plate is touched to the X plate, a voltage will be developed on the Y plate. By accurately measuring this voltage, the position on the screen can be determined. The connections between the SS7646 and the touch screen should be as short as possible.

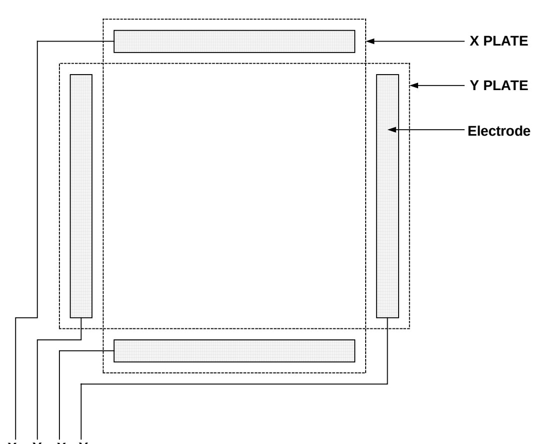
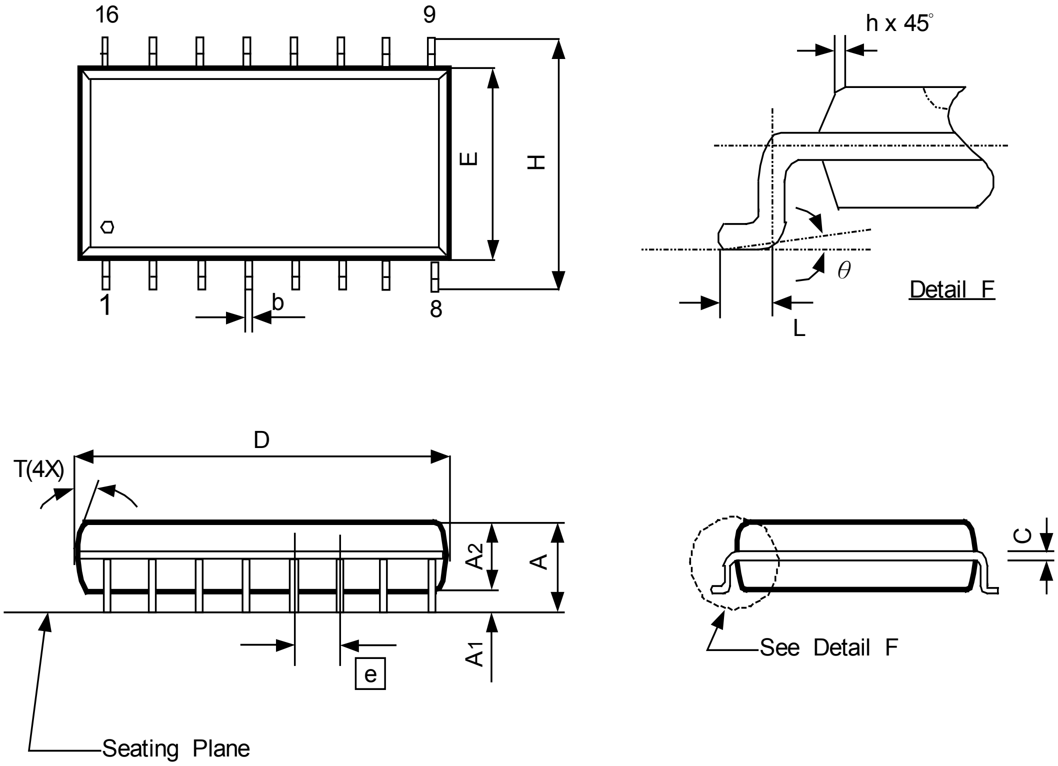


Figure 13. 4-wire Resistive Touch Screen

PACKAGE INFORMATION

SSOP-16



SYMBOLS	DIMENSIONS (MM)			DIMENSIONS (MIL)		
	MIN.	NOM.	MAX.	MIN.	NOM.	MAX.
A	1.35	1.60	1.75	53	63	68
A1	0.10	0.15	0.25	4	6	10
A2			1.50			59
b	0.20	0.254	0.30	8	10	12
C	0.18	0.203	0.25	7	8	10
D	4.80	4.90	5.00	189	193	197
E	3.80	3.90	4.00	150	154	157
H	5.80	6.00	6.80	228	236	244
e	0.6358 BSC			25 BSC		
L	0.40	0.635	1.27	16	25	50
h	0.25	0.42	0.50	10	17	20
θ	0°		8°	0°		8°