NetSilicon
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Interfacing ADCs to the NS9750

Version 0.3

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1 Overview

1.1 Analog to Digital Converters (ADC)

Analog to Digital Converters are used to digitize analog signals so that a microprocessor system can interpret the outside world. ADCs allow many physical parameters such as temperature, pressure, and humidity to be easily measured and stored. More complex signals, such as audio and video are also easy to digitize. ADCs come in many varieties, with different speeds, resolutions, input ranges, cost, and interface options. This document describes some of the ADCs manufactured by Analog Devices and Maxim Inc., which can interface to the NS9750 without glue. There are numerous other ADCs not mentioned here, which can interface to the NS9750. Texas Instruments, Fairchild Semiconductor, Cirrus Logic, Intersil, Linear Technology, and National Semiconductor all manufacture ADCs which interface to the NS9750.

1.2 ADC Functionality

An ADC digitizes the input voltage range that exist between two reference voltages. The lower of the two references is usually ground. The higher voltage reference is usually provided by an external component but in some cases it is part of the ADC's internal circuitry. Different ADCs have different reference voltages and the ADC should be chosen so that it has a reference voltage range close to the input signal range. This cannot always be done if the input signal is unusually large or small, in which case the input signal would have to be adapted by either attenuation of amplification. The maximum ADC's input signal should be about 90% of the reference voltage. It's true that 10% of the ADC's range is wasted, but it is best to leave a little room for a safety margin. Any input signal that exceeds the reference voltage will produce the ADC's maximum number. It is best that the ADC never produces its maximum number because you can never be sure if it was produced by an input signal that exactly equaled the reference voltage or by an input that exceeded the reference voltage.

The following three tables show the output numbers that 8-bit, 12-bit, and 16-bit ADCs would produce with seven different inputs voltages. These numbers are based on having ground (0 volts) for the low reference and 2.2 volts for the high reference. These numbers were calculated by dividing the 2.2 volts reference range by the highest number that the ADCs can produce. The input voltage is divided by the results of this calculation to determine the output number that the ADC would generate with a given input.

Output Number = Input Voltage / ((voltage reference range) / (highest ADC output number))

Note that the last input voltage in the table (2.3 volts) generates the same output as the 2.2 volt input because it exceeds the reference voltage.

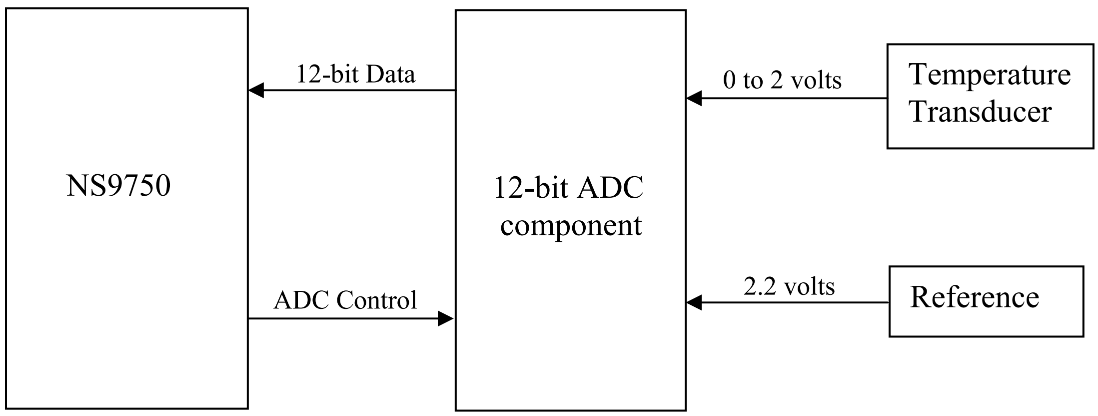
8-bit ADC	
Input	Output
0.0 volts	0
0.5 volts	60
1.0 volts	116
1.5 volts	174
2.0 volts	232
2.2 volts	255
2.3 volts	255

12-bit ADC	
Input	Output
0.0 volts	0
0.5 volts	931
1.0 volts	1861
1.5 volts	2792
2.0 volts	3723
2.2 volts	4095
2.3 volts	4095

16-bit ADC	
Input	Output
0.0 volts	0
0.5 volts	14894
1.0 volts	29787
1.5 volts	44683
2.0 volts	59577
2.2 volts	65535
2.3 volts	65535

1.3 Temperature Measurement Example

There are many ADC applications. A temperature conversion example is shown below.



When designing an ADC system you start by analyzing the nature of the signal you are measuring. The three main parameters to consider are speed, signal range, and resolution. This example shows a temperature measurement system, with a temperature transducer that produces a 0 to 2 volt signal when the temperature varies from 0 to 120 degrees. This transducer can produce a noticeable change in 100mS. 1/10 of a second is very slow, any ADC can handle this, so the speed of the ADC won't be a factor. The designer would probably choose a serial interface ADC device because although slower than parallel ADCs, they are usually cheaper and require less interface signals between the ADC and microprocessor. The next factor is the signal's range, which in this example is 0 to 2 volts. The designer would choose an ADC with slightly more than the 2 volt range. A 2.2 volt reference was chosen for this example. The last factor is the ADC's resolution. In this example the transducer has resolution of 0.1 degrees. 120/0.1 = 1200 divisions over the full range. A 10-bit ADC, with 1024 divisions doesn't quite make it so the designer would choose a 12-bit ADC. A 12-bit ADC will produce the numbers 0 to 4095 over the 2.2 volt range, which is 2.2 / 4095 = 537.2 uV per division. The transducer only goes to 2 volts, so 2 / .0005372 = 3720 divisions over the 0 to 120 degree range. 120 / 3723 = 0.032 degrees per division. This is three times the required resolution.

Steps should be taken to reduce noise on the analog side when designing an ADC system. The board layout is very important. The reference voltage component should be decoupled and placed very close to the ADC. Two ground planes, one for the digital components and one for the analog, further reduces noise.

After the ADC hardware is in place, everything is done with software. The software reads the ADC's numbers and uses them in some way. In the temperature example, the software would read the ADC's output and convert that number to a temperature. For example, if the software reads the number 2017 from the ADC it would multiply this by 0.032 to determine that the temperature is 64.54 degrees. The software could do anything with this information such as display it on a web page, send it in an email, turn on a fan, or store it in memory for use as a temperature chart recorder.

Measuring temperature is one of many ADC applications. Virtually any analog signal can be digitized. The basic design procedure is always the same. First determine the required speed, resolution and voltage range for the analog signal and then go hunting through the manufacture's ADC specs to find the best component.

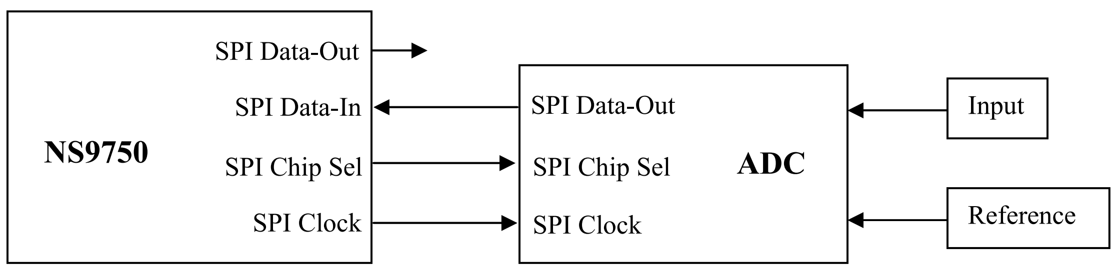
2 Serial Interfacing

SPI is a trademark of Motorola Inc.

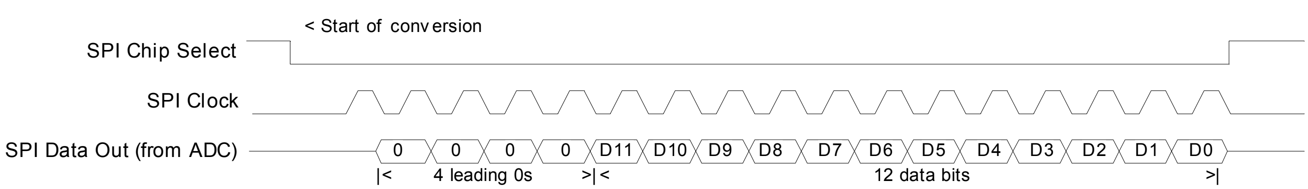
2.1 Interfacing with SPI

Interfacing the NS9750 to many ADC devices can be as simple as connecting three SPI signals (Chip Select, Data in, and Clock) to the ADC to read the data that the ADC produces. Other ADCs with additional analog inputs or features will require all four SPI signals. This section describes these two methods of interfacing to ADCs and lists some components from Analog Devices and Maxim which can interface with the NS9750. The criteria for including these components is that they can be powered with a single 3.3V supply and will interface to the NS9750 without glue. It is by no means a complete list of the ADC devices which can interface to the NS9750 using the SPI protocol.

2.1.1 ADCs needing only the SPI Chip Select, Data in, and Clock signals



ADCs that require only three SPI signals are simple devices, with only one input and no additional features. The ADC will digitize the analog input when the SPI Chip Select signal goes low and will then send the digitized data to the NS9750 one bit at a time on the rising edge of the SPI clock that the NS9750 provides. The protocol for communication with a 12-bit device is shown below. There are variations among the different ADC devices such as number of bits, bit order, speed, leading or trailing zeros, but the basic access is always the same.



2.1.1.1 Configuring the SPI Channel

Any of the four SPI channels can be used to communicate with an ADC. The following steps are required.

1- Configure the GPIO pins for the SPI function.
2- Configure the Serial module to the SPI Master mode with the Serial Control Registers.
3- Set the bit rate with the Bit-Rate Register to the fastest speed that the ADC can handle.

2.1.1.2 Communicating with the Serial ADC

Either a DMA or interrupt driven routines can be used to extract the data from the ADC. The SPI signals are enabled when SPI data is transmitted. Simultaneously data is received. There cannot be any SPI receive data if the SPI channel doesn't transmit something. It is therefore necessary to transmit some data even though the ADC won't use this transmitted data.

If a DMA driver is used both a transmit and receive buffer are required. The buffers should be the same size. The receive DMA channel should be enabled before the transmit DMA buffer. When the transmit DMA channel is enabled, the SPI Chip Select signal will be go low and the SPI Clock will toggle. This will cause the ADC to digitize its input and to send this data on the SPI's data input line to be deposited in the DMA channel's receive buffer.

If an interrupt driven routine is used the SPI channel must transmit before it receives. Data is written to the FIFO Data Register and then the data that the ADC produced is read from FIFO Data Register after the RRDY bit in the Serial Status Register indicates that the data is available.

2.1.1.3 3-Wire ADC Devices

The following ADCs from Analog Devices and Maxim will interface to the NS9750 by using the procedure described above.

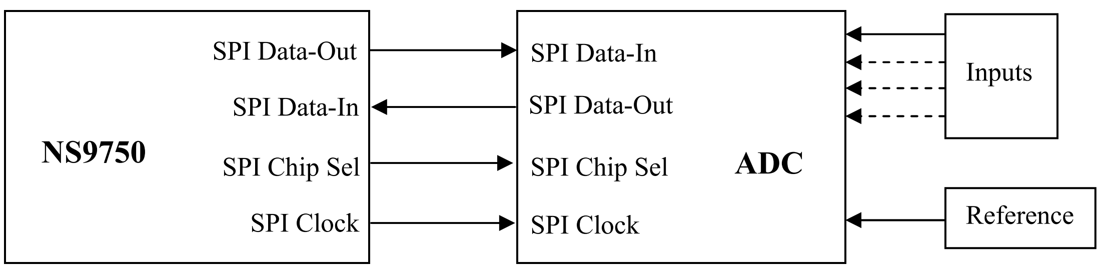
Copyright notice for Motorola and Maxim components ???

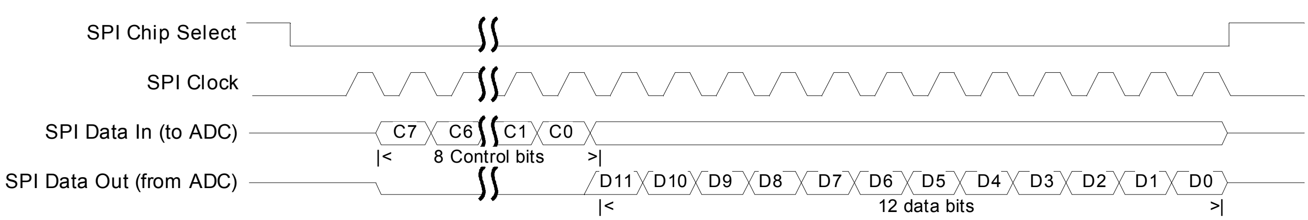
3-wire SPI Analog to Digital Converters from Analog Devices							
Name	Bits	Inputs	Sample Rate	Supply Voltage	Power	Package	Price (1K)
AD7266	12	6	2 MSPS	2.7V-5.25V	20mW	CSP, QFP	-
AD7440	10	1	1 MSPS	2.7V-5.25V	9mW	SOT	$2.94
AD7441	10	1	1 MSPS	2.7V-5.25V	9.3mW	SOP, SOT	$2.94
AD7451	12	1	1 MSPS	2.7V-5.25V	9.25mW	SOP, SOT	$5.00
AD7452	12	1	555 KSPS	2.7V-5.25V	7.25mW	SOT	$3.47
AD7453	12	1	555 KSPS	2.7V-5.25V	7.25mW	SOT	-
AD7457	12	1	100 KSPS	2.7V-5.25V	3mW	SOT	-
AD7466	12	1	200 KSPS	1.6V-3.6V	900µW	SOP, SOT	$2.76
AD7467	10	1	275 KSPS	1.6V-3.6V	630µW	SOP, SOT	$2.24
AD7468	8	1	320 KSPS	1.6V-3.6V	570µW	SOP, SOT	$1.35
AD7476	12	1	1 MSPS	2.7V-5.25V	17.5mW	SOT	$14.12
AD7476A	12	1	1 MSPS	2.35V-5.25V	17.5mW	SC70, SOP	$4.71
AD7477	10	1	1 MSPS	2.7V-5.25V	17.5mW	SOT	-
AD7477A	10	1	1 MSPS	2.35V-5.25V	17.5mW	SC70, SOP	$2.94
AD7478	8	1	1 MSPS	2.7V-5.25V	17.5mW	SOT	$3.35
AD7478A	8	1	1.2 MSPS	2.35V-5.25V	17.5mW	SC70, SOP	$1.12
AD7495	12	1	1 MSPS	2.7V-5.25V	13mW	SOIC, SOP	$6.11
AD7680	16	1	100 KSPS	2.5V-5.25V	16.25mW	SOP, SOT	$6.64
AD7683	16	1	100 KSPS	2.3V-5.5V	2.4mW	CSP, SOP	-
AD7684	16	1	100 KSPS	2.3V-5.5V	2.4mW	SOIC	-

3-wire SPI Analog to Digital Converters form Maxim							
Name	Bits	Inputs	Sample Rate	Supply Voltage	Current (ma)	Package	Price (1K)
MAX1085	10	1	300 KSPS	2.7 to 3.6	2.5	8/SO.150	$3.88
MAX1241	12	1	73 KSPS	2.7 to 5.25	0.9	8/PDIP.300 8/SO.150	$3.10
MAX1240	12	1	73 KSPS	2.7 to 3.6	1.4	8/PDIP.300 8/SO.150	$3.85
MAX1243	10	1	73 KSPS	2.7 to 5.25	0.9	8/PDIP.300 8/SO.150	$2.45
MAX1242	10	1	73 KSPS	2.7 to 5.25	1.4	8/PDIP.300 8/SO.150	$2.75

2.1.2 ADCs needing all four SPI signals

ADCs that require all four SPI signals are a little more versatile. They can have more than one input and/or they have additional features such as power-down mode. Everything is configured in the same way as the three wire devices. The only difference is that the data transmitted from the NS9750 will have an affect on the ADC. This data is used by the ADC to choose an input or to enable one of the ADC's features.





2.1.2.1 Communicating with a 4-Wire ADC

Just like a 3-wire device, the 4-wire ADC can be controlled with DMA or with an interrupt driven routine. Everything is configured the same way for 4-wire devices as would be for 3-wire devices and the software is the same. The only difference is that the receive buffer must be as large as both the control data that it will ignore and the ADC data that it will read. 4-wire ADCs typically require a control word before they produce the data. The SPI receive channel reads meaningless data while this control word is transmitted.

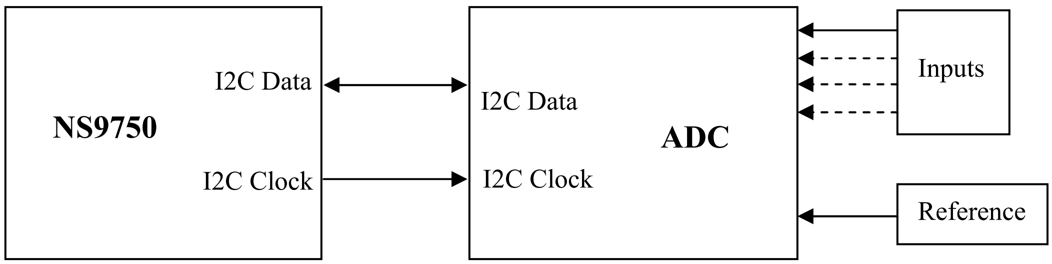
2.1.2.2 4-Wire ADC Devices

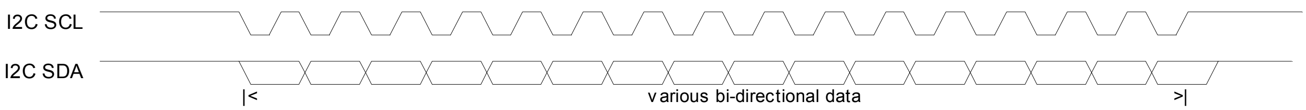
4-wire SPI Analog to Digital Converters from Analog Devices							
Name	Bits	Inputs	Sample Rate	Supply Voltage	Power	Package	Price (1K)
AD7490	12	16	1 MSPS	2.7V-5.25V	12.5mW	CSP, SOP	$7.00
AD7685	16	1	250 KSPS	2.3V-5.5V	4.8mW	CSP, SOP	-
AD7687	16	1	250 KSPS	2.3V-5.5V	4.8mW	CSP, SOP	-

4-wire SPI Analog to Digital Converters from Maxim							
Name	Bits	Inputs	Sample Rate	Supply Voltage	Current (ma)	Package	Price (1K)
MAX1081	10	8	300 KSPS	2.7 to 3.6	2.5	20/TSSOP	-
MAX1283	12	4	300 KSPS	2.7 to 3.6	2.5	16/TSSOP	$5.04
MAX1281	12	8	300 KSPS	2.7 to 3.6	2.5	20/TSSOP	$5.24
MAX1085	10	1	300 KSPS	2.7 to 3.6	2.5	8/SO.150	$3.88
MAX1249	10	4	133 KSPS	2.7 to 5.25	0.8	16/PDIP.300 16/QSOP	$3.05
MAX1248	10	4	133 KSPS	2.7 to 3.6	1.2	16/PDIP.300 16/QSOP	$3.15
MAX1241	12	1	73 KSPS	2.7 to 5.25	0.9	8/PDIP.300 8/SO.150	$3.10
MAX1240	12	1	73 KSPS	2.7 to 3.6	1.4	8/PDIP.300 8/SO.150	$3.85
MAX147	12	8	133 KSPS	2.7 to 5.25	0.9	20/CDIP.300 20/PDIP.300 20/SSOP	$5.95
MAX146	12	8	133 KSPS	2.7 to 3.6	1.2	20/CDIP.300 20/PDIP.300 20/SSOP	$6.25
MAX149	10	8	133 KSPS	2.7 to 3.6	1.2	20/CDIP.300 20/PDIP.300 20/SSOP	$3.20
MAX148	10	8	133 KSPS	2.7 to 5.25	0.8	20/CDIP.300 20/PDIP.300 20/SSOP	$3.10
MAX1247	12	4	133 KSPS	2.7 to 5.25	0.8	16/PDIP.300 16/QSOP	$5.80
MAX1246	12	4	133 KSPS	2.7 to 3.6	1.2	16/PDIP.300 16/QSOP	$6.15
MAX1245	12	8	100 KSPS	2.375 to 3.3	0.8	20/PDIP.300 20/SSOP	$8.13
MAX1111	8	4	50 KSPS	2.7 to 5.5	0.085	16/PDIP.300 16/QSOP	$1.69
MAX1110	8	8	50 KSPS	2.7 to 5.5	0.085	20/PDIP.300 20/SSOP	$1.86
MAX1108	8	2	50 KSPS	2.7 to 3.6	0.07	10/µMAX	$1.55

2.2 Interfacing with I2C

I2C is a 2 wire interface supported by the NS9750. Some ADCs can interface to the NS9750 using the I2C protocol.





2.2.1 I2C ADC Devices

I2C Analog to Digital Converters from Analog Devices							
Name	Bits	Inputs	Sample Rate	Supply Voltage	Power	Package	Price (1K)
AD7992	12	2	79KSPS	2.7V-5.5V	-	SOP	
AD7993	10	4	79KSPS	2.7V-5.5V	7mW	SOP	
AD7994	12	4	79KSPS	2.7V-5.5V	-	SOP	
AD7998	12	8	79KSPS	2.7V-5.5V	-	SOP	

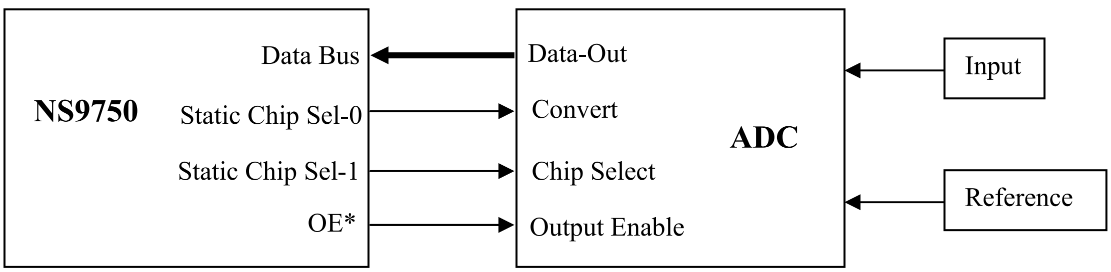
I2C Analog to Digital Converters from Maxim							
Name	Bits	Inputs	Sample Rate	Supply Voltage	Current (ma)	Package	Price (1K)
MAX1039	8	12	188 KSPS	2.7 to 3.6	0.35	16/QSOP	$1.90
MAX1037	8	4	188 KSPS	2.7 to 3.6	0.35	8/SOT23	$1.65
MAX1239	12	12	94.4 KSPS	2.7 to 3.6	0.670	16/QSOP	$4.19
MAX1237	12	4	94.4 KSPS	2.7 to 3.6	0.670	8/µMAX (µSOP)	$3.85
MAX1139	10	12	94.4 KSPS	2.7 to 3.6	0.670	16/QSOP	$2.99
MAX1137	10	4	94.4 KSPS	2.7 to 3.6	0.670	8/µMAX (µSOP)	$2.75

3 Parallel Interfacing

Digitizing video and other fast signals require the speeds that parallel ADCs can offer. The NS9750 has five static ram chip selects which can be used to interface with parallel ADCs. After the ADC's input is digitized the NS9750 reads the data as it were any static RAM memory location. At a minimum the data bus, a static chip select signal and OE (output enable) signal, must be connected to the ADC. Sometimes the WE (write enable) and a few address lines will be needed if the ADC has multiple inputs or additional features.

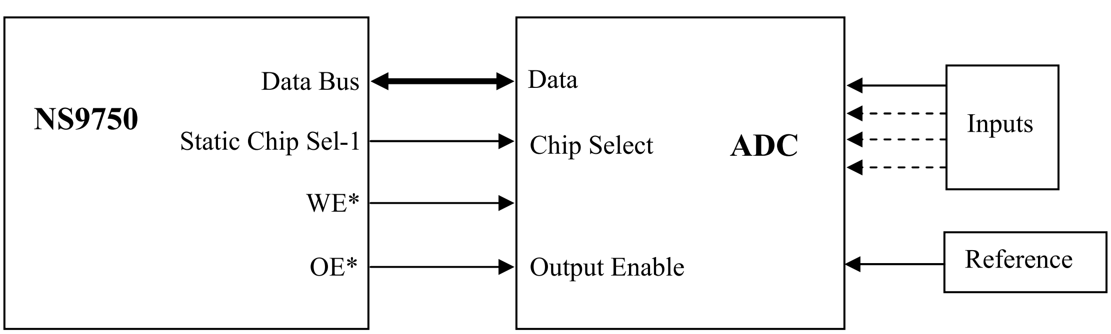
3.1 Single Input ADCs

One of the ways to interface with an ADC is to issue a convert pulse, wait a small amount of time, and then read the data. The NS9750 can easily handle this, without glue, by configuring two static chip selects. When the first chip select is asserted, the ADC would digitize the input signal. After waiting the specified conversion time, the second chip select should be asserted to read the ADC's data.

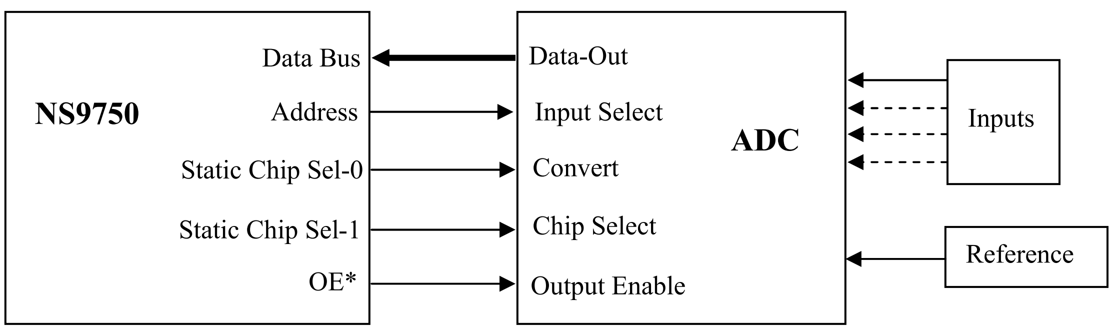


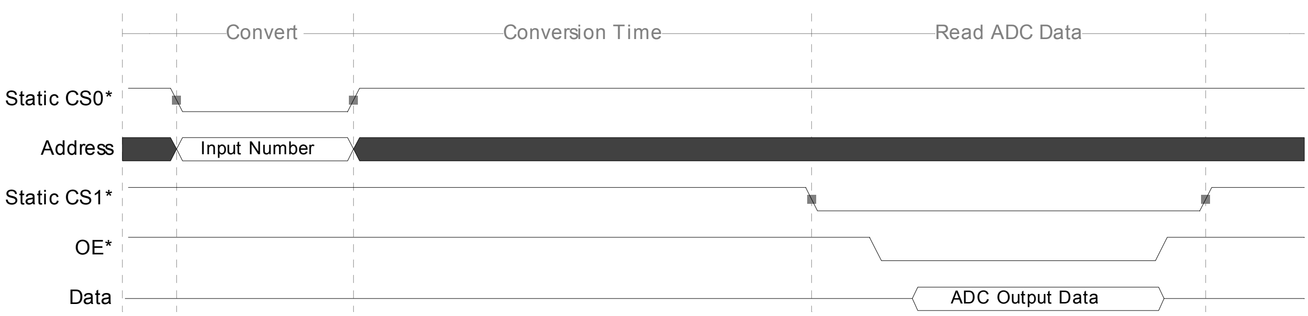
3.2 Multiple Input ADCs

When an ADC has multiple inputs, the ADC must be told which input to digitize. One way to do this is to write a command to the ADC, telling it what to do. Some ADCs will still need two chip select signals, but many will need only one. The NS9750 will first initiate a write cycle, where it will tell the ADC which input to digitize, and then a read cycle where it will take the ADC's data.



Another way that an ADC will choose its input is to use address lines during the conversion phase. After the conversion the ADC's data is accessed using a standard static RAM read cycle.





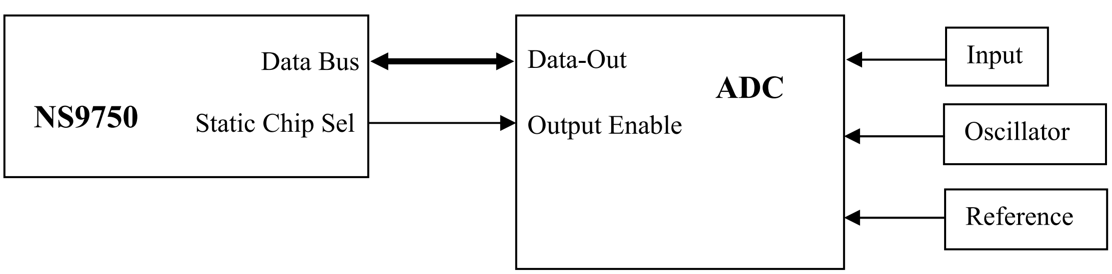
3.3 Medium Speed Parallel ADC Devices

The following parallel ADC components from Analog Devices and Maxim will interface with the NS9750, without glue, using one of the previously described methods.

Parallel Analog to Digital Converters from Analog Devices							
Name	Bits	Inputs	Sample Rate	Supply Voltage	Power	Package	Price (1K)
AD7470	10	1	1.75MSPS	2.7V-5.25V	12mW	SOP	$3.53
AD7472	12	1	1.2MSPS	2.7V-5.25V	12mW	SOIC, SOP	$7.30
AD7813	10	1	400KSPS	2.7V-5.5V	17.5mW	DIP, SOIC, SOP	$3.26
AD7819	8	1	200KSPS	2.7V-5.5V	17.5mW	DIP, SOIC, SOP	$2.50
AD7822	8	1	2MSPS	2.7V-5.5V	60mW	DIP, SOIC, SOP	$3.77
AD7825	8	4	2MSPS	2.7V-5.5V	36mW	DIP, SOIC, SOP	$4.35
AD7829	8	8	2MSPS	2.7V-5.5V	36mW	DIP, SOIC, SOP	$4.73
AD7854	12	1	200KSPS	3V-5.5V	30mW	DIP, SOIC, SOP	-
AD7854L	12	1	100KSPS	3V-5.5V	30mW	DIP, SOIC, SOP	-
AD7859	12	8	200KSPS	3V-5.5V	30mW	LCC, QFP	-
AD7859L	12	8	100KSPS	3V-5.5V	30mW	QFP	-
AD7933	10	4	1.5MSPS	2.7V-5.25V	16mW	SOP	-
AD7934	12	4	1.5MSPS	2.7V-5.25V	16mW	SOP	-
AD7938	12	8	1.5MSPS	2.7V-5.25V	16mW	CSP, QFP	-
AD7939	10	8	1.5MSPS	2.7V-5.25V	16mW	CSP, QFP	-

3.4 High Speed Parallel ADC Devices

The fastest ADCs don't have to be told to do a conversion. These devices will constantly convert the analog input using a clock input as a time base. The digitized data can be read anytime. The last conversion is always available for the NS9750 to read.



High Speed Parallel Analog to Digital Converters from Maxim							
Name	Bits	Inputs	Sample Rate	Supply Voltage	Current (ma)	Package	Price (1K)
MAX1196	8	2	40 MSPS	2.7 to 3.6	29	48/TQFP-7x7EP	$4.95
MAX1190	10	2	120 MSPS	2.7 to 3.6	149	48/TQFP-7x7EP	$19.95
MAX1198	8	2	100 MSPS	2.7 to 3.6	80	48/TQFP-7x7EP	$10.49
MAX1197	8	2	60 MSPS	2.7 to 3.6	40	48/TQFP-7x7EP	$5.80
MAX1195	8	2	40 MSPS	2.7 to 3.6	29	48/TQFP-7x7EP	$4.95
MAX1186	10	2	40 MSPS	2.7 to 3.6	35	48/TQFP-7x7EP	$8.97
MAX1183	10	2	40 MSPS	2.7 to 3.6	40	48/TQFP-7x7EP	$8.97
MAX1185	10	2	20 MSPS	2.7 to 3.6	35	48/TQFP-7x7EP	$4.95
MAX1184	10	2	20 MSPS	2.7 to 3.6	35	48/TQFP-7x7EP	$4.95
MAX1182	10	2	65 MSPS	2.7 to 3.6	65	48/TQFP-7x7EP	$11.76
MAX1181	10	2	80 MSPS	2.7 to 3.6	82	48/TQFP-7x7EP	$13.36
MAX1180	10	2	105 MSPS	2.7 to 3.6	125	48/TQFP-7x7EP	$17.12

4 ADC Manufacturer Links

http://www.analog.com/

http://www.maxim-ic.com/ADCDACRef.cfm

http://www.cirrus.com/en/products/

http://www.fairchildsemi.com/parametric/select.jsp

http://www.linear-tech.com/prod/prod_home.html?product_family=atod

http://www.national.com/appinfo/adc/

http://www.ti.com/

http://www.intersil.com/product_tree/