SID™ Hardware

The Sound Input Device (SID) is an audio digitizer designed for the Macintosh computer. It produces a continuous stream of digitized samples at 22 KHz and is software compatible with other existing audio digitizer software.

Hardware Description

POWER GENERATION

SID is a "parasitically powered" device, that is, it draws its power from the signal lines coming from the Mac. This is similar to serial mouse devices in the PC world. They draw power from up to three of the signal output lines from the PC. The SID draws its power from the two serial transmit data lines (TxD- and TxD+) from the Mac. The short circuit drive capability of each of these lines is up to 150 mA, many times the few mA of current required by the SID.

In addition to low current availability, a parasitically powered device must overcome two other problems. One is polarity reversal of the signal during data transmissions, the other is dealing with the low voltage available. The polarity reversal can be ignored in some cases, as the program collecting the digitized data does not send data to the SID. There is also the possibility, however, of future digitizers receiving commands for other purposes. The problem is solved by directing the positive voltage to the positive supply with diodes D3 and D4 (see schematic), and directing the negative voltage to the negative supply with D5 and D6. Since the transmit signals from the Mac are differential, one of the transmit lines is always positive and one is always negative, so both voltages are always available.

The positive voltage available is typically three to four volts. This is less than the five volts normally used for powering digital circuitry. The negative voltage is also typically three to four volts negative. The positive voltage is regulated to 2.5 Volts by VR1 and the negative voltage is regulated to -2.5 Volts by VR2. This provides a ± 2.5 Volt split supply for the analog circuitry and a 5 Volt supply differential (+2.5 V to -2.5 V) for the digital circuitry. For the Analog to Digital (A/D) converter, oscillator, and timing generation, the -2.5 V supply acts as ground and the +2.5 V supply acts as Vcc (+5 V). This solves another problem. The Mac requires a signal which goes positive and negative in relation to ground for the Handshake Input (HSKI) and a differential signal for received data (RxD+ and RxD-). Since the digital signals output from the SID swing from +2.5 V to -2.5 V they meet the requirements for the HSKI signal, and by tying RxD- to ground, the data signal out of the SID presents a ±2.5 V differential to the receive inputs on the Mac.

OSCILLATOR

A 1.558 Mhz master clock is provided by a ceramic resonator and two sections of a hex inverter. The oscillator circuit is taken from the muRata Erie application notes.

TIMING GENERATION

Two timing signals are needed by the A/D converter. One is a clock, which will determine the output bit rate and maximum conversion rate. The other is a Chip Select (CS), which determines when data is sent, and therefore, the conversion rate. The conversion rate must be 22254.5454 Hz, the rate at which the Mac will resynthesize the data. Programs which offer slower sample rates accomplish this by discarding every other sample (for 11127.2727 Hz sample rate) or three of every four (for 5563.6363 Hz). Note that these odd numbers are referred to as 22 Khz, 11 Khz, and 5Khz sample rates. Additionally, Apple provides MACE through APDA which performs some real-time audio compression and expansion in software.

The master clock is divided by 5 using part of U1, 74HC390, a dual decade counter. This 311.6 Khz data clock signal becomes the A/D clock signal. Bits will output from the A/D at half this rate. This signal is also output to the Mac as the HSKI signal. Two sections of the hex inverter U2 act as drivers for the HSKI signal. The serial port on the Mac is initialized to use an external clock at a times one rate, the external clock being the HSKI signal. It is also set for asynchronous, no parity, with one or two stop bits. Figure 1, Fine Timing, shows the relationship between the master clock, data clock (HSKI), and data signals.

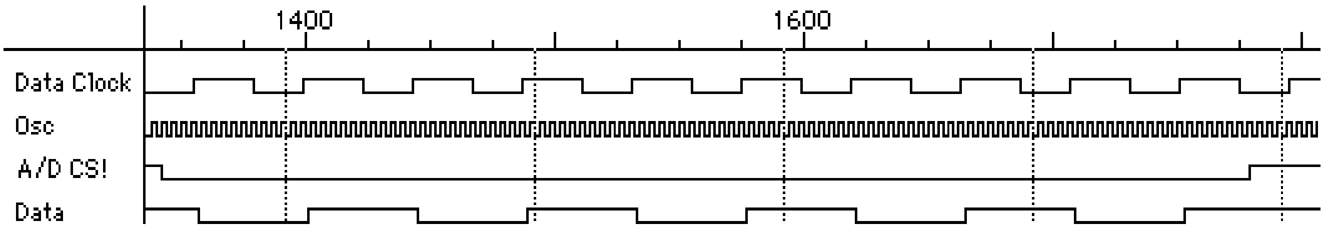

Figure 1, Fine Timing

The Data Clock is further divided by 14 by the remaining sections of U1 to provide the A/D CS signal. The rate of this signal is 22257.142 Hz, the required data rate. The divide by 14 is really a divide by 20 which is cut short by a reset generated by D1, D2, and R1 acting as an AND gate. The A/D CS signal is low for 10 counts and high for 4 (at which point the reset occurs). The 10 low counts is the time period when the A/D outputs 10 bits of serial data (one start bit, 8 data bits, and one stop bit). The time the output is disabled can be considered as a second stop bit plus a 3 bit gap between bytes, or as a 4 bit gap. See both Figure 1, Fine Timing, and Figure 2, Course Timing.

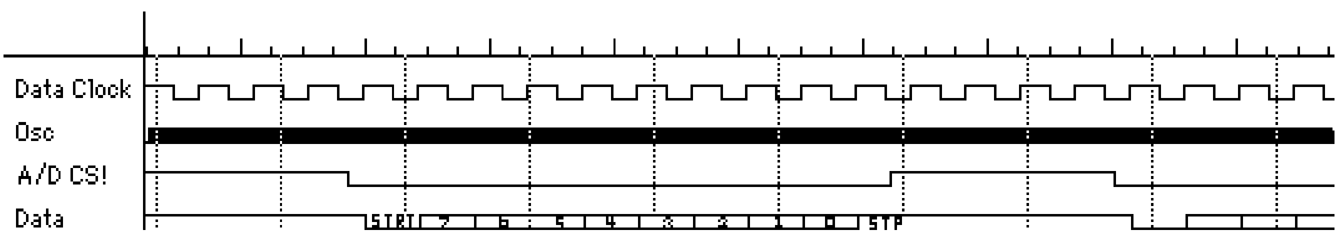

Figure 2, Course Timing

A/D CONVERSION

A/D conversion is performed by a National Semiconductor ADC0831CCN 8 bit serial A/D converter. It has several features which make it ideal for use in the SID:

- Serial output
- Single +5 supply required
- Low power consumption
- Zero is output on the first clock which becomes the serial start bit

The A/D converter uses a successive approximation method. This is essentially a half interval search. The output is the result of the current interval test. Therefore the converter outputs the most significant bit first (the result of the “is it greater or less than half way” test) followed by the second most significant, and so on. This is the opposite of the serial data protocol and requires the software to reverse the data.

The digital signals described earlier are all that are needed to cause the A/D to generate data at the proper rate. The data output signal is pulled up by R30 (the output is open drain) and driven by two of the sections of the hex inverter U2. This signal is the receive input to the Mac, and a trick similar to one used by RS232 serial devices is used to provide the differential input required (ground RxD- and drive RxD+ with a bipolar signal).

The software is expecting an A/D output value of 128 to represent no signal input. Zero represents maximum negative swing, and 255 represents maximum positive swing. Since the operational amplifiers (OP Amps) in the analog portion are not capable of handling signals which reach the positive supply voltage, a swing of less than 5 Volts total must represent the full digital output range. By connecting the A/D converter's Vref pin to ground, a swing of 2.5 Volts (the difference between Vref and the A/D converter's ground) becomes the full range swing. Vin- is tied to a voltage divider (R29 and R32) which provides 1.25 Volts. This is subtracted from Vin+ inside the A/D. Vin+ is referenced to ground by R31.

With no signal (0V) input Vin+ is at ground, which is at 2.5 V above A/D ground. This input has 1.25 V subtracted by Vin-, leaving 1.25 V. This is 1/2 of Vref, 1/2 the total range, and therefore 128 counts. Similarly a maximum input signal of 1.25 V above ground, which is 3.75 V above A/D ground at Vin+, has 1.25 V subtracted by Vin-, leaving 2.5 V. This is equal to Vref, which is maximum, which is 255 counts. An input signal of -1.25 V referenced to ground is 1.25 above A/D ground. 1.25 V is then subtracted by Vin- leaving 0, which outputs a zero. To summarize, the 2.5 V on Vref restricts the range and the 1.25 V on Vin- converts the ± swing in relation to ground in the analog circuitry to the different ground reference used by the A/D and other digital circuitry.

MIC PRE-AMP

One section of the quad OP Amp U3 is used to boost microphone level signals to line level signals. A built in microphone can be used and is automatically switched out when an external mic is connected. Diodes D9 and D10 prevent damage in the event too strong a signal is connected.

LINE-AMP

Another section of OP Amp U3 is used to bring line levels up to a higher amplitude (± 1 V). Again D7 and D8 provides protection from strong signals. The Mic Pre-Amp is switched out when a line input is connected.

LP FILTER

With a 22 Khz sample rate the HIGHEST signal which can theoretically be produced is an 11 Khz signal. Signals above 11 Khz will produce unwanted frequencies at less than 11 Khz. The low pass (LP) filter attenuates signals above 11 Khz to avoid undesirable results. The filter was actually computed to attenuate signals above 7 Khz. This number was arrived at as a compromise of the desire to have the widest unattenuated range and the need to attenuate signals above 11 Khz so that they produce NO signal (less than 1 bit of signal strength). The more filter "poles," the closer the filter frequency can be to 11 Khz. SID uses a five pole filter. The first 3 poles are implemented with one section of the Op Amp U3, the last 2 sections with another section of the Op Amp. The last two poles also provide a slight amount of gain, boosting the signal from a 2 V swing to the 2.5 V swing required by the A/D converter.

CONSTRUCTION

Appendix A is a list of parts to construct the SID. The part numbers listed are for Digi-Key Corp. unless otherwise noted. Many more parts are available at Radio Shack than shown in the parts list but at a higher price. Since Digi-Key is a source for the more difficult to find A/D converter, you may as well purchase the less expensive parts from them along with the A/D.

A schematic is provided in an additional file. The pin numbers for the Mac 8 pin mini-DIN are shown with the 9 pin D connector pin numbers following in parenthesis. The SID may be constructed by normal construction techniques. The first few units built were wire wrapped. You should use some care in parts placement and ground distribution to avoid coupling noise into the more sensitive analog input sections.

TROUBLESHOOTING

Before attempting to fix the unit, make sure there really is a problem. Make sure everything is connected and that the proper ports are selected in the software. ALSO NOTE - Since the unit draws power from the transmit lines - THE TRANSMITTER IN THE MAC MUST BE ENABLED. The SID software as well as existing commercial sound input software enable the transmitter lines properly.

If SID is not operating properly, run the SID Demo program and test the following:

- Check for +2.5 V and -2.5 V supplies. If not present make sure the transmitter is enabled, then check for shorts.
- Check for the presence of the Osc master oscillator signal.
- Check for the A/D converters clock (CK) and chip select (CS) signals.
- Check for A/D converter data out (DO)
- Check the analog sections for signals which are nominally at ground level.
- Check the analog sections using a signal generator to assure that the signal is not being distorted.

APPENDIX A

#	DESCRIPTION	P/N	$	Ref. Des.
2	22 Ohm 1/4 W Resistor	22Q	.25/5	R6,R7
4	27 Ohm 1/4 W Resistor	27Q	.25/5	R4,R5,R8,R9
3	1K 1/4 W Resistor	1.0KQ	.25/5	R2,R17,R30
2	4.7K 1/4 W Resistor	4.7KQ	.25/5	R16,R21
1	8.2K 1/4 W Resistor	8.2KQ	.25/5	R19
2	10K 1% 1/4 W Resistor	10.0KX	.50/5	R29,R32
5	10K 1/4 W Resistor	10KQ	.25/5	R1,R11, R14, R22,R31
4	47K 1/4 W Resistor	47KQ	.25/5	R25,R26,R27,R28
1	51K 1/4 W Resistor	51KQ	.25/5	R23
1	68K 1/4 W Resistor	68KQ	.25/5	R24
1	100K 1/4 W Resistor	100KQ	.25/5	R18
2	120K 1/4 W Resistor	120KQ	.25/5	R10, R15
1	1M 1/4 W Resistor	1.0MQ	.25/5	R3
2	22pF ceramic capacitor	P4016	.56/10	C9,C10
2	100pF ceramic capacitor	P4024	.56/10	C2,C3
1	390pF ceramic capacitor	P4031	.79/10	C21
2	470pF ceramic capacitor	P4032	.79/10	C18,C19
1	560pF ceramic capacitor	P4033	1.05/10	C20
1	4700pF ceramic capacitor	P4193	1.09/10	C22
7	.1uF ceramic capacitor	P4164	1.13/10	C1,C4,C5,C6, C16,C17,C24
4	1uF ceramic capacitor	P4537	.76	C11,C12, C14, C23
2	47uF electrolytic capacitor	P6607	.21	C7,C8
1	TL064 quad op amp I/C	Texas Instruments TL064CN	?	U3
1	ADC0831CCN A/D conv. I/C	ADC0831CCN	3.13	U4
1	74HC390 dual decade cntr I/C	MM74HC390N	.70	U1
1	74HC04 hex inverter I/C	MM74HC04N	.28	U2
10	1N914 signal diodes	1N4148	.60/10	D1-D10
2	LM336Z-2.5 2.5 V Ref.	LM336Z-2.5	1.20	VR1,VR2
1	1.558 Mhz Cer. Res.	muRata Erie CSA1.558MK040	?	Y1
2	1/8" closed circuit jack	Radio Shack 274-248	1.69/2	J1,J2
1	Electret Microphone	Radio Shack 270-092	2.99	
1	10K Potentiometer	Radio Shack 271-218	.69	R13
1	Enclosure	Radio Shack 270-233	2.19	
1	8 Pin mini DIN conn.	Jameco Elect. 8MDJ	1.49	
1	Mac serial cable	Jameco Elect. APC3	4.95	

All part numbers are Digi-Key part numbers unless specified otherwise.

Digi-Key	(800) 344-4539
Jameco Elect.	(415) 592-8097
muRate Erie	(404) 436-1300