Analog Input/Output Unit For PC Computer.

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Properties of the unit are as follows:

- Analog input part is built around A/D converter ADC0809. The chip offers 8 bit resolution for conversion of analog voltages into digital representation, It takes approximatelly 100 micro seconds to do a conversion. It's specified differential nonlinearity is below 1/2 LSB. It can measure voltages fromn 0 to 5V.
- Analog output part is built around DAC0808, 8 bit digital to analog converter. Again it's differential nonlinearity is below 1/2 LSB, conversion time is around 1us. It's output current ranges from 0 to 2mA.
- Four inputs are available at the front plate. Those inputs are fed to four amplifiers and outputs of them are connected to ADC0809. Therefore it is possible to measure four voltages simulatneously. Furthermore it is possible to change gain of two amplifiers by software. The other two amplifiers have differential inputs and fixed gain.
- Currently selected gains for the two inputs are: 0.5: input voltage range is 0 to 10V 1 : input voltage range is 0 to 5V 2 : input voltage range is 0 to 2.5V 5 : input voltage range is 0 to 1V Gain for each of the two channels can be set independently.
- Currently selected gains for two differential inputs are: 1 : input voltage range is 0 to 5V 10 : input voltage range is 0 to 0.5V
- All analog inputs are protected from overvoltage up to 20V.
- The output of DAC0808 is fed to simple current to voltage converter on the board. This produces voltage in the range from 0 to 5V corresponding to digital equivalent written into DAC0808. This voltage is available to the user at front panel.
- The unit is additionally equipped with four TTL compatible digital outputs and four TTL compatible digital inputs. These are available at front plate through D9 connector.

The unit is assembled on single EURO size board. It fits into Agency propagated EURO crates. From there it uses + 15V, -15V and +5V power supplies. A connection to the PC SLOT unit inside a PC computer is made by means of D25 connector which is located at the front plate.

1.2. Circuit description

The circuit's block diagram can be seen in appendices in Fig.1. From there it can be seen that the following blocks are needed:

a) analog to digital converter
b) input amplifier
c) input amplifier
d) input amplifier
e) input amplifier
f) digital to analog converter with latch
g) current to voltage convertor
h) digital input
i) digital output
j) address decoding

a) Analog to digital converter U2

ADC0809 is used. Detailed specifications on the chip can be found in National data book about linear integrated circuits. The chip itself has 8 analog inputs named IN0 to IN7. These inputs accept input voltages in the range from 0 to 5V (depending on connection of the chip, range span and offset can be altered, see data book for details). Reference voltage for the chip has to be provided externally. A single zener diode D1 takes care of it.

Since the converter has eight inputs it is obvious that it can not measure all the inputs simultaneously. It can measure one input at a time. User can select which input to measure by writting a digital number of the input selected into a chip through corresponding pins (A0 to A2). Writting is again done through data bus of the computer, so lines DB0 to DB2 are connected to A0 to A2 inputs of the converter chip. Writting of pattern from data bus into the converter will take place when ALE line of the converter chip is pulled low. If this line is high, pattern on data bus has no influence on operation of converter chip.

ADC0809 needs a clock for proper operation. The frequency of it should be maximum 640KHz and it should be applied to CLK input of the chip. Stability and precise frequency of the clock are not very important, only converion time is affected by clock frequency. Therefore a simle clock generator suffices and this is constructed around U3A, Schmidt trigger input NAND gate. The frequency of oscillation is around 550KHz.

The converter chip needs a kick to start a conversion. This kick has to be provided by the user or in this case by computer. Corresponding signal is connected to START input of the chip. When this line is pulled low the conversion is initiated.

The result of conversion is available at chip's digital outputs D0 to D7. These are connected to PC SLOT's data bus (DB0 to DB7). Outputs of the chip are three stated, so whenever computer wants to read a result of conversion from this chip it has to pull the three state control line for the converter low. This line is named OE, Output Enable.

The complete sequence of signals needed for this converter to operate is therefore: - select input you want to measure, you do it by writting number of input to A0 to A2 input of the chip, - start conversion by asserting START signal - wait for converion to finish (about 100 micro seconds) - read result of the conversion from D0 to D7 lines.

Since it is difficoult to wait 100 microseconds for conversion to end this chip has another output called End Of Conversion, EOC. It is high during the conversion and goes low afterwords. This signal is also available to the computer. It is connected to PC SLOT's data bus through a three state buffer. Therefore by reading this signal computer can determine if conversion is already finished. It does not need to wait for 100 micro seconds, it rather waits until the conversion is finished. Waiting for specified time difficoult since different computers may be used to run the software, also different conversion times will result in different clock frequencies. Third line of the previous recipe therefore reads: - wait until EOC signal from converter chip goes back low.

On the board one simplification is introduced. Lines START and ALE are connected together. This results in modified select input / start conversion procedure. Instead of writting selected input number and after this starting a conversion software should rather write selected channel number twice one after another.

b) Input amplifier

Input of the ADC0809 can accept only voltages between 0 and 5V. This is not enough, since users want to measure voltages of different spans. One operational amplifier is used to build input stage that will accomodate for user's needs.

For input 0 (IN0) of ADC chip one quarter of TL084, U6A is used. The operational is connected as normal noninverting amplifer. It's gain is determined with feedback resistor R7 and resistor conncted from inverting input (-) to ground (R2, R3, or R4). Two more resistors are added at noninverting input of operational to protect it's input from overvoltage. These are R1 and R8. Since R1 is equal to R8 voltage applied to the noninverting input of U6A will be one half of voltage at INPUT0, the one connected at the front plate by a user. Gain of the stage can therefore be expressed as:

$$G = 0.5 \cdot \left(1 + \frac{R7}{RX}\right)$$

Rx stands for one of R2, R3, or R4 resistors depending on selection. With resistor values used in the circuit the gain can be:

B	A	Selected resistor	Gain	Max. Input voltage
0	0	R2	5	1V
0	1	R3	2.5	2V
1	0	R4	1	5V
1	1	NONE	0.5	10V

and with a certain gain selected maximum input voltage which can be measured is also determined. By selecting different resistor different sensitivity of conversion can therefore be selected.

In order to select different resistor a switch is needed. There are various versions of analog switches available. One of the possible solutions would be to use relays. By closing contacts of a certain relay gain would be selected. There are better components for this purpose than relays. These are so called analog switches.

In the circuit analog switch named CD4051 is used (U5). Internally it imploys MOS transistors to open a conductive path between pins selected. A connection exists between X# (#is a number between 0 and 7) and X. Which of the X# will be connected to X is determinewd with a pattern applied to A,B and C inputs of the chip. Combination A=low, B=low, C=high for instance connects X4 with X. By applying certain combination of logic levels certain resistor of R2, R3, R4 is connected to ground thereby used in formula given above. Digital pattern applied at A, B, C determines gain of the stage.

Since there are only four possible gains (R2, R3, R4 or none of them), only two digital inputs to analog switch chip are needed. A and B are used. See former table for possible combinations.

Appropriate digital pattern is supplied by computer through digital output chip. A Zener diode D2 is added in the circuit to clamp voltage at the input of ADC chip to maximum 5V.

c) Input amplifier 1 (U6B, U7)

Does the same as input amplifier 0, the connection is replica of connection of input amplifier 0. In this circuit U6B and U7 are used in place of U6A and U5. Output of this stage is connected to IN1 of the ADC chip.

d) Input amplifier 2 (U6C)

It is assumed that user sometimes wants to measure differential voltages. For this purpose input amplifier 2 was built as differential amplifier. It's gain is fixed to 1 since all resistors used have equal value. Output of the amplifier is connected to IN2 of ADC chip. The voltage at this output is again clamped to 5V maximum to prevent ADC chip from being damaged.

e) Input amplifier 3 (U6D)

Input amplifier 3 is again replica of input amplifier 2 with small differences. Gain for this stage is selected to be 10. Output of the stage is connected to IN3 af ADC chip.

f) Digital to analog converter with latch

This part of circuit is built around simple digital to analog converter circuit DAC0808. This is 8 bit chip and it has current output. Reference voltage for it must be supplied externally, manufacturer recommends reference voltage of 5V in combination with reference resistor of 2.5K for inverting and noninverting reference voltage inputs. See data book about the chip for details.

As mentioned output of this converter is current. It can range from 0 to the same value as current flowing into reference pin has. In our case 5V reference voltage flows through 2.5K reference resistor, therefore reference current is 2mA. This is at the same time recommended value by the producer. Output current of the chip can consequently range from 0 to 2mA.

The converter chip will try to sink current (in the connection used) of 2mA through it's pin ## when digital combination on it's inputs is all ones, &hFF. Output current will be 0 for digital combination of all zeroes at the inputs of the chip. Any intermediate pattern at the inputs of the chip will dictate corresponding different output current.

The user wants output current to hold desired value. Since the pattern on the data bus of a computer is not fixed a latch is introduced at the inputs of DAC chip. Data pattern from computer's data bus is stored into the latch when writting at certain address occures. Integrated circuit used for the purpose is 'LS374. It's outputs are permanently enabled, writting into it occures on low-to-high transistion at pin ##.

g) Current to voltage convertor

Generating current as an output value of digital to analog converter is not so very useful. Majority of users request output voltage to conform to computer dictated value. Therefore a converter from current to voltage is needed. This consists of a single operational amplifier type LM318. The amplifier is additionally compensated against ringing which might occure due to large capacitive loads (long cables connected to the output of a circuit). The values of components used in this additional circuit are selected to give output voltage of 0 volts for digital pattern of all zeroes at the input of DAC chip and 5V for pattern of all ones.

h) Digital input

Computer can read digital pattrern from peripheral units or from any devices we need to connect there. However an information from peripheral must not be permanently tied to computer's data bus. It should be present there only during the time computer is trying to read peripheral data in question. Therefore a three state buffere must be inserted between peripheral and computer's data bus.

In the circuit LS245 is used for the purpose. It is transparent for information present at it's inputs during computer's read operation from predefined address. Therefore data pattern present at int's inputs is placed onto the computer's data bus during this time.

Four digital input lines are available. One additional bit from computer's data bus is connected to EOC signal of ADC0809 analog to digital converter. By reading this input port user also read status of ADC chip.

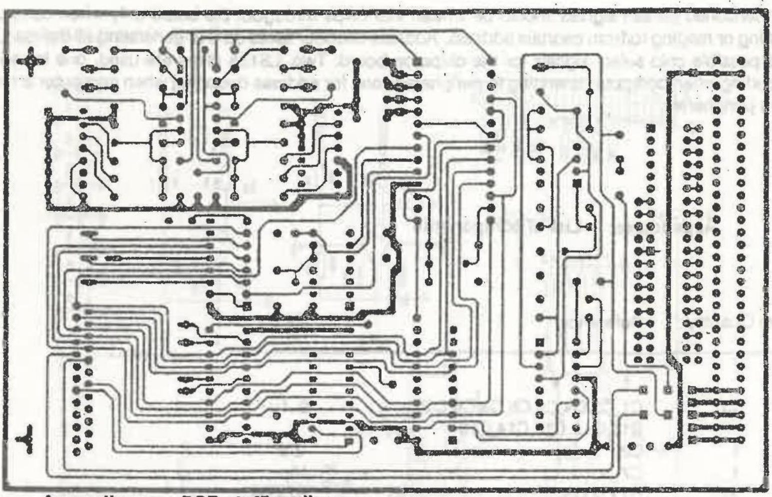
i) digital output

Pattern of signals on data lines of computer changes all the time. If user wants to send a message to a peripheral and this message is to remain fixed for some time, then the message has to be locked from data bus into a latch. This should happen on computer write operation at certain address.

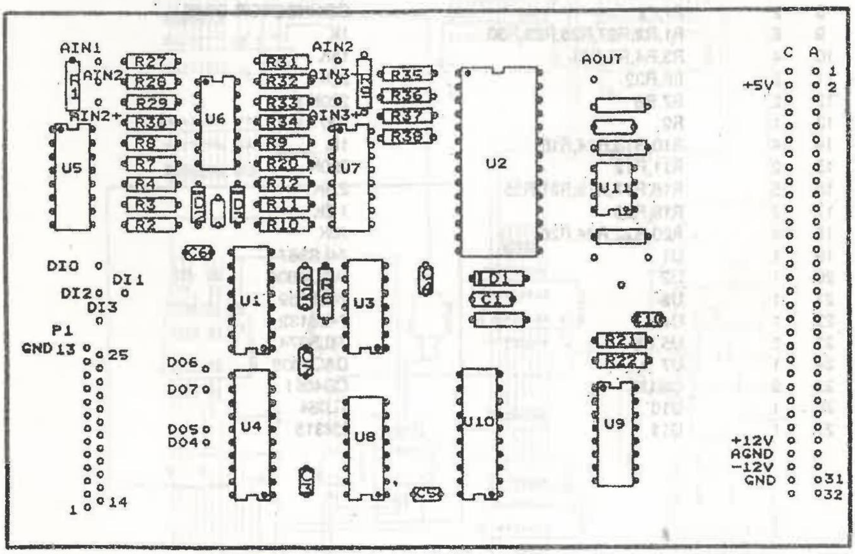
One 'LS374 is used in the circuit to accomplish this operation. It's outputs are permanently active and data pattern from computer's data bus is written into the chip on low-to-high transition of clk signal, which in turn happens only when computer is writting onto certain address.

Upper four outputs of this chip are available to a user for it's purpose (D4 to D7). Additional four outputs are used on board to control gain of input amplifiers 0 and 1, two bits per amplifier stage.

Appendices: PCB layout, solder side



Appendices: PCB stuffing diagram



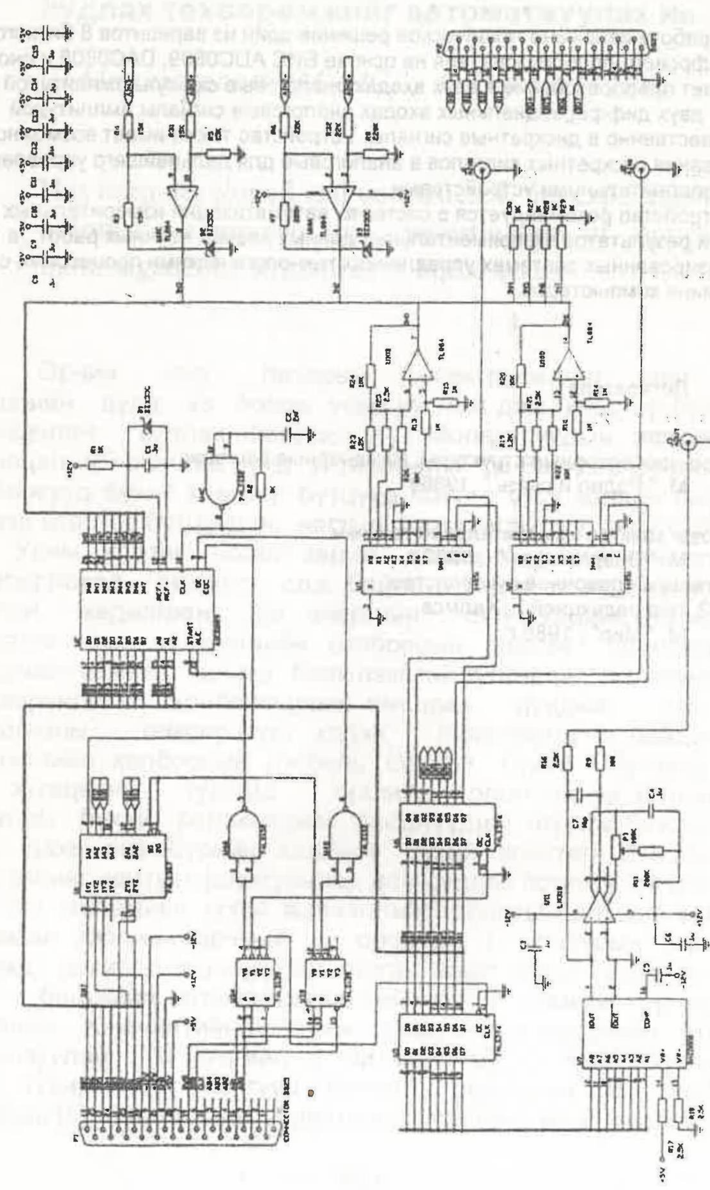
j) Address decoding

As mentioned certain signals should be written into chips througout the board only when computer is writting or reading to/from cedrtain address. Address decoder takes care of generating all the read, write and possible chip select signals for the chips on board. Two 'LS138 chips are used, one for address decoding when computer is writting to peripherals, one for address decoding when computer is reading from peripherals.

Appendices: List of components

Item	Quantity	Reference	Part
1	13	C1,C3,C4,C5,C6,C8,C9,C10 C11,C12,C13,C14,C15	0.1u
2	1	C2	2nF
3	1	C7	10p
4	3	D1,D2,D3	BZX55C
5	1	J1	BNC CONNECTOR
6	1	J2	BNC CONNECTOR
7	1	J3	BNC CONNECTOR
8	2	P1,P2	CONNECTOR DB25
9	6	R1,R2,R27,R28,R29,R30	1K
10	4	R3,R4,R5,R31	15K
11	2	R6,R32	22K
12	2	R7,R8	220K
13	1	R9	100
14	4	R10,R13,R14,R15	1M
15	2	R11,R12	200K
16	5	R16,R17,R18,R21,R25	2.5K
17	2	R19,R23	1.2K
18	4	R20,R22,R24,R26	10K
19	1	U1	74LS367
20	1	U2	ADC0809
21	1	U3	74LS139
22	1	U4	74LS132
23	2	U5,U6	74LS374
24	1	U7	DAC0808
25	2	U8,U9	CD4051
26	1	U10	TL084
27	1	U11	LM318

Appendices: 1. Detailed shematic



Аннотация

В данной работе изложено техническое решение один из вариантов 8 битного аналого-цифрового преобразователя на основе БИС ADC0809, DAC0808 и оно обеспечивает преобразование в двух входах аналоговые сигналы амплитудой от 0V до 10V, и в двух дифференциальных входах аналоговые сигналы амплитудой от 0V до 5V соотвественно в дискретные сигналы. Устройство также имеет возможность преобразования пискретных сигналов в аналоговые для дальнейшего управления разными исполнительними устройствами.

Данное устройство рекомендуется в системах автоматизации измерительных работ и обработки результатов эксприментальных данных разных научных работ , а также в автоматизированных системах управлениях технологическими процессами с помощью мини компьютеров.

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