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Interfacing and off-line analysis for VOS-1A Barry ionosonde

Enrico Zuccheretti
Istituto Nazionale di Geofisica, Roma, Italy

Abstract
Ionospheric studies have a great importance in radiopropagation and planetary atmospheric physics. The basic instrument for the investigation of ionospheric physics is the sweep frequency *H-F* radar called ionosonde. Ionospheric measurements, like other geophysical quantities, are useful only if there is a long and unbroken history, both for scientific and service purposes. Therefore a huge amount of data is produced and only a few ionospheric characteristics are scaled. In the Istituto Nazionale di Geofisica, the ionospheric hard copy data bank (paper and film) already requires a large storage space. The rough data on hard copy are not suitable for complete analysis and they should be completely digitized before processing. Usually only some characteristics are digitized and stored (scaled ionogram), but in this way it becomes more difficult to extract important physical quantities like the electron density profile. In order to overcome these problems, an Ionospheric Data Acquisition System (IDAS) based on commercial PCs has been developed. This ensures reliability for data acquisition and the availability of commercial software packages for analysis, compression and storage.

Key words *ionosphere – data acquisition – ionogram scaling – interfacing*

1. General description of the system and software facilities

The general purpose of this system is the acquisition, storage and analysis of ionograms coming from the ionosonde.

Referring to the block diagram of fig. 1 the PC is connected to the ionosonde through an interface.

Such interface, described later, is necessary to synchronise the ionosonde and the PC and generates all the functions necessary to control the analog-digital conversion of the signal and the interrupt pulse sequence. Data acquisition is managed by an interrupt routine which takes data from parallel port and then stores them in the memory. The ionogram is accompanied by a header which contains parameter values of the measurements as shown in fig. 2 (year, day, hour, minutes, start and end frequency and frequency increment step). Some parameters are used to identify the data in the PC file names.

The ionograms first digitized and temporarily stored in RAM memory are sent to the hard disk for further analysis and compression. They can later be printed if required. In its maximum length the ionogram is 280 kbyte of rough data that are fed directly into the memory.

Other off-line analyses – such as data compression and final storage, data retrieval to read the ionogram sequence, data scaling to carry out the ionosphere characteristic including the electron density profile and transmission – are possible. This system allows operators great flexibility in collecting, storing, retrieving and analysing data by using custom and commercial software packages.

Mailing address: Dr. Enrico Zuccheretti, Istituto Nazionale di Geofisica, Via di Vigna Murata 605, 00143 Roma, Italy; e-mail: zuccheretti@marte.ingrm.it

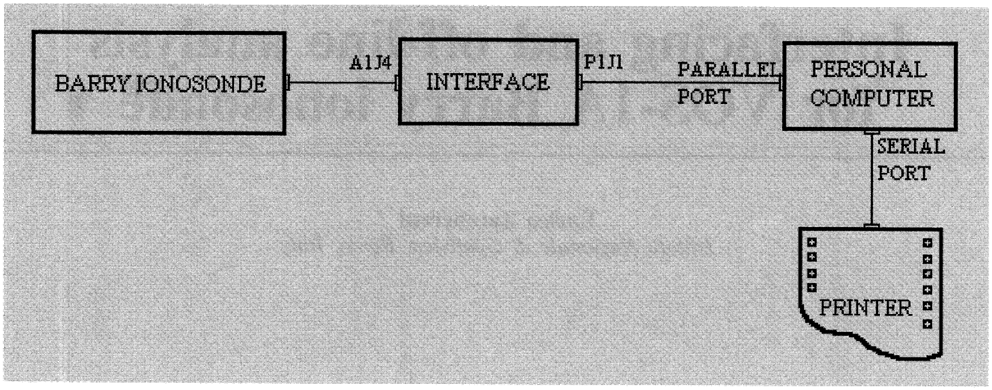

Fig. 1. Block diagram of the system.

Turbo C language has been employed both for data acquisition and off-line analysis. In fact, with such programs, not only compiling, but also hardware functions – such as interrupt routine management, input-output operations (parallel and serial port), internal management of the μP registers and memory locations – are more flexible.

The software automatically manages two main operations (acquisition and printing) as well as the other operations that require the operator's decision: data compression, ionogram sequence display and ionogram scaling.

2. Acquisition, printing and data compression

The PC acquires data from the interface at the rate of 1 kbyte/s through the parallel port. Data transmission is asynchronous because the interrupt is generated in the interface and the PC can perform other operations among the interrupt pulses, for example ionogram display.

The beginning and the end of data transmission are fixed by the ionosonde so that the acquisition system can receive any kind of vertical sounding measurements. The only limit is the conventional memory of the PC.

The amount of data depends on the length of the vertical ionospheric sounding, 10 kbyte/MHz, so that a 2-30 MHz ionogram (in oblique sounding modality) requires ~ 280 kbyte data.

The use of the parallel port is suggested by the fact that, in this way, it is not necessary to insert in the PC other devices (*i.e.* A/D board); a portable PC can also be employed. Moreover, the parallel port is the most common input/output communication way between the PC and peripheral devices. The parallel port employment is not restrictive with respect to the internal PC boards because it allows work to be carried out under the hardware interrupt (IRQ 7) that is normally used in printing operations.

The first interrupt pulse received allows the PC to record the local ionosonde time, and the program creates a file in which the sounding parameters are contained.

At each interrupt pulse, the interface sends to the PC a byte that is temporarily stored in the memory at increasing locations until the last pulse. At this point the amount of data is transferred to the hard disk.

The acquisition system is controlled by a software «watch dog» routine that tells the main program if the last interrupt pulse received is the end of the sounding. It is only at this point that the other above mentioned utilities of the software package are available because the acquirement routine has priority. The ionogram is recorded in the following form:

MMMDDHHm.S.YY

where, MMM is the month, DD the day, HH

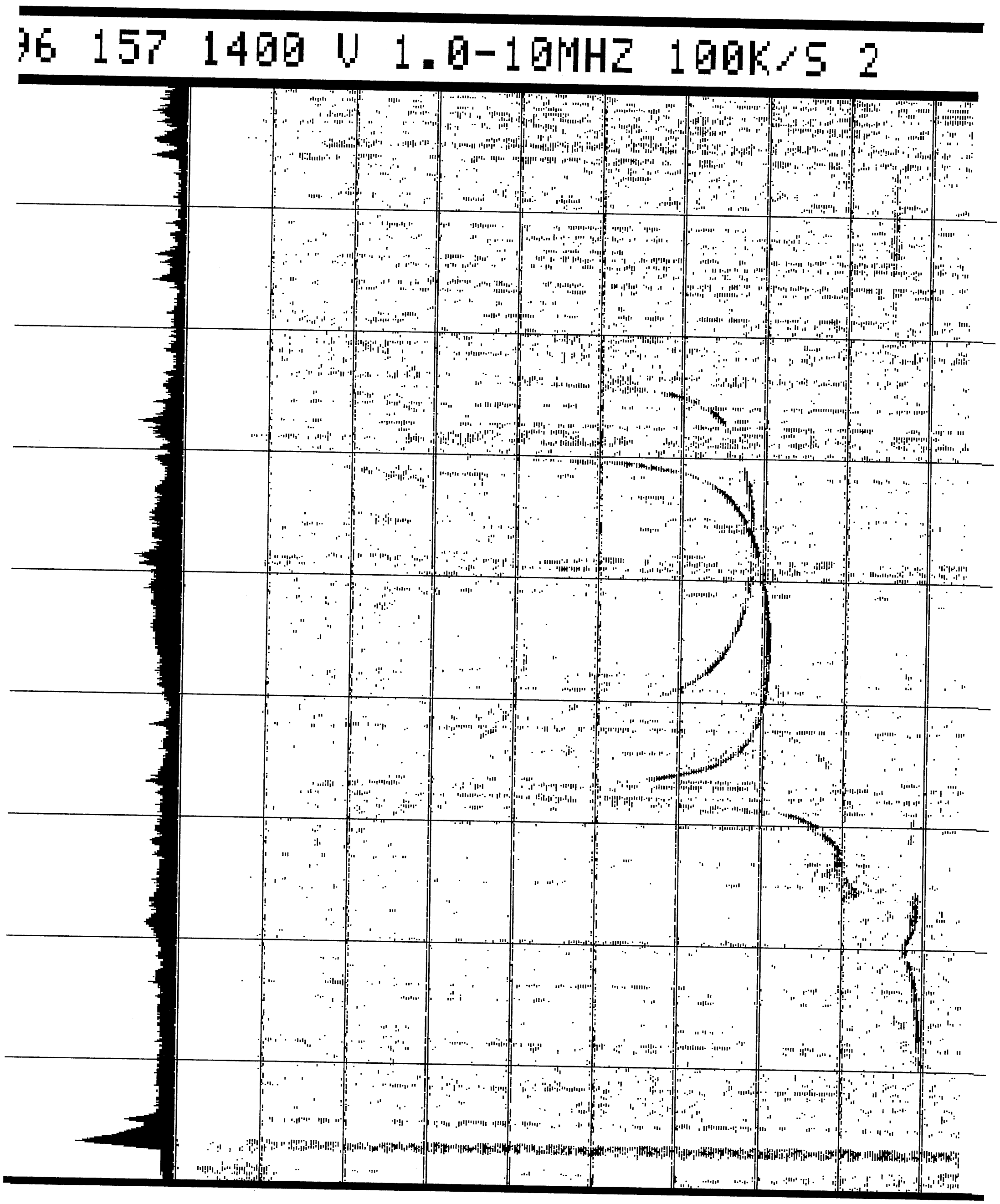

Fig. 2. Ionogram acquired from Barry ionosonde generated by IDAS.

the hour, m the tenths of minutes, S the station and YY the year.

The ionogram is practically recorded as graphic file, and this represents a great advantage in data compression. Current estimates of data packing suggest that the data may be compacted to 25% of its initial volume, thus increasing the data storage capability. It is also possible to regulate the percentage of data compression before A/D conversion as described later. In the usual routine operation (1 ionogram per hour) data from one year occupies only ~ 230 Mbyte in magneto-optic disk, and a CD-ROM could contain 3 years of ionograms.

The bitmap file can easily be displayed, modified and elaborated by most software packages including WINDOWS; it is also possible to quickly retrieve the ionograms on the screen. This option allows a continuous display of the ionograms, and apart from the movie effect this option is very useful to study some particular dynamic ionospheric phenomena.

The print utility is very useful and allows the desired ionogram (or set of ionograms) to be retrieved using the search key supported by the DOS. The program also permits an interface with the most common printer by means of the serial and parallel port if necessary.

3. Ionogram scaling and electron density profile

The sweep frequency ionosonde produces rough data, $h'(f)$, as shown in fig. 3, *i.e.* virtual heights *versus* frequency, that have to be scaled to obtain the most remarkable ionospheric characteristics.

In fact the operator follows the program in a semiautomatic procedure.

Output records which can be analysed to obtain some physical quantities useful in such kinds of study are produced.

Simply by positioning the cursor on particular points of the ionogram trace and clicking on the mouse, a record of the principal ionospheric characteristics can be stored in the memory.

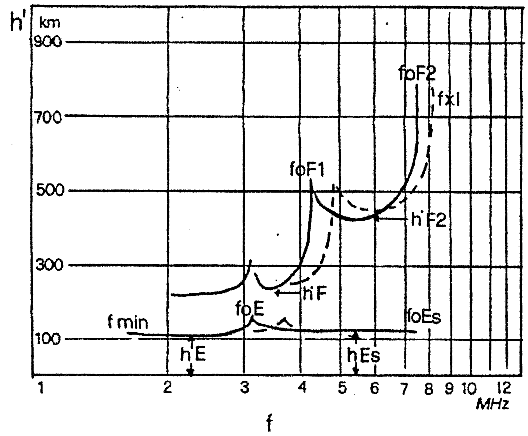

Fig. 3. Example of ionogram with its main characteristics.

The main characteristics (see fig. 3) deduced are: f_0F_2 f_0F_1 f_0E_s as critical frequency of the ionospheric layers (F and E) and $h'F_2$, $h'E$ as their heights, etc.

For service purposes we also have to extract also the maximum usable frequency at the distance D (MUF_D) given by

$$MUF_D = f_0F_2 \cdot \sec \varphi_0$$

where φ_0 is the angle of incidence of the oblique radio propagation between two points at distance D. A complete expression for the maximum usable frequency is the following:

$$MUF_D = f_0F_2 \cdot \sec \left[\operatorname{arctg} \frac{\sin \frac{\theta}{2}}{1 + \frac{h'}{R} - \cos \frac{\theta}{2}} \right]$$

where R is the Earth's radius and θ is the ratio between D and R.

IDAS program generates a graph (fig. 4) of this function movable across the screen in the frequency axis to be superimposed over the displayed ionogram to calculate the MUF value.

Among these ionospheric characteristics one of the most important is the electron density profile $N = N(h)$ at real height h.

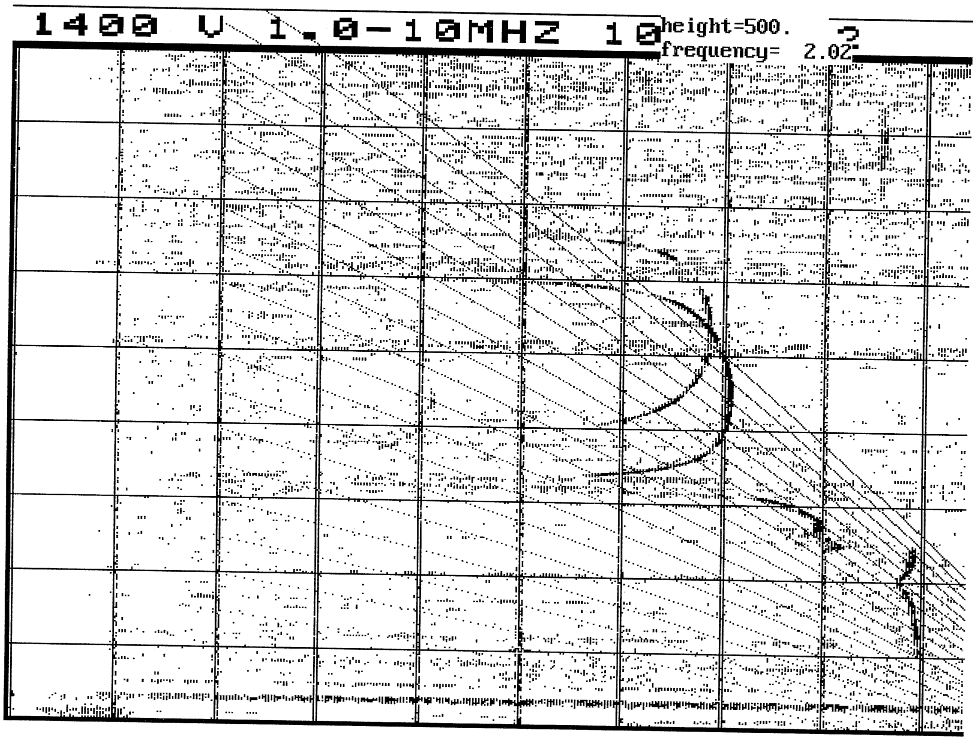

Fig. 4. Curves generated by IDAS to calculate MUF value.

At this point, it is possible to use the computing availability that, starting from a record value $h'(f)$ which has been previously obtained, can produce the real height analysis.

For a not perturbed horizontally stratified ionosphere the virtual height for a radiowave of frequency f is given by

$$h'(f) = \int_0^{h_r} \mu'(f, f_N)\, dh$$

where μ' is the group refractive index, f_N the plasma frequency corresponding at height h and h_r the real height of reflection.

The inversion of this integral equation, as shown in fig. 5, is now possible using recent programs based on polynomial profile-fitting method to work out $f_N = f_N(h)$ that is proportional to $N = N(h)$.

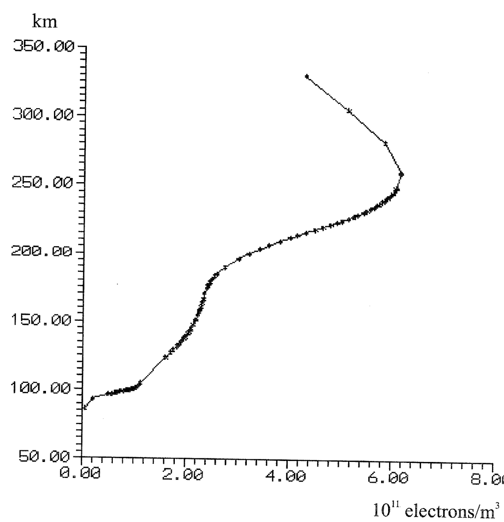

Fig. 5. Electron density profile as obtained by IDAS.

4. Technical description of the interface hardware

The unit indicated as interface in the system block diagram (see fig. 1) generates all the functions necessary for the acquisition system and is briefly described here. In table I the connectors with all the electronic functions necessary to the system are described.

The differential *synchro* and *clock* lines at A1J4, internally generated, control the analog 0.1 s signal segment that the ionosonde sends at each *synchro* pulse.

The segment of the signal is digitized and clustered in bytes (more precisely at exactly 100 byte per segment) to be sent via P1J1 to the parallel port of the PC.

All the functions of the interface (fig. 6) come from the 16 MHz oscillator U1 (EXO-3) that is set to provide 1 MHz to the input of the divider chain U2, U3, U4 and U6. Except for U4 (74LS197) that is a binary counter, all the dividers are quinary-decade type (74LS390) and two simple eight-input NAND gates U5-U8 (7430) which are connected to the chain, generate the functions *synchro* and *interrupt*. The *synchro* pulses at output of monostable U10 are 1 μs width.

The other internal functions (1 kHz, 4 kHz) and external *clock* are directly connected to the counters.

The *run/stop* coming from the controller of the ionosonde allows the counters to run and to reset.

The A/D conversion circuit shown in fig. 7 is practically composed of two inverting comparators U12 (LM339) that yield three levels fixed by the thresholds at 0.64 V and 1.23 V. By adjusting the two resistive trimmers it is possible to choose the level of the signal intensity to optimise the data compression without losing information.

The reference levels come from two resistive voltage dividers after the reference voltage at zener 1N5229 connected to the noninverting input of the comparator.

After the A/D conversion the two serial lines are sent to the D flip-flop U13 (7474) then to the serial-parallel 8-bit shift register U14, U15, and at last to the tri-state latch U16 (74LS374). The result of this conversion is 100 byte every 0.1 s signal segment with a sampling frequency of 4 kHz (about 400 samples per segment).

At this point the data are sent to the parallel port of the PC through the five open collector NOT gates 74LS05 (U17).

Table I. External connections.

Connector A1J4 (D25)		Connector P1J1 (D25)	
Pin connector	Function	Pin connector	Function
10	synchro	1	bit 0 (lsb)
11	synchro	14	bit 1
4	run/stop	16	bit 2
1	analog data	17	bit 3
12	clock	15	bit 4
13	clock	13	bit 5
3	gnd	12	bit 6
5	gnd	11	bit 7 (msb)
		10	interrupt
		25	gnd

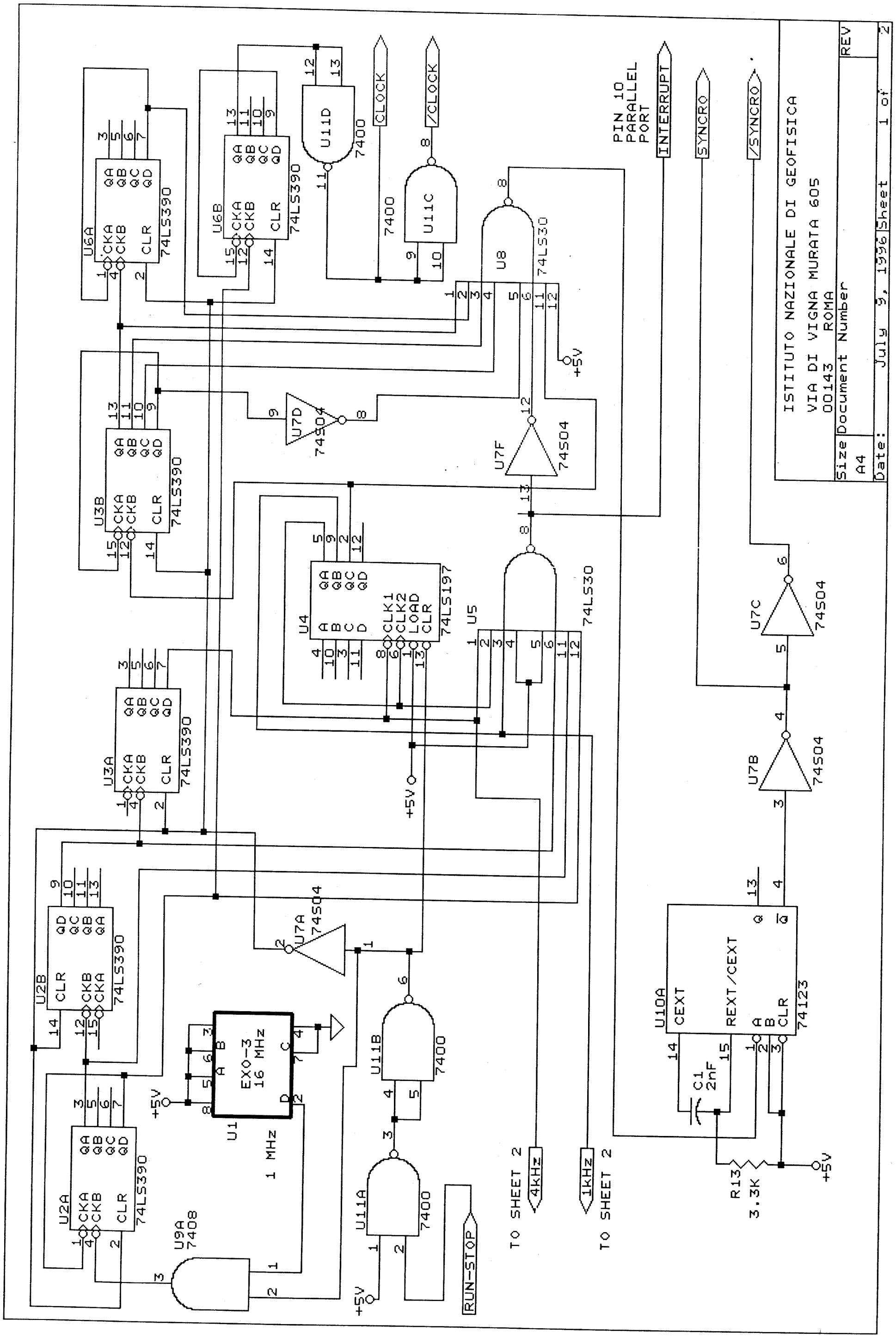

Fig. 6. Interface function synthesis circuit.

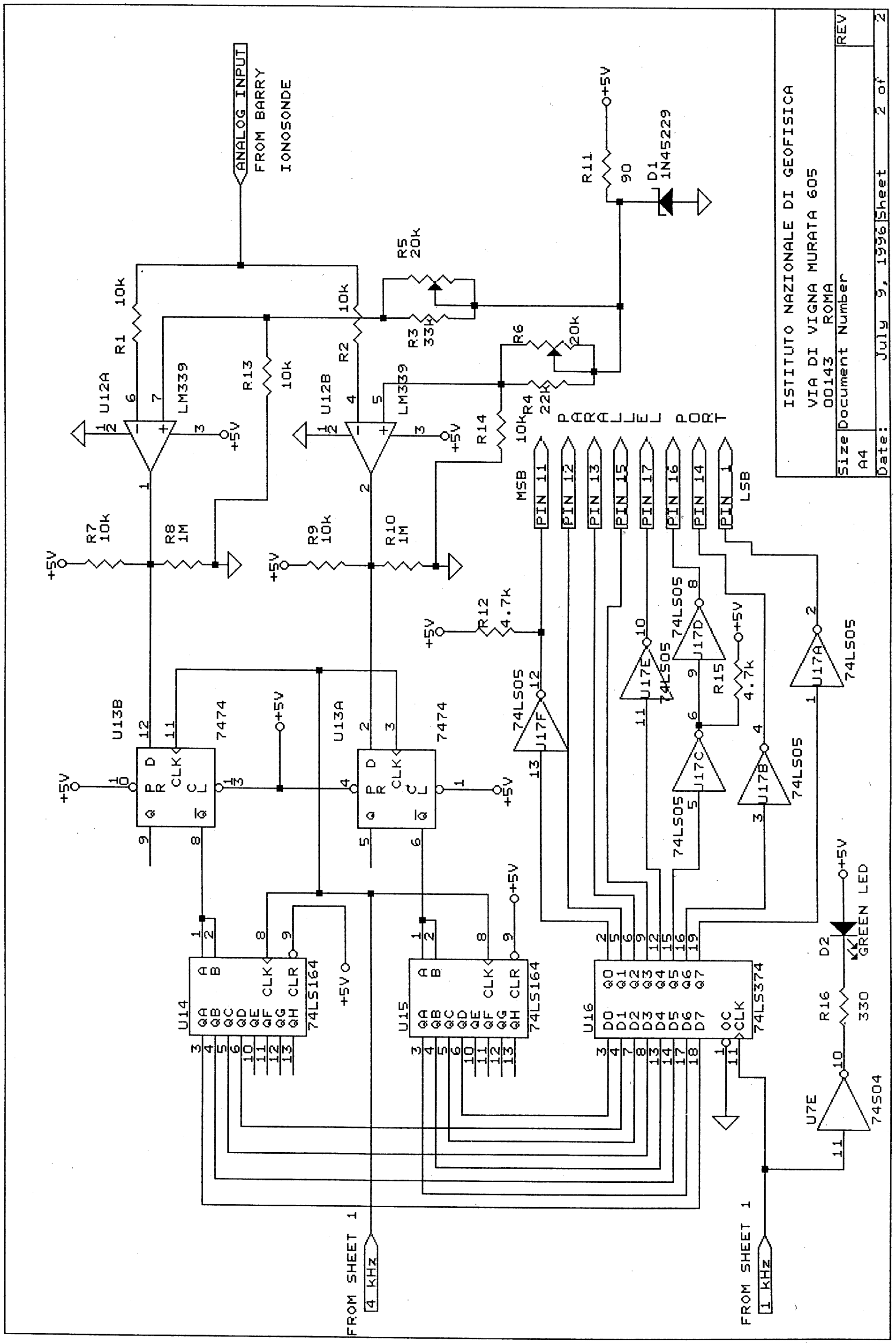

Fig. 7. A/D conversion circuit.

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