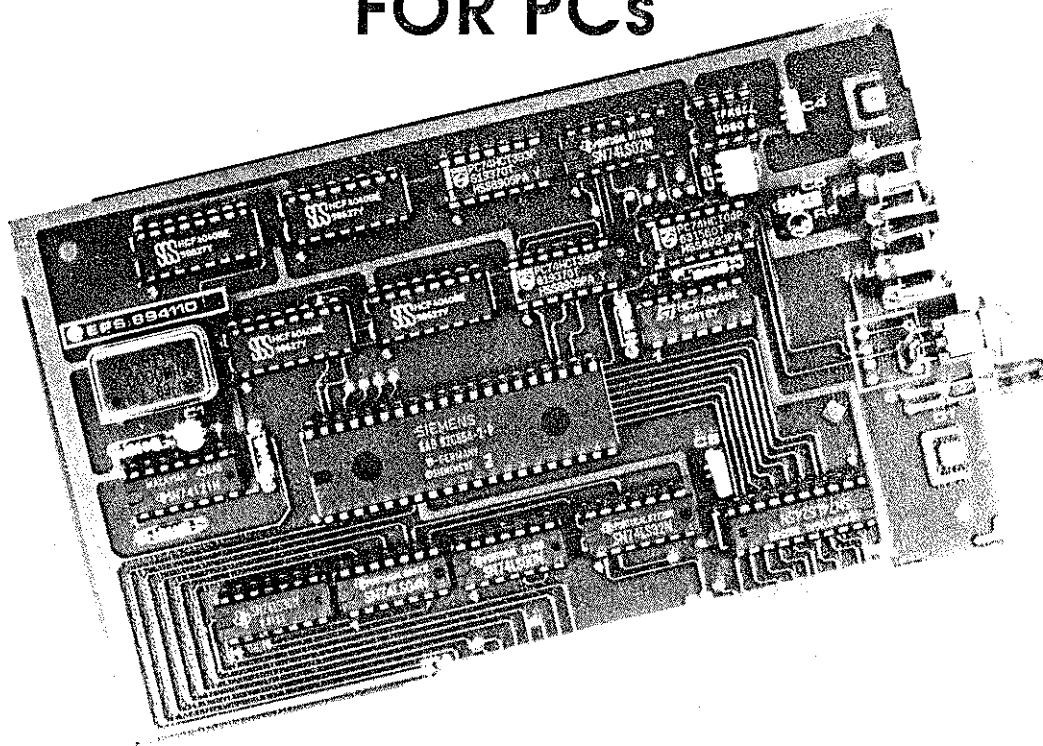


# 1 GHz FREQUENCY METER CARD FOR PCs



H. Kolter

**This plug-in card for IBM PC-XT/AT and compatibles forms a cost-efficient alternative to a stand-alone frequency meter. Simple to build and program, the card has a TTL input as well as a prescaler input with high sensitivity that can handle frequencies up to 1 GHz.**

The signals on the expansion slots of an IBM PC or compatible machine form the starting point for the design of any extension card for this type of computer. The hardware that arranges the data flow and addressing must be laid out carefully to meet the technical requirements drawn up during the design stages. In practice, the eight bidirectional datalines between the extension card and the motherboard must be buffered to prevent the drive capacity of the CPU and associated peripheral chips being exceeded at the risk of permanent damage to the computer. The next requirement is that the extension circuit must occupy a carefully selected address range that can be accessed by the CPU in accordance with the I/O (input/output) map defined by IBM. Hence, the address range occupied by the extension card must be unique in the computer system to avoid I/O contention problems.

The frequency meter card presented here has a Type 8255 PPI (Programmable Peripheral Interface) to meet the above requirements as regards buffering and address decoding. All control of counter and clock circuits on the extension card is arranged by the CPU via the three data reg-

isters and one control register contained in the 8255 PPI.

## Frequency measurement

Frequency measurement almost invariably requires a counter and a reference clock oscillator. Here, the latter function is realized by a 4 MHz oscillator block controlled by an on-board quartz crystal. This device comes in an encapsulated metal enclosure with pins that fit into an IC socket. The output signal of the oscillator block is applied to a divider circuit composed of individual, cascaded counter ICs. The output pulses of the last counter are applied to a NOR gate, the second input of which is driven by the measured signal. The output signal of the NOR gate clocks a counter cascade for the duration of the gate time. When the gate time is over, the counter state — which is proportional to the frequency of the measured signal — is taken over by one of the PPI ports, which transfers it to the CPU. A small BASIC program translates the counter state into the corresponding frequency, which is shown on the monitor. Before the next measurement cycle, all

counters are cleared by a reset pulse of accurately defined length, generated with the aid of a programmed port line and a monostable multivibrator.

## Ports and peripherals

The 8255 is probably the best known programmable I/O device designed for use with Intel microprocessors. It provides 24 I/O pins which may be individually programmed in two groups of 12, and used in one of three modes of operation. The content of the control register on board the 8255 determines whether the port lines function as an input or an output. In Mode 0, each group of 12 I/O pins may be programmed in sets of four to be input or output. In Mode 1, each group may be programmed to have 8 lines of input or output. Of the remaining four pins, three are used for handshaking and interrupt control signals. The third mode of operation, Mode 2, is a bidirectional bus mode that uses 8 lines for a bidirectional bus, and 5 lines for handshaking, borrowing one from the other group.

The 8255 on the frequency meter card, IC1, operates in Mode 0 with all port lines

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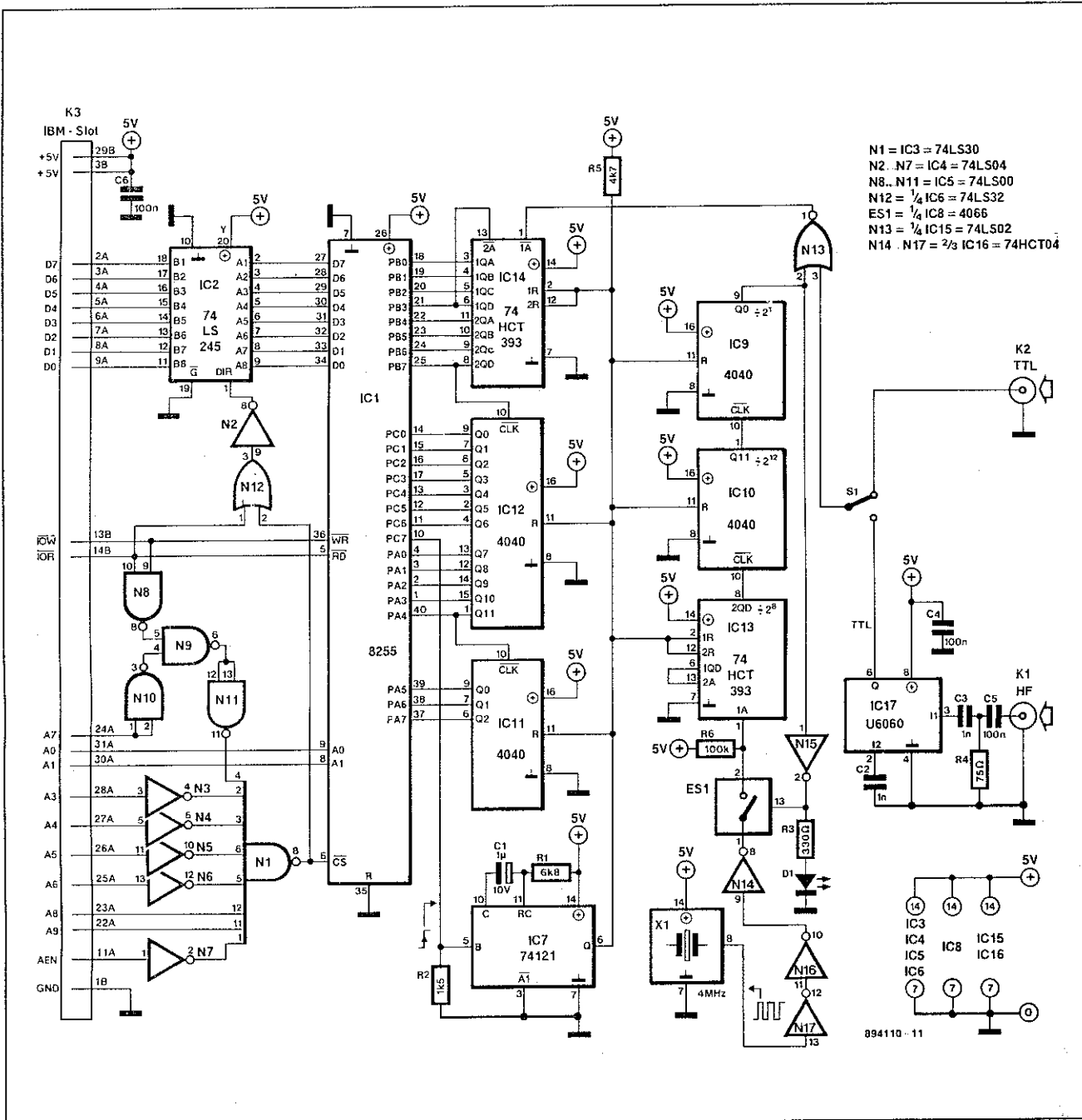


Fig. 1. Circuit diagram of the plug-in frequency meter card: the key components are the PPI, IC1, and the prescaler, IC17.

switched to inputs Port C forms an exception, because one of its lines functions briefly as an output to supply the reset pulse for the counter cascade. The remaining pins of the 8255 are used to ensure correct interfacing with the CPU in the computer. PPI input pins WR (write) and RD (read) are driven direct by the PC expansion bus IOW (input/output write) and IOR (input/output read) signals that control the data direction. The 8255 is enabled by a low level at its CS (chip select) input. The CS signal is supplied by address decoder N1.

PPI inputs PORT SELECT 0 (A0) and PORT SELECT 1 (A1), together with inputs RD and WR, control the selection of

the ports and the control register in the 8255.

### Circuit details

The input of counter cascade IC13-IC10-IC9 is clocked by 4 MHz crystal oscillator block X1. The counters are reset at power-on, so that output Q0 of IC9 is low. This level is inverted by N15, and electronic switch ES1 is consequently closed. The clock pulses are counted by IC13, a Type 74HCT393 set to a divisor of 2<sup>8</sup>. Its output pulses clock IC10, which is configured to divide by 2<sup>12</sup>. Counter IC9, finally, provides a divisor of 2<sup>1</sup>, and supplies an output signal with a period of about 0.524 s

at pin Q0. Pin 2 of gate N13 is held low until counter state 2<sup>8</sup> × 2<sup>12</sup> × 2<sup>1</sup> is reached. The measured signal taken from connector K2 or the prescaler (IC17) is applied to the second counter cascade, IC14-IC12-IC11, via gate N13. When the gate time (0.262 s) has lapsed, pin 2 of N13 goes high. This results in ES1 being opened, so that the measured signal is no longer processed.

Next, the CPU reads the dataword (bit-combination) provided by ports A, B and C of the PPI at addresses 300H, 301H and 302H (768, 769 and 770 decimal). The counter state of IC11, IC12 and IC14 is taken over as a 23-bit word for further processing. A series of BASIC commands (from line 910 onwards in the control program)

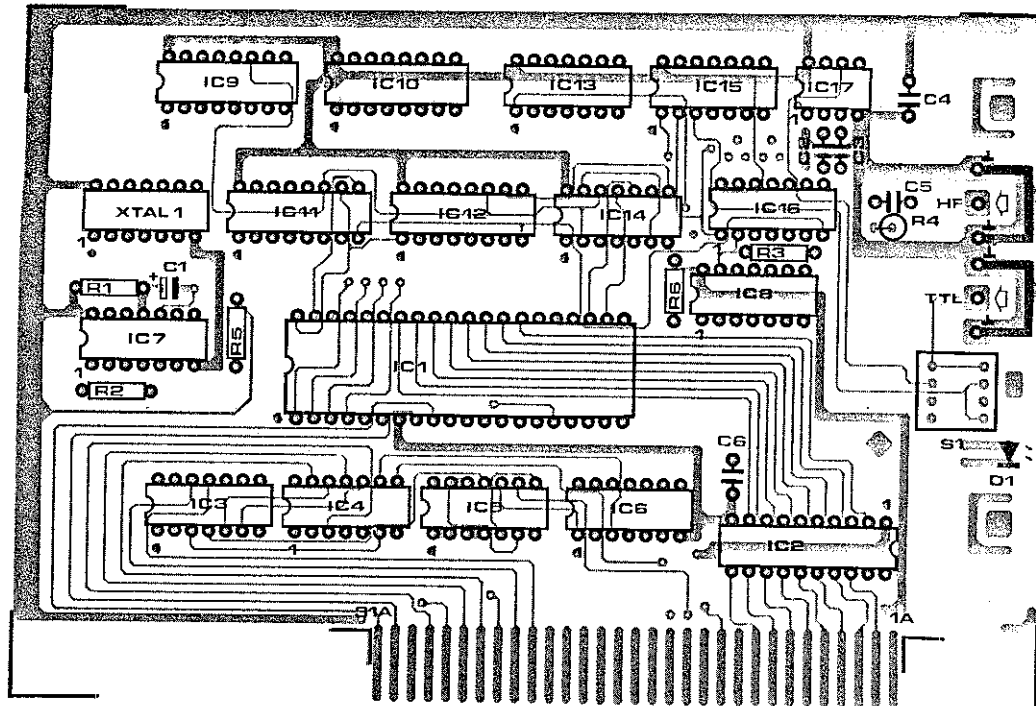


Fig. 2. Component overlay of the double-sided, through-plated printed circuit board. The PC slot contacts are gold-plated.

#### Parts list

##### Resistors:

R1 = 6k8  
 R2 = 1k5  
 R3 = 330Ω  
 R4 = 75Ω  
 R5 = 4k7  
 R6 = 100k

##### Capacitors:

C1 = 1μ0; 10 V; radial  
 C2; C3 = 1n0  
 C4; C5; C6 = 100n

##### Semiconductors:

D1 = LED (5 mm)  
 IC1 = 8255AC-2  
 IC2 = 74LS245  
 IC3 = 74LS30  
 IC4 = 74LS04  
 IC5 = 74LS00  
 IC6 = 74LS32  
 IC7 = 74121  
 IC8 = 4066  
 IC9; IC10; IC11; IC12 = 4040  
 IC13; IC14 = 74HCT393  
 IC15 = 74LS02  
 IC16 = 74HCT04  
 IC17 = U6060B (Telefunken)

##### Miscellaneous:

S1 = miniature SPDT switch for PCB mounting.  
 X1 = 4 MHz oscillator block.  
 K1; K2 = RCA (phono) socket for PCB mounting.  
 PCB Type 894110 (see Readers Services page).

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10 CIS: BEEP: KEY OFF
20 GATETIME=.262144: FACTOR=1: B$= Hz
30 GOSUB 460: REM start first measurement (also initialises FFI 0255)
40 PRINT"
50 PRINT"      *** PC FREQUENCY METER ***      *** ELEKTOR ELECTRONICS ***
60 PRINT"
70 LOCATE 23,1
80 PRINT"      H => Hz      K => kHz      M => MHz      R => RANGE      Q => QUIT
90 REM TTL
100 LOCATE 5,8: PRINT"RANGE 1: 4 Hz - 32 MHz (+/- 4 Hz) "
110 LOCATE 7,8: PRINT"SWITCH TO LOWER INPUT SOCKET (TTL-input)
120 PRESCALER=1
130 GOSUB 350: REM measurement
140 GOSUB 280: REM operation
150 IF A$="R" OR A$="r" THEN BEEP: GOTO 180
160 GOTO 130
170 REM HF
180 LOCATE 5,8: PRINT"RANGE 2: 30 MHz - 1 GHz (+/- 1 kHz) "
190 LOCATE 7,8: PRINT"SWITCH TO UPPER INPUT SOCKET (RF-input)
200 PRESCALER=256
210 GOSUB 350: REM measurement
220 GOSUB 280: REM operation
230 IF A$="R" OR A$="r" THEN BEEP: GOTO 100
240 GOTO 210
250 REM leave program
260 CLS: KEY ON: END
270 REM operation subroutine
280 A$=INKEYS
290 IF A$="Q" OR A$="q" THEN GOTO 260
300 IF A$="H" OR A$="h" THEN FACTOR=1:      B$="Hz"
310 IF A$="K" OR A$="k" THEN FACTOR=1000!:  B$="kHz"
320 IF A$="M" OR A$="m" THEN FACTOR=1000000!:B$="MHz"
330 RETURN
340 REM measurement subroutine
350 WHILE TIMER<MITV: WEND: REM wait for measurement interval to lapse
360 A=INP(768)
370 B=INP(769)
380 C=INP(770)
390 GOSUB 460: REM start next measurement
400 C=C AND &H7F: REM mask bit 7 on port C
410 COUNT=32768!*A+256*C+B: REM use bytes read to calculate counter state
420 F=COUNT*PRESCALER/(GATETIME*FACTOR)
430 LOCATE 13,8: PRINT"FREQUENCY IN ";B$: = INT(F/5)
440 RETURN
450 REM start next measurement
460 OUT 771,147
470 OUT 770,128
480 OUT 770,0
490 OUT 771,155
500 MITV=TIMER+ 5
510 RETURN: REM
  
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894110-15

Fig. 3. Listing of the GWBASIC program that controls the frequency meter card.

Fig. 4.  
address

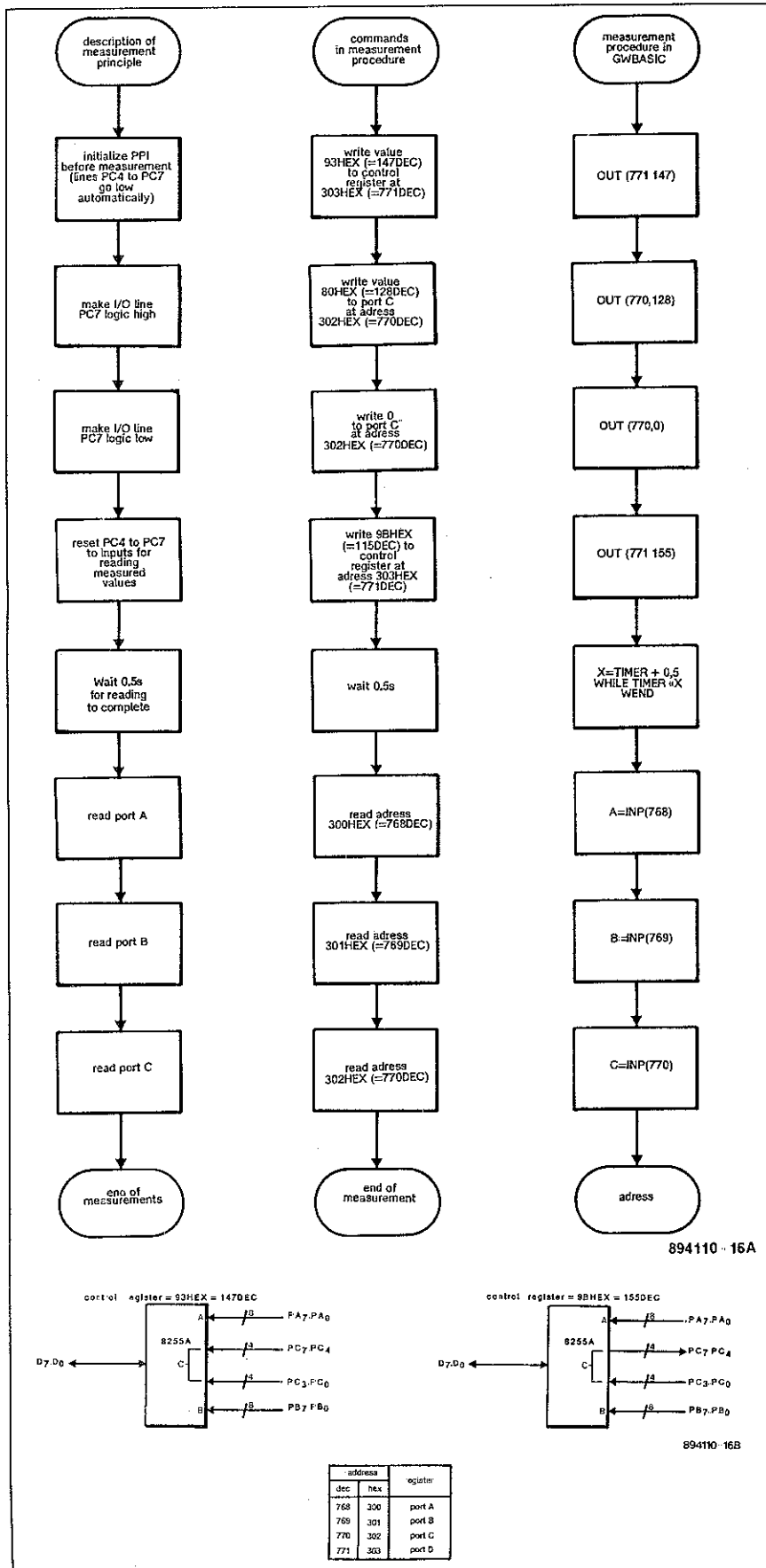


Fig. 4. Flow-charts of the control program, and functional representation of the PPI in the address space it occupies in the PC.

then takes effect Port C is briefly switched to output and supplies data-word FFH (255 decimal). The leading edge of the signal at pin PC7 triggers monostable multivibrator IC7, which responds by resetting all counters by means of its output signal at pin 6. A counter state of 0 results in a low level at the input of N1s. Also, ES1 is closed, so that the circuit is ready for a new measurement cycle.

The fact that the CPU starts every measurement cycle by making PC7 high already indicates that it has ample time to read the port contents, calculate the frequency, and update the screen. Moreover, the clock oscillator is automatically disabled after the gate time. Not surprisingly, therefore, the speed offered by BASIC is ample for the control program.

The 1 GHz prescaler, IC17, is a Type U6060 from Telefunken, originally designed for use in PLL-controlled TV tuners. The chip has a balanced input (which is not used here), a fixed divide-by-256 prescaler, and a TTL output level converter. The input sensitivity of the 50 Ω input is better than 20 mV for frequencies between 30 MHz and 1,000 MHz.

**Addresses**

An address decoder set up around IC3, IC4 and IC5 monitors the logic levels on expansion bus address lines A3 through A9. The CS input of the 8255 is actuated only when A3 through A6 are low, and A8 and A9 are high, in combination with the AEN (address enable) line. When the 8255 is enabled, one of its four registers is selected by the bit combinations on A0 and A1. This means that the frequency meter card occupies the four I/O addresses, 300H through 303H, provided for prototyping cards in the PC. If any other extension card in the PC occupies the same addresses, it must be relocated by altering its jumper configuration as specified by the manufacturer. In general, extension cards can not share I/O address space without causing bus contention problems.

**Software**

The operation of the BASIC control program for the frequency meter may be analyzed in three ways as shown by the respective flow diagrams in Fig 4. The BASIC program itself (Fig 3) is straightforward, offering a kind of minimum user interface. The program is simply typed in under GWBASIC (available on any MS/DOS PC), saved to disk, and started with the RUN command. LED D1 flashes during measurements to indicate activity of the card. The program prompts you to select between the LF/TTL input and the HF input, and automatically switches between kHz and MHz readings on the screen.