DESIGN AND DEVELOPMENT
OF A VIRTUAL FREQUENCY METER

Oleh

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ABSTRACT

Recently in the radio amateur's practice became popular the so-called virtual measuring meters. In this case by "virtuality" is implied the fact that a certain part of the functions or its main measuring meter realizes with the aid of the personal computer. Virtual measuring meters can be conditionally broken into two categories. The instruments of the first group "are completely virtual" and actually they consist of one program for computer, and functions on the input-output of the measured or generatable signal are placed on the regular hardware. The instruments of the second group have besides "virtual" part even and material. With a 4MHz maximum frequency, a selectable time base of 0.1 seconds, 1.0 second, 10 seconds and 100 seconds, the hardware can measure frequency of digital signal up to the 4MHz crystal limit. A comparator is needed to measure analog signal. To the computer in this case the certain device, which is the main part of the virtual instrument, is connected. Such devices realize some functions or knots of measuring meter. These devices can have different complexity - from "heaped" industrially produced interface boards, built in into the computer, to the simple devices, connected to the computer through computer serial port.

ABSTRAK

Sejak kebelakangan ini, proses pengukuran meter “maya” amat popular dikalangan pembangun radio amatur. Dalam kes ini, “maya” bermaksud terdapat bahagian yang berfungsi atau dengan ertikata lain meter pengukuran utama ini dilaksanakan dengan bantuan komputer. Pengukur frekuensi maya boleh dikategorikan kepada dua bahagian. Bahagian pertama instrumentasi ini adalah “maya sepenuhnya” dimana ia mengandungi suatu aturcara untuk computer dan fungsi pada input-output ukuran isyarat dilaksanakan pada perkakasan lain. Bahagian kedua pula, terdapat bahagian yang “maya” dan sebahagian lagi dalam bentuk perkakasan. Dengan nilai 4MHz bagi nilai isyarat maksimum, dan masa asas 0.1 saat, 1.0 saat, 10 saat dan 100 saat, perkakasan ini boleh mengukur frekuensi gelombang digital sehingga ke nilai maksimum 4Mhz iaitu bergantung pada nilai kristal yang digunakan. Suatu litar pembanding diperlukan bagi pengukuran isyarat analog Perkakasan ini perlu disambungkan pada sebuah komputer. Fungsi utama peranti ini adalah untuk melaksanakan tugas sebagai meter pemgukur. Peranti ini memiliki pelbagai kegunaan, dari bidang industri - dengan menghasilkan papan antaramuka dan dibina di dalam komputer dan juga untuk peranti yang mudah. Kedua-duanya dengan menggunakan komunikasi sesiri.

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Bismillahirrahmanirrahim

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Special thanks and acknowledgement for Mr. Dick Cappels in Nondu, Thailand, for helping me to have a better understanding on my projects and giving ideas on troubleshooting the problems.

My appreciations are also for all the lecturers and technicians from School of Electric and Electronic for giving me opinions and ideas to complete this project. My thanks are also for the all technicians, especially the Printed Circuit Board's (PCB) technicians for preparing such a fine PCB for me, for being timely and cooperative. Finally, this appreciation also goes to my parents for supporting me in many ways. Thanks a lot. Thank you to all my friends for your helps and ideas. I must admit that, without these people, I would be never able to finish this project.

Prepared by,

ZAMRY BIN ROSLI

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INTRODUCTION

1.1 Introduction

In chapter 1, focus will be given on to have a better understanding on the title of the project which is design and development of a virtual frequency meter. This chapter will also cover the objectives of the project, scope of project, and the report guidelines.

1.2 Introduction to the virtual frequency meter

The virtual frequency meter is a meter which is generally used to measure frequency like other frequency meters. The only thing that distinguishes this meter from the others is that it is build to display its result to a terminal program or to software which is design to communicate with the measuring instrument. A virtual frequency meter has a very wide definition. For this project, it will involve software and hardware development.

Frequency meters are generally used to measure frequency of an unknown signal source. **Frequency meter** is a device for measuring the repetitions per unit of time (customarily, a second) of a complete electromagnetic waveform. Various types of frequency meters are used. Many are instruments of the deflection type, ordinarily used for measuring low frequencies but capable of being used for frequencies as high as 900

Hz. These operate by balancing two opposing forces. Changes in the frequency to be measured cause a change in this balance that can be measured by the deflection of a pointer on a scale. (Dr. Eugenii Katz, 2001)

1.3 Project objectives

The objectives of this project are:

1. To design and develop a virtual frequency meter which has a 4MHz maximum frequency, a selectable time base of 0.1 seconds, 1.0 second, 10 seconds and 100 seconds. (However the maximum can be increased by changing the crystal).

2. Testing the designed and developed virtual frequency meter by applying a 0V – 5V square wave signal input to the pin 9 AT90S2313 micro-controller before displaying the result to a computer via RS232 on a terminal program.

1.4 Research scopes

In the process of implementing this project, the scope of the project covers certain areas: For this project, there are three different part of software development and two parts of hardware development. Firstly, the design of the circuit used in this project will be designed by using Eagle Layout Editor 4.13r1® software. Secondly, assembly language for the AVR AT90S2313 microcontroller was built by using AVR Studio Assembler. This program is used to compile the assembly language which has been used for the system. Thirdly, graphic user interface software has been designed to let users to interact with the AT90S2313 micro-controller. Microsoft® Visual Basic 6.0 Enterprise Edition is used to produce it. Besides that, a terminal program called HyperTerminal was used as a backup, to display the result from the micro-controller. Then for the hardware development, by using a 7805 voltage regulator, a 0-5V voltage is generated. Besides that, a virtual frequency meter is also constructed by using components such as resistors, capacitors, AT90S2313 micro-controller, and a MAX232 chip.

1.5 Report guidelines

This report includes six chapter which describes the overall project which has been done. Chapter 1 will give a brief description of the overall project such as introduction, objectives, and the research scopes. Chapter 2 describe the literature review of the project has been done. This includes the information on the components that has been used in designing and developing a virtual frequency meter, the program Eagle Layout Editor 4.13r1® as a circuit designer and to produce the layout for printed circuit board fabrication process. The implementation of the project, will be described entirely in Chapter 3. Detail information about design and development of the virtual frequency meter will also be discussed. In chapter 4, various types of testing will be done to fullfill the objectives of the project. Testing is an important stage of the whole process because by doing so, troubleshooting and analyzing the circuits and software would be an easier task. Results and analysis will be included in Chapter 5. Lastly, chapter 6 will conclude the whole project and suggestions to improve the project will be discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 ATMEL AT90S2313

The AT90S2313 is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. Executing powerful instructions in a single clock cycle, the AT90S2313 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed. The AVR core combines a instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clockcycle. The resulting architecture is more code efficient while achieving throughputs up toten times faster than conventional CISC microcontrollers.

The AT90S2313 provides the following features: 2K bytes of In-System Programmable Flash, 128 bytes EEPROM, 128 bytes SRAM, 15 general purpose I/O lines, 32 general purpose working registers, flexible Timer/Counters with compare modes, internal and external interrupts, a programmable serial UART, programmable Watchdog Timer with internal oscillator, an SPI serial port for Flash memory downloading and two software selectable power-saving modes. The Idle mode stops the CPU while allowing the SRAM, Timer/Counters, SPI port and interrupt system to continue functioning. The Power-down mode saves the register contents but freezes the oscillator, disabling all other chip functions until the next external interrupt or Hardware

Reset. The device is manufactured using ATMEL's high-density non-volatile memory technology. The On-chip In-System Programmable Flash allows the Program memory to be reprogrammed in-system through an SPI serial interface or by a conventional non-volatile memory programmer. By combining an enhanced RISC 8-bit CPU with In-System Programmable Flash on a monolithic chip, the ATMEL AT90S2313 is a powerful micro-controller that provides a highly flexible and cost-effective solution to many embedded control applications.

The AT90S2313 AVR is supported with a full suite of program and system development tools including: C compilers, macro assemblers, program debugger/simulators, In-Circuit Emulators and evaluation kits.

2.1.1 AT90S2313 Pin Description

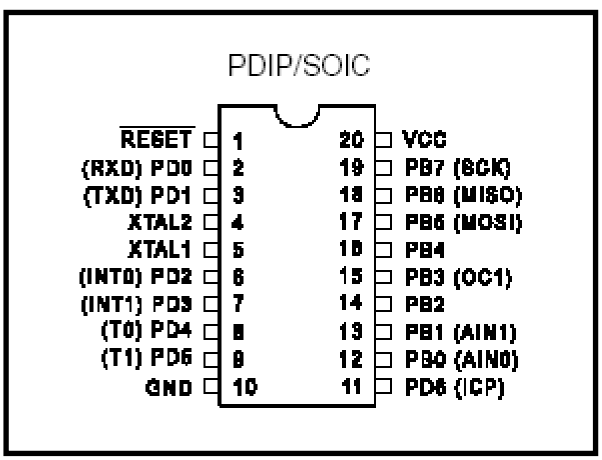

Figure 2.1: Pins for AT90S2313

From Firgure 2.1, we noted that the AT90S2313 have 20 pins which are Vcc, Ground (GND), Port B (PB7..PB0), Port D (PD6..PD0), RESET, XTAL1 and XTAL2. The functions of each pin is unique.

Vcc and GND is the supply pin and the ground pin connection respectfully.

Port B is an 8-bit bi-directional I/O port. Port pins can provide internal pull-up resistors (selected for each bit). PB0 and PB1 also serve as the positive input (AIN0) and the negative input (AIN1), respectively, of the On-chip Analog Comparator. The Port B output buffers can sink 20 mA and can drive LED displays directly. When pins PB0 to PB7 are used as inputs and are externally pulled low, they will source current if the internal pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not active.Port B also serves the functions of various special features of the AT90S2313.

Port D has seven bi-directional I/O ports with internal pull-up resistors, PD6..PD0. The Port D output buffers can sink 20 mA. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not active. Port D also serves the functions of various special features of the AT90S2313.

Reset input. A low level on this pin for more than 50 ns will generate a Reset, even if the clock is not running. Shorter pulses are not guaranteed to generate a Reset.

XTAL 1 is the input to the inverting Oscillator amplifier and input to the internal clock operating circuit while XTAL2 is output from the inverting oscillator amplifier.

2.1.2 Characteristic of Crystal Oscillattor

XTAL1 and XTAL2 are input and output, respectively, of an inverting amplifier that can be configured for use as an On-chip oscillator, as shown in Figure 2. Either a quartz crystal or a ceramic resonator may be used. To drive the device from an external clock source, XTAL2 should be left unconnected while XTAL1 is driven, as shown in Figure 2.2

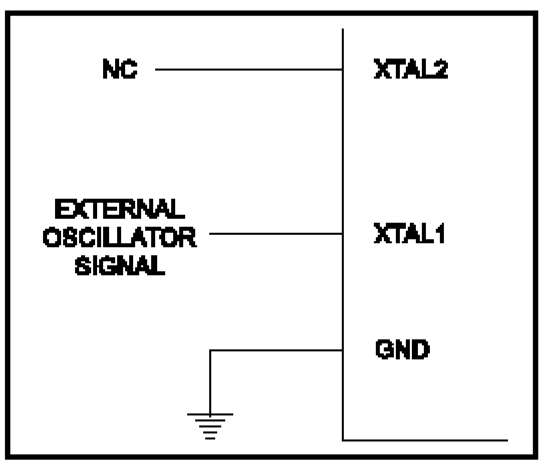

Figure 2.2 : External Clock Drive Configuration

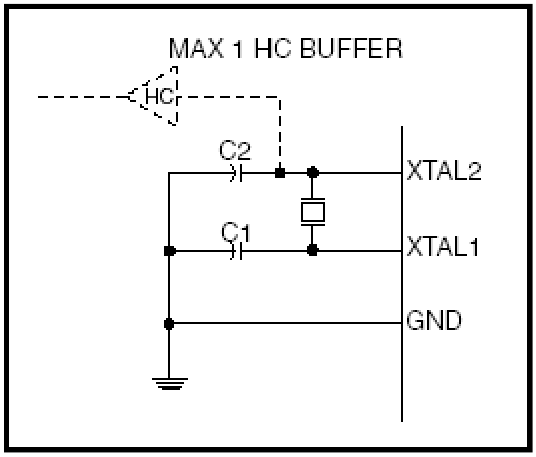

Figure 2.3 : Oscillator Connections

2.1.3 Programmable Flash Program Memory and EEPROM Data Memory

The AT90S2313 contains 2K bytes On-chip In-System Programmable Flash memory for program storage. Since all instructions are 16- or 32-bit words, the Flash is organized as 1K x 16. The Flash memory has an endurance of at least 1,000 write/erase cycles. The AT90S2313 Program Counter (PC) is 10 bits wide, thus addressing the 1,024 program memory addresses.

It also contains 128 bytes of EEPROM data memory, organized as a separate data space in which single bytes can be read and written. The EEPROM has an endurance of at least 100,000 write/erase cycles.

ATMEL's AT90S2313 provides 2K bytes of In-System Reprogrammable Flash Program memory and 128 bytes of EEPROM Data memory. The AT90S2313 is shipped with the On-chip Flash Program and EEPROM Data memory arrays in the erased state and ready to be programmed. This device supports a high-voltage (12V) Parallel

Programming mode and a low-voltage Serial Programming mode. The +12V is used for programming enable only, and no current of significance is drawn by this pin. The Serial Programming mode provides a convenient way to download program and data into the AT90S2313 inside the user's system. The program and EEPROM memory arrays in the AT90S2313 are programmed byte by- byte in either programming mode. For the EEPROM, an auto-erase cycle is provided within the self-timed write instruction in the Serial Programming mode. During programming, the supply voltage must be in accordance with Table 2.1.

Table 2.1: Supply voltage during programming AT90S2313

Part	Serial Programming	Parallel Programming
AT90S2313	2.7 - 6.0V	4.5 - 5.5V

2.2 MAX232

The MAX232 device is a dual driver/receiver that includes a capacitive voltage generator to supply EIA-232 voltage levels from a single 5-V supply. Each receiver converts EIA-232 inputs to 5-V TTL/CMOS levels. These receivers have a typical threshold of 1.3 V and a typical hysteresis of 0.5 V, and can accept ±30-V inputs. Each driver converts TTL/CMOS input levels into EIA-232 levels. The MAX232 is characterized for operation from 0°C to 70°C. The MAX232 is characterized for operation from –40°C to 85°C..

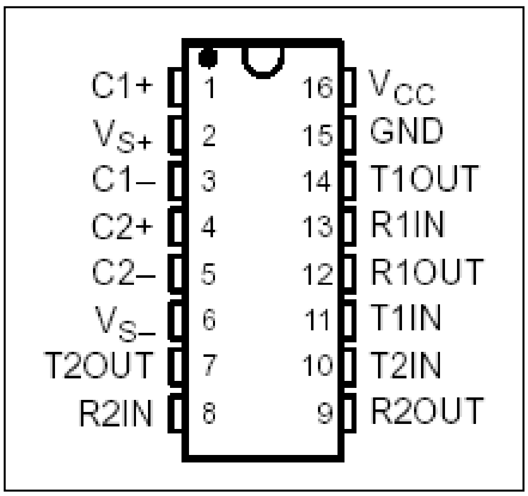

Figure 2.4 : Pins for MAX232

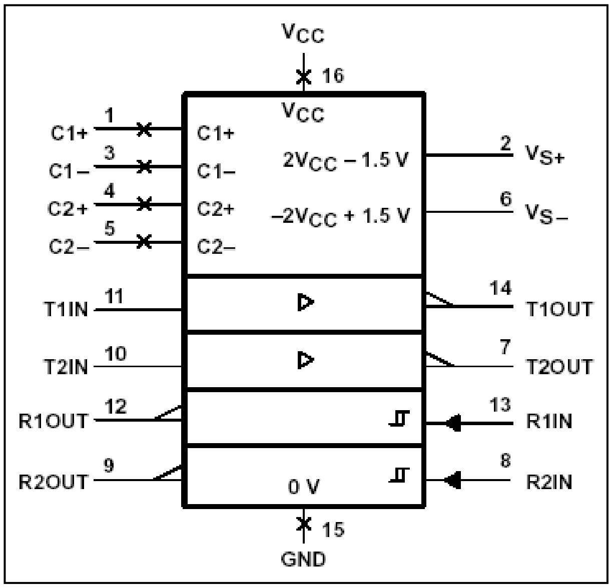

Figure 2.5 : Logic Symbols for MAX232

2.2.1 Maximum ratings for MAX232 operation

Table 2.2 : Ratings for MAX232

Input supply voltage range, VCC		– 0.3 V to 6 V
Positive output supply voltage range, VS+		VCC – 0.3 V to 15 V
Negative output supply voltage range, VS–		–0.3 V to –15 V
Input voltage range, VI	Driver	–0.3 V to VCC + 0.3 V
	Receiver	±30 V
Output voltage range, VO	T1OUT, T2OUT	VS– –0.3 V to VS+ + 0.3 V
	R1OUT, R2OUT	–0.3 V to VCC + 0.3 V
Short-circuit duration: T1OUT, T2OUT		Unlimited
Storage temperature range, Tstg		–65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds		260°C

2.2.2 MAX232 and RS232 configuration

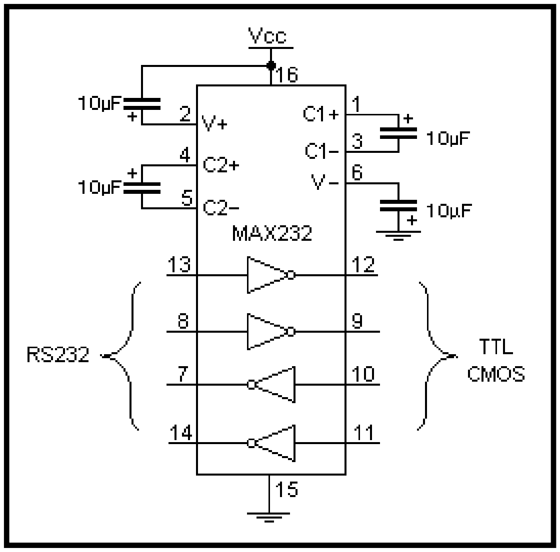

Figure 2.6 : MAX232 chip configurations

As most of electronic devices are using TTL logic or CMOS, it is a necessity to change the level of voltage from RS232 to 0 and 5 volts. MAX232 is used in this operation. Each receiver converts EIA-232 inputs to 5-V TTL/CMOS levels. Figure shows the chip configuration. MAX232 has a charge pump which produces +10V and -10V powered by a 5V source.

2.3 DB-9

DB-9 is a serial socket which has nine pins with different functions. Table 2.3 shows the pins of DB-9.

Table 2.3: Pins description for DB-9

Pin	Function	Full Name
Pin 1	CD	Carrier Detect
Pin 2	RxD	Receive Data
Pin 3	TxD	Transmit Data
Pin 4	DTR	Data Terminal Ready
Pin 5	GND	Signal Ground
Pin 6	DSR	Data Set Ready
Pin 7	RTS	Request To Send
Pin 8	CTS	Clear To Send
Pin 9	RI	Ring Indicator

Figure 2.7: Pins assignments for DB-9 male connector

2.3.1 DB-9 connections

It is essential to configure DB-9 computer port correctly as it will allow instrument to communicate with computer. Without the right configuration there will be no communication between instrument and computer, resulting no data will be sent to the computer and no result will be displayed.

There are two main types of connection for RS232. Direct connection is one type of configuration for RS232. It is sho+

-wn in Figure 2.9. The other type of connection is the null modem connection which is show in Figure 2.10.

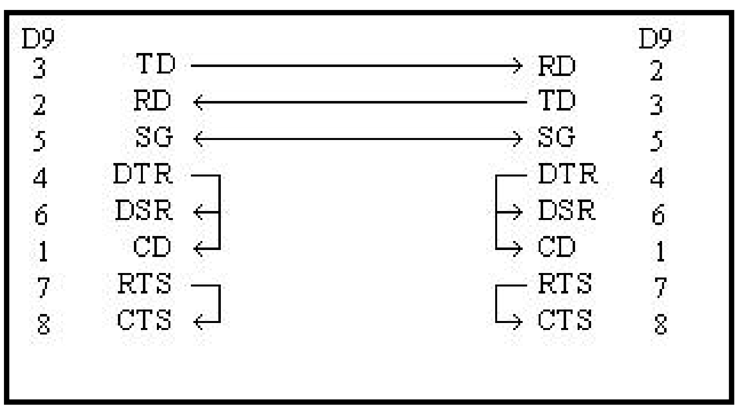

Figure 2.8: Configuration for direct connection

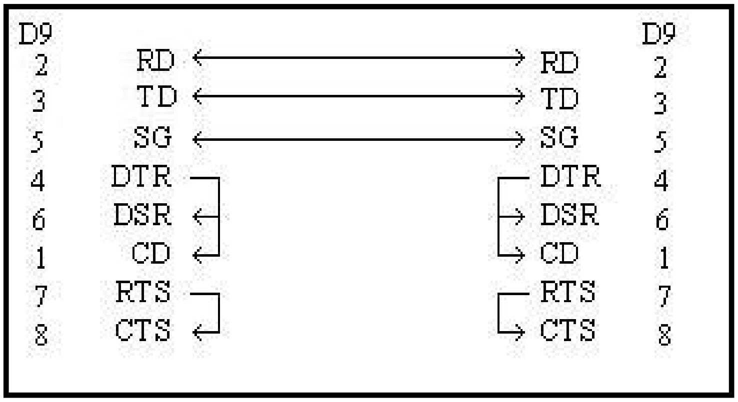

Figure 2.9: Configuration for null modem

2.4 Voltage Regulator (L 7805C)

The L 7805C series of regulator has a fixed output voltage of 5V making them useful in a wide range of applications. It helps eliminating the distribution problems associated with single point regulation. The voltage available allows these regulators to be used in logic systems, instrumentation and other solid state electronic equipment. Although designed primarily as fixed voltage regulator, this device can be used with external components to obtain adjustable voltages and currents.

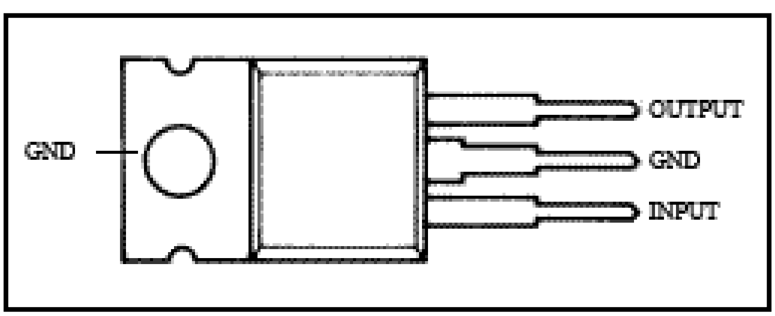

Figure 2.10**: L** 7805C Voltage Regulator

It is easy to use and minimize the number of external components. It is not necessary to bypass the output, although this does improve transient response. Input bypassing is needed only if the regulator is located far from the filter capacitor of the power supply.

2.5 Frequency meter operational principle

Frequency meter functions under control of the computer, which will give to it the commands through serial port. Back, into the computer, device returns answers to the commands and measurement data. Frequency meter has only one external entrance for the supply of the measured signal. In this project, the signal can only be digital. An analog signal is possible to be measured by the help of a comparator. Under different phases, of measurements the micro-controller produces the reconfiguration of its internal hardware. The configuration of device for measuring of time intervals and repetition period of pulses is shown to Figure 2.11.

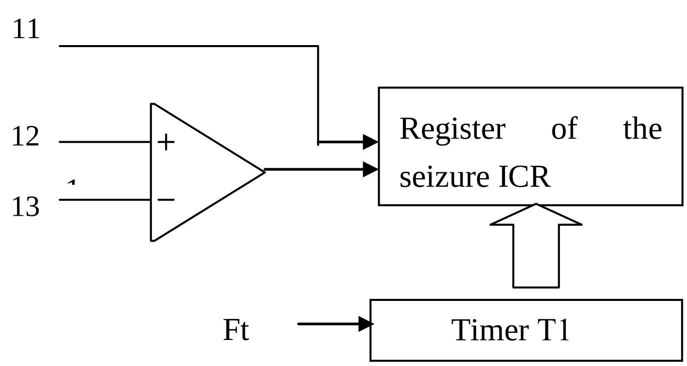

Figure 2.11: Configuration of device for measuring time intervals & repetition period

In this regime to the entrance (Pin 16) - TI of discharge timer T1 will be given the clock frequency. The fixation of the moment of beginning or end of pulse is achieved with the aid of the special register of seizure. If instrument is disposed to the measurement of signal with the digital levels, then the memorization of the state of timer is achieved with respect to a change in the signal on conclusion ICP (Pin 11), if analog signal is measured, then the signal of seizure will be given from the output of the built-in analog comparator, to entrance AIN0 (Pin12) which will be given the analog signal, and to entrance AIN1 (Pin 13) will be given the level. The duration of interval, by program is calculated after the memorization of beginning and end of time interval. The configuration of device for the measurement of frequency is depicted in Figure 2.12.

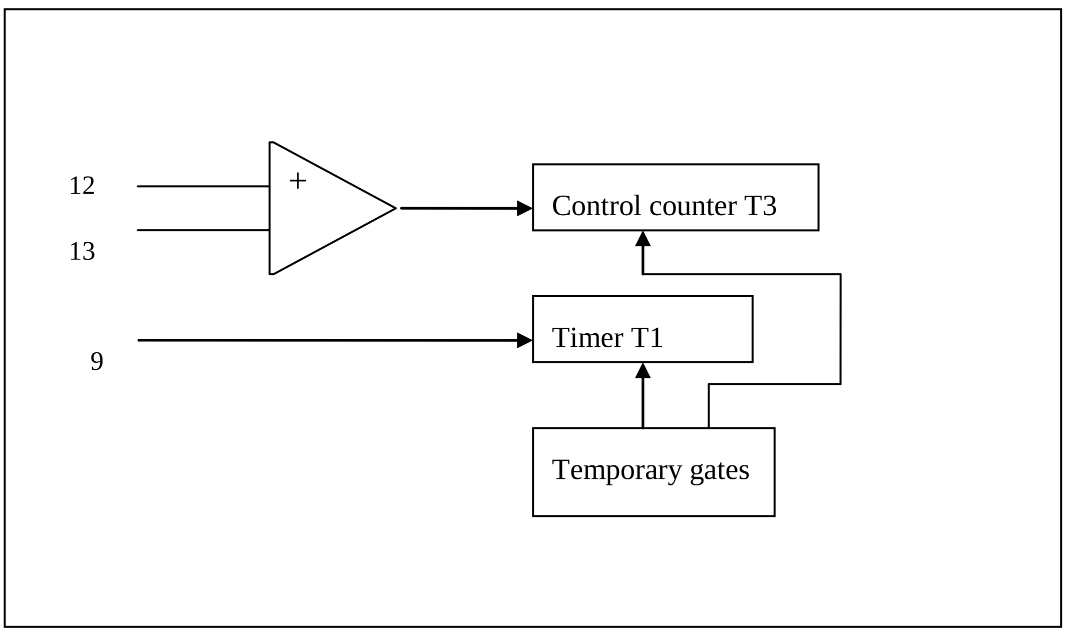

Figure 2.12: Configuration for measuring frequency

With the measurement of signals with the digital levels the signal will be given directly to the entrance of the timer of T1 (Pin 9). Unfortunately it is not possible to switch the output of the built-in comparator to the entrance of timer T1; therefore for measuring the frequency of analog signals is organized control counter T3. It possesses lower speed in comparison with the apparatus timer T1. Therefore frequency range on the analog entrance is considerably less than on the digital.

2.6 Other people's work on Frequency Meter

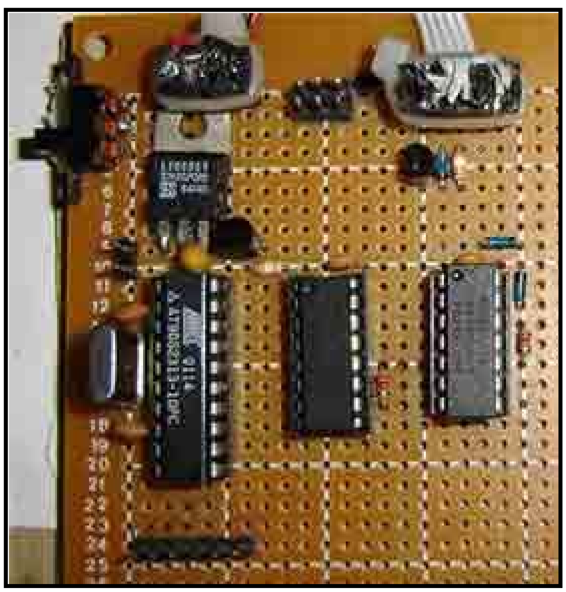

Figure 2.13: Construction of a frequency meter by Dick Cappels (September, 2004).

This is a frequency meter with higher resolution and a higher maximum frequency. As for microcontroller choice, the requirements for this firmware are that the controller be an AVR with a 16 bit counter, has a ram stack and UART or USART, and the ability to operate at 10 MHz. Some modification may be required to the code to accommodate a USART instead of a UART, a 16 bit stack pointer instead of the 8 bit pointer on the AT90S2313, and the specific controls of the 16 bit counter registers. I used an AT90S2313 is used because they are suitably small. For the 10 MHz input single-chip configuration, an AVR that can clock at 20 MHz is needed. In this case, ATtiny2313-20 is used. When programming the ATtiny2313, the internal clock oscillator is set to fuse setting. The AT90S2313 does not have clock fuse settings.

The first phase was to make a high resolution frequency meter/counter just using the AT90S2313 or ATtiny2313, then to add the external prescaler. Without the prescaler, the maximum input frequency for the frequency meter is 5 MHz or 10 MHz, depending upon the chip and firmware used. With the multi-chip version that includes a prescaler, the maximum input frequency, according to the component specifications, is about 30 MHz - this will vary with individual external prescaler chips and circuit layout. To summarize, there are three versions of the code available: The 5 MHz single-chip version, which is basically an AT90S2313-10 clocked at 10 MHz and a serial interface, the 10 MHz single-chip version with is basically an ATtiny2313-20 clocked at 20 MHz with a serial interface, and the 30 MHz multi-chip version, which is the same circuit as the 5 and 10 MHz versions, but with the prescaler and quad NOR gate added. In the 30 MHz version, the maximum input frequency for the counter mode (counts until reset via ASCII command) is 5 MHz. The time base selections between the two versions differ as well. The 30 MHz version has time bases of 0.1, 1, 10, and 100 seconds. The 5 MHz version only has 1, 10, and 100 second time bases.

To summarize:

Table 2.4: Summary of types of design of a frequency meter.

Design	Frequency Measuring Mode	Counting Mode	Time bases
30MHz	30 MHz maximum	5 MHz maximum	0.1, 1, 10, and 100 seconds
10 MHz	10 MHz maximum	10 MHz maximum	1, 10, and 100 seconds
5MHz	5 MHz maximum	5 MHz maximum	1, 10, and 100 seconds

The multi-chip meter has five modes of operation: 0.1 second time base, 1 second ,time base 10 second time base 100 second time base and counting mode. The single-chip versions have four modes of operations: 1 second, time base 10 second time base 100 second time base and counting mode. Modes can be switched by sending any ASCII character making the instrument cycle through the five modes over and over.

ASCII "R" ($52) is a special case. In the 0.1, 1, 10, and 100 second time base modes, it causes the instrument to cycle to the next mode. When in the counting mode, ASCII "R" causes the counter to reset to zero.

As for this frequency meter, two push-buttons are added to one of the 2 line x 16 character LCD display. One button is used to send an ASCII carriage return ($0D) and the other is used to send an ASCII "R" ($52), so they can be used to advance the operating mode, and reset the counter, when in the counting mode, respectively.

Figure 2.14: LCD Display for the frequency meter

The binary-to-BCD conversion is 32 bits wide, so the largest number that can be displayed is 4,294,967.295. At 5 MHz, it takes nearly 15 minutes to overflow. It will not overflow in the frequency meter mode - even at 30 MHz, it takes about 143 seconds to reach this count, in excess of the longest time base available, 100 seconds. When the counter exceeds 32 bits, whether in frequency meter or counter mode, an overflow indicator displayed in the form of a plus sign (+) immediately to the right of the right-most digit. The counter counts as long as the input signal crosses the input thresholds of the 74HC02. An outboard preamp/precaler, which extends the frequency measurement capabilities to beyond 300 MHz, was designed after this project.

2.6.1 Circuit description

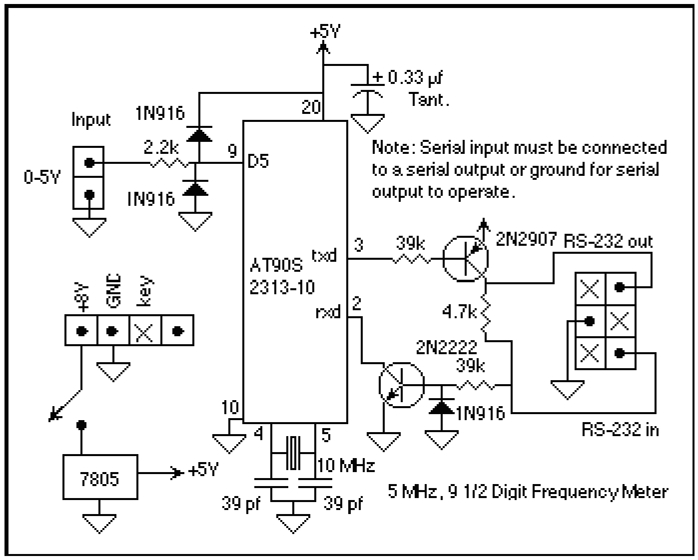

Figure 2.15: Schematic diagram for 5MHz frequency meter

The 5 MHz and 10 MHz single-chip versions only need inverters for the serial interface, the microcontroller, and a few passive components. Be sure to use a 20 MHz crystal and an ATtiny2313-20 for the 10 MHz version, and a 10 MHz crystal for the 5 MHz single-chip version.

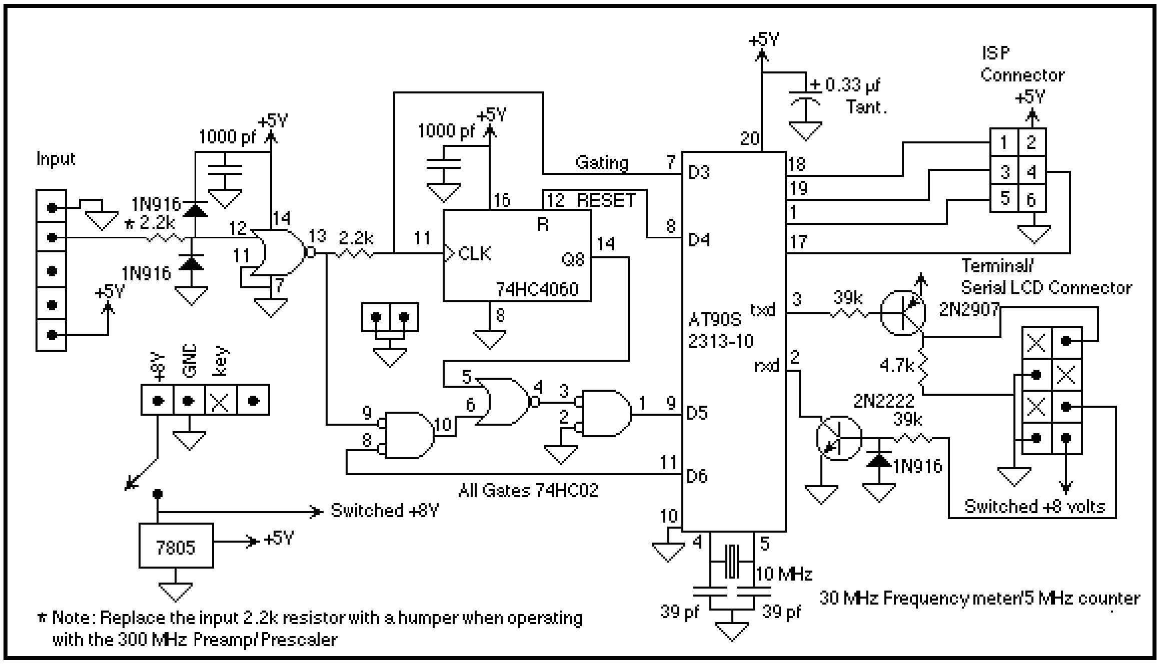

Figure 2.16: Schematic diagram for a 30MHz frequency meter

The 5 MHz and 10 MHz frequency meter versions take their inputs directly on pin 9 of the AT90S2313. The 74HC4060 and 74HC02 and their associated circuitry are omitted. This version of the serial interface only drives from +5 volts to ground. If this circuit is used with the 300 MHz Preamp/Prescaler, omit the 2.2k resistor on the input and connect the input directly to pin 12 of the 74HC02.

Frequency measurement is performed by clocking the 74HC4060, which is capable of being clocked at over 30 MHz, and then counting the overflow pulses from the 8th flip-