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Micro Controlling Radio Transmitting Frequency

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Abstract

This paper analyses and proposes two methods for digital control of the radio transmitting frequency. Setting the frequency transmission is ensured by a Microchip family microcontroller. A PLL-based transmitter is described, and also our experiments for direct control of the frequency using PIC circuits. We present the advantages and disadvantages, programs and program sequences for future research and design of radio modules using digitally controlled transmitting frequency.

Key words: *Phase Lock Loop, microcontroller, radio frequency, radio transmitting channels*

Introduction

Determining the exact radio transmitting frequency is an important factor in analog and digital transmissions contributing to the extremely large demands of speed and accuracy on the communications market. The control of the radio transmitting systems operates on the model showed in figure 1:

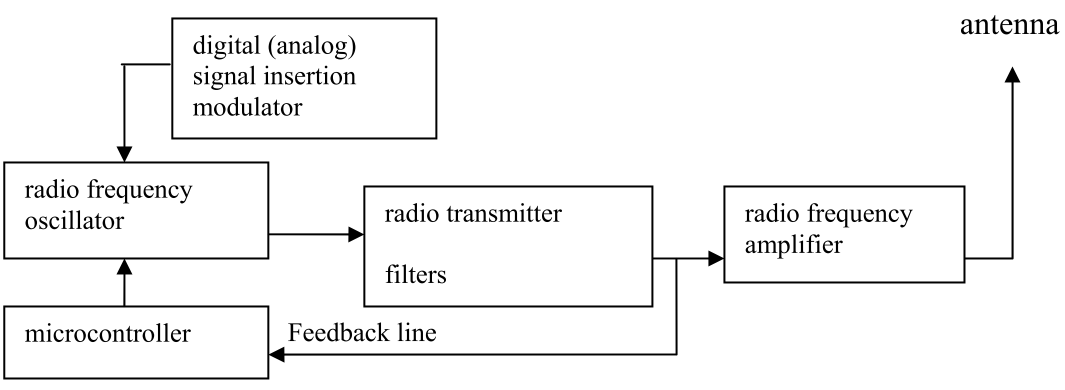

Fig. 1. Microcontroller-based radio transmitting system

This system works in both areas – analog (voice or image) and digital (bit-stream representing data, voice or image). The information insertion module for transmission performs a series of adjustments to the signal such as compression, encryption, insertion of integrity control keys and modulating it using the base transmitting frequency which is called a 'carrier'. The oscillator generates the base radio frequency over which the flow of information is added, resulting the modulated carrier wave. This is processed in the transmission module to obtain the desired frequency, which is inserted into the final transmitting stage. The resulting power is sufficient to command the power amplifier module that radiates through the antenna into the surrounding area. The circuit also contains a feedback line, which allows the command module to make adjustments of any errors arising due to temperature, humidity or voltage fluctuations.

In this article we analyze and propose two methods of digital transmission frequency control using a microcontroller which generates a pulse on an output port.

Theoretical Details: Phase-Locked Loop – PLL

The professional modern transmission devices control all types of their inside transmitters using a device called PLL. This is the most advanced method of transmission control. In this case the transmitter does not multiply its base frequency, but already has the base signal frequency determined. The control is done by running a variable voltage into two varicap diodes coupled in parallel with the oscillating circuit. This voltage is applied by the PLL module and can control a wide range of frequencies, from transmissions on short-wave, high, ultra high and micro waves up to 10 and even 20 GHz.

PLL module provides control for frequency transmission through a mechanism of negative reaction or negative feedback line. The diagram for the PLL module is presented in figure 2:

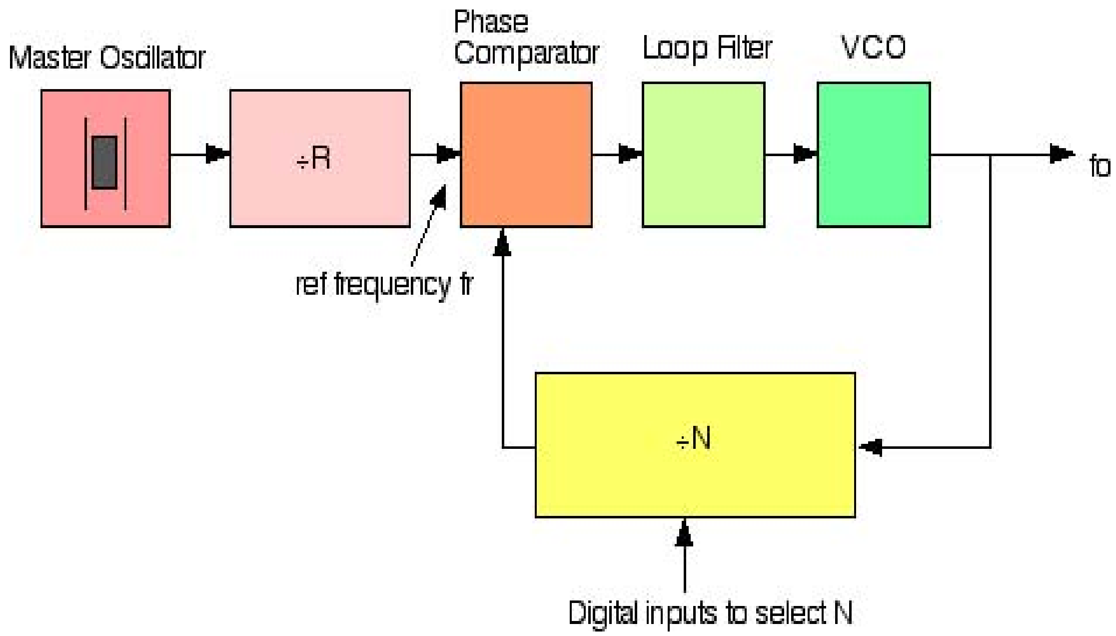

Fig. 2. Phase-Locked Loop Diagram [4]

According to the definition in [4], a phase lock loop (PLL) is a control system that generates a signal that has a fixed relation to the phase of a "reference" signal. A phase-locked loop circuit responds to both the frequency and the phase of the input signals, automatically raising or lowering the frequency of a controlled oscillator until it is matched to the reference in both frequency and phase. A phase-locked loop is an example of a control system using negative feedback. It compares the frequencies of two signals and generates an error signal which is proportional to the difference between the input frequencies. The error signal drives a voltage-controlled oscillator (VCO) which creates an output frequency. The output frequency is fed through a frequency divider back to the input of the system, generating a negative feedback loop. If the output frequency drifts, the error signal will increase, driving the frequency in the opposite direction to reduce the error and the output is locked to the frequency at the other input which is called a reference and it is often derived from a crystal oscillator, which is very stable in frequency. [4]

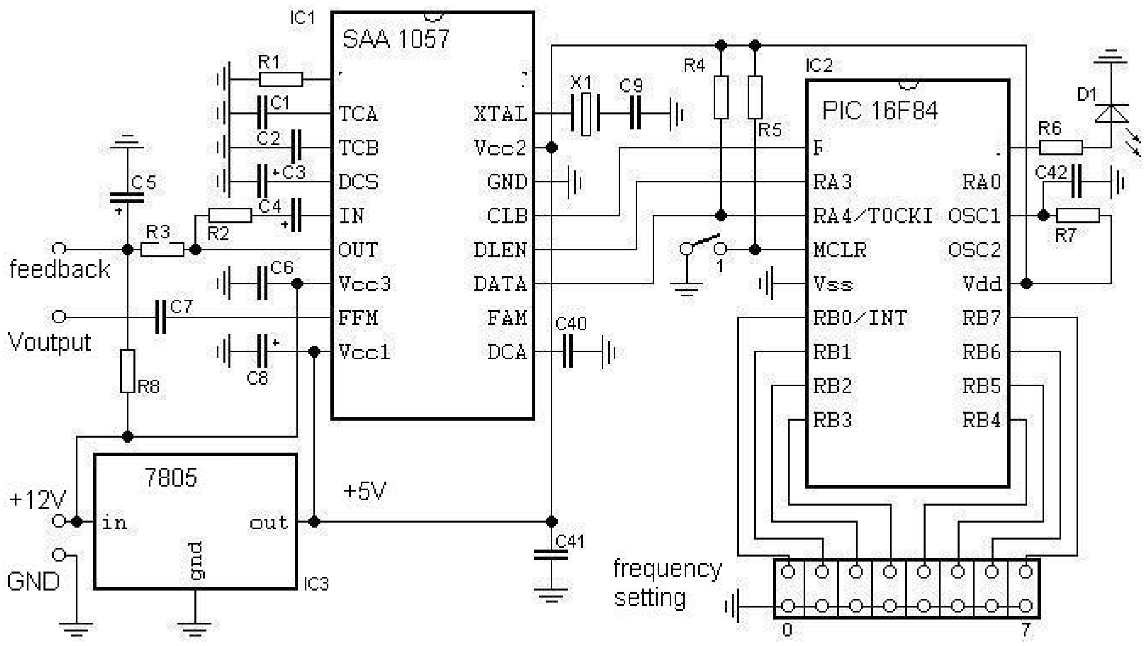

Fig. 3. Phase-Locked Loop electric schematic using PIC16F84 and SAA1057

Figure 3 shows the electric schematic of a simple early development stage PLL module with manual frequency selection using jumpers which was used to experiment the automatic voltage output adjust for the varicap diodes and automatic frequency control using the feedback line [5].

The most common frequency control circuits easy to find in specialized components stores are SAA1057, LMX2306 and TSA5511.

Figure 4 shows an advanced PLL module for controlling a VCO (voltage-controlled oscillator) commonly used in commercial FM transmitters, using the specialized SAA1057 control circuit. The device was built for experiment using data from [8].

This module also uses a LCD for visual display of transmitting parameters - frequency, phase and lock, and it was used to experiment the transmission stability on radio channels between 90 and 100 MHz.

It is possible to adapt this module into a digital data transmitter by adjusting the software in the same easy to follow JAL programming language [2] and it is presented at reference [9].

Our system that is presented in this paper uses only a microcontroller and no other specialized circuits.

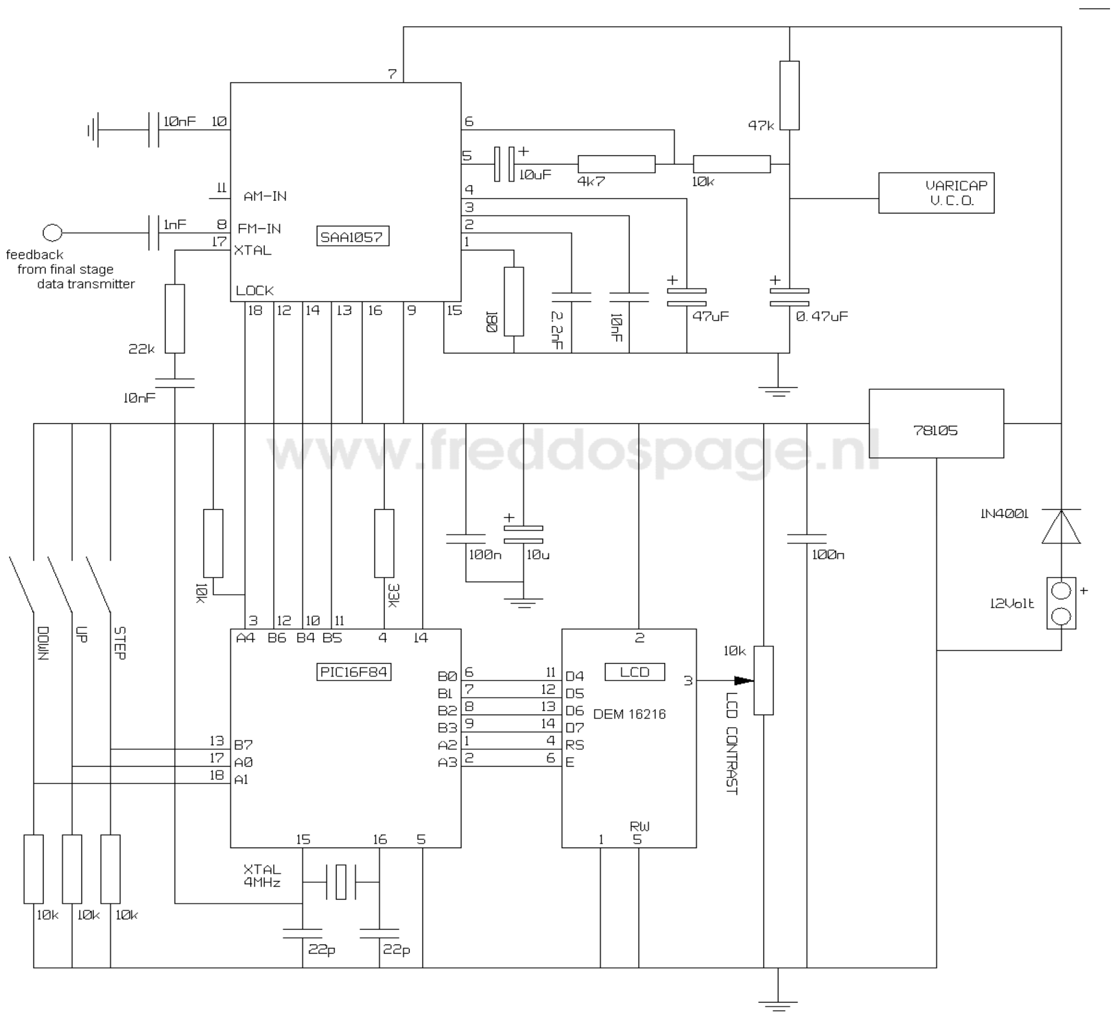

Fig. 4. Phase-Locked Loop advanced module using LCD display [8]

Direct Control

Depending on the distance the radio communication is necessary, the radio transmitters can be needed for local or long distance communications. Figure 5 shows the block schematic for long distance communication transmitter using medium wave, short wave with ionosphere reflection, or high frequency waves up to ultra high frequencies.

In this particular presented case, the microcontroller is also the oscillating circuit.

The radio signal having the base frequency *f0* modulated to contain the data is injected into the first frequency multiplier module, where it is doubled or tripled. The next multiplier modules run the same procedure until the authorized frequency channel is obtained. Each module multiplies its input signal using its second or third harmonic. For stability in transmission it is recommended to use a small number of multipliers. The advantage of this system is an extremely powerful signal radiated in the air using robust components.

Turning to the low multiplier modules and already knowing the microcontroller can generate the maximum frequency equal to that of quartz crystal which commands it - up to 10 MHz, shows that the final frequency is recommended to be in the band of 160-180 MHz for successive doubling, and the band of 400 MHz for successive tripling. Multiplication using third harmonica in the next multiplying stages has disadvantages in instability and reduced amplifying. It is common to use a single tripling followed by successive doubling. It follows that this method is not effective for high frequencies control and is used for high power transmissions on large distances that are in short-wave ionosphere reflections - up to 30 MHz, in the high wave frequencies up to 144 - 145 MHz and the ultrahigh to the 400 - 450 MHz band. In Romania the band located around the frequency of 160 MHz is limited to army and police only and access without special authorization is prohibited by the law.

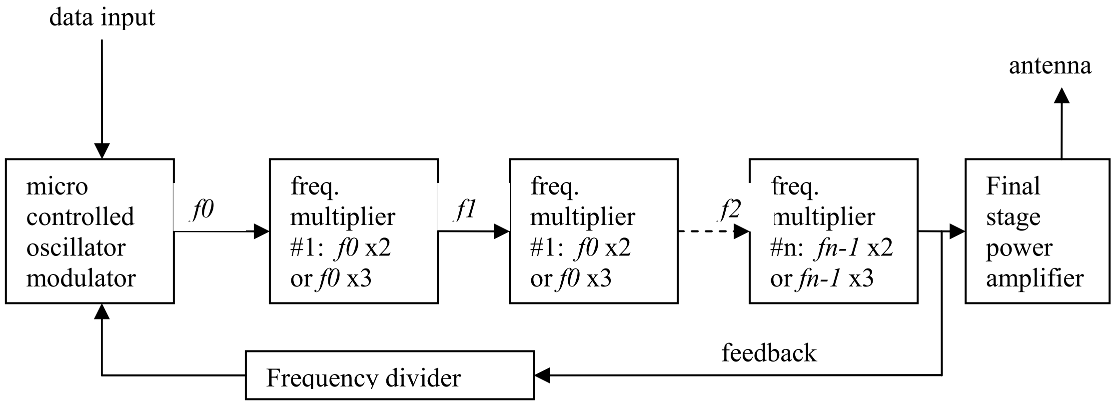

Fig. 5. Radio transmitter for long distance LW/MW/SW/HF/VHF

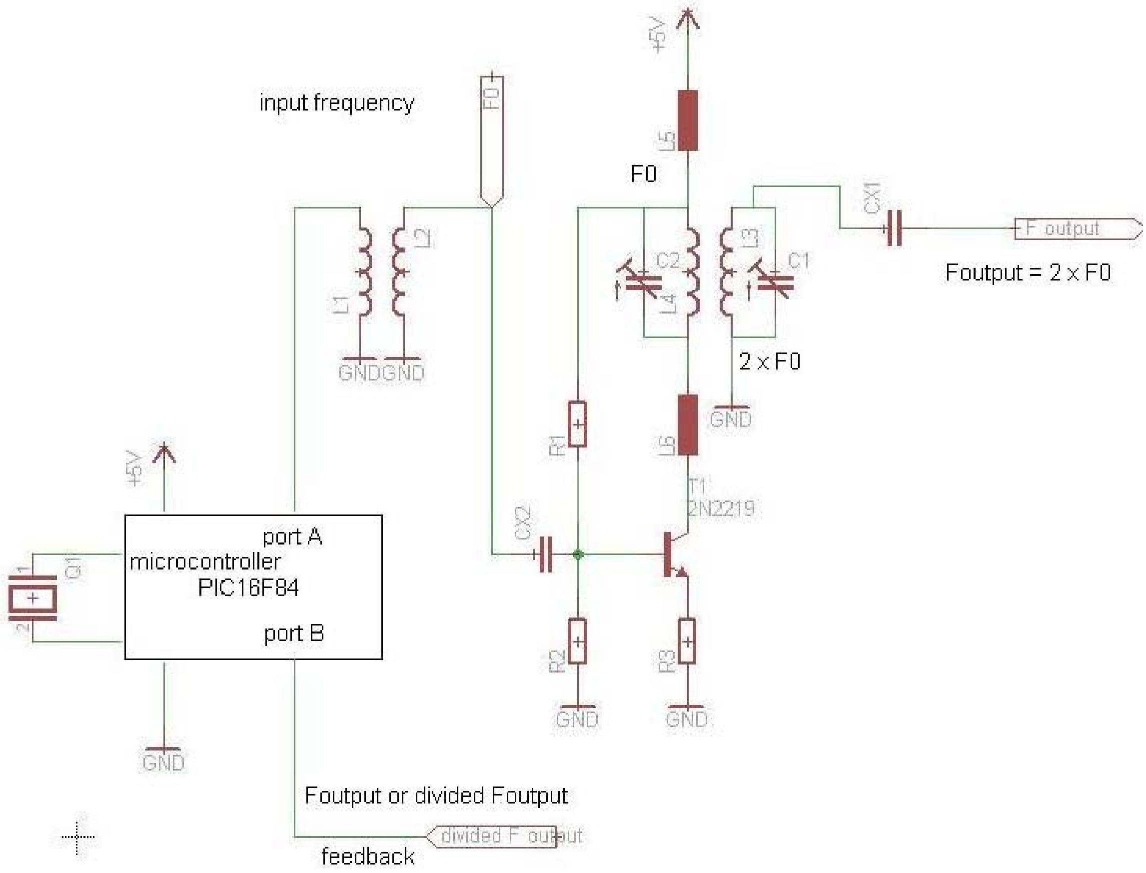

Fig. 6. The base frequency generator

The digital control of frequency is possible by changing the output pulse of the microcontroller, which involves these doubling and tripling mechanisms, which results in the control of the final frequency. The feedback line carries the output signal, reducing its frequency by a divider for the microcontroller to compare it with a reference inside its memory so that influences of disturbing factors such as temperature, humidity or voltage fluctuations can be prevented.

Figure 6 shows a micro controlled oscillator followed by a doubling-frequency module. The schematics was build using the CadSoft Eagle Layout Editor [10].

For the ease of understanding the program commanding the pulsing the JAL programming language (Just Another Language) was used [2]:

```
include 16c84_10
include jlib

var bit freqbase is pin_a0
pin_a0_direction = output

forever loop
  delay_1us( 2 )
  freqbase = high
  delay_1us( 2 )
  freqbase = low
end loop
```

The program is working with PIC16C84/PIC16F84 and standard JAL libraries. Variable 'freqbase' represents a bit having values of 0 or 1 and controls pin 0 inside port A which is set to generate output signals. An infinite loop generates a square signal and the frequency is controlled using the delay_1µs procedure. The controller will wait two microseconds with pin0 in high state and two microseconds with pin0 in low state, resulting 5 MHz as base frequency.

The transmitting channels can be defined as variables which can be passed to the delay procedures.

During the experiment a high instability in automatic frequency control was noticed due to the delays which were caused by the multiplier modules, the frequency divider in the feedback line and the high radio frequencies the microcontroller had to analyze.

After disconnecting the feedback line, the experimental results were analyzed and they are presented in the following tables:

Table 1. Pulses and resulting frequencies

Number of 1uS delays	Resulting base frequency (MHz)
1	10
2	5
3	2.5
4	1.25
5	0.625

Table 2. Base and final frequencies

Base frequency (MHz)	Final stage frequency multiplied into the doubling frequency module:
0.625	1.25
1.25	2.5
2.5	5
5	10
10	20

By modifying the pulse delays we can notice the fast increase of the base frequency and the wide band covered by the first multiplier stage.

It is obviously that the transmitting channels will never be close to each other in terms of the value of the transmitting frequency:

Multiplying several times the base frequency will have results into a wide band transmitting channel dispersion, which results into a high instability of the final transmitting stage.

As a conclusion, this method of controlling the transmitting frequency is not optimal, it is highly unstable and the final output frequency cannot be controlled.

Integrating Module

The pulse of the microcontroller output port is applied to an integrator circuit based on a Resistor-Capacitor low-pass filter or a bipolar transistor followed by an R-C low-pass filter. It performs a conversion from frequency as an input to a voltage as an output, these units being directly proportional. The variable voltage is applied to a group of variable capacitance diodes directly controlling the oscillatory circuit. In this case the transmission module may be the one with successive multiplying frequency shown in figure 6 or without multiplication but with control varicap diodes shown in figure 7:

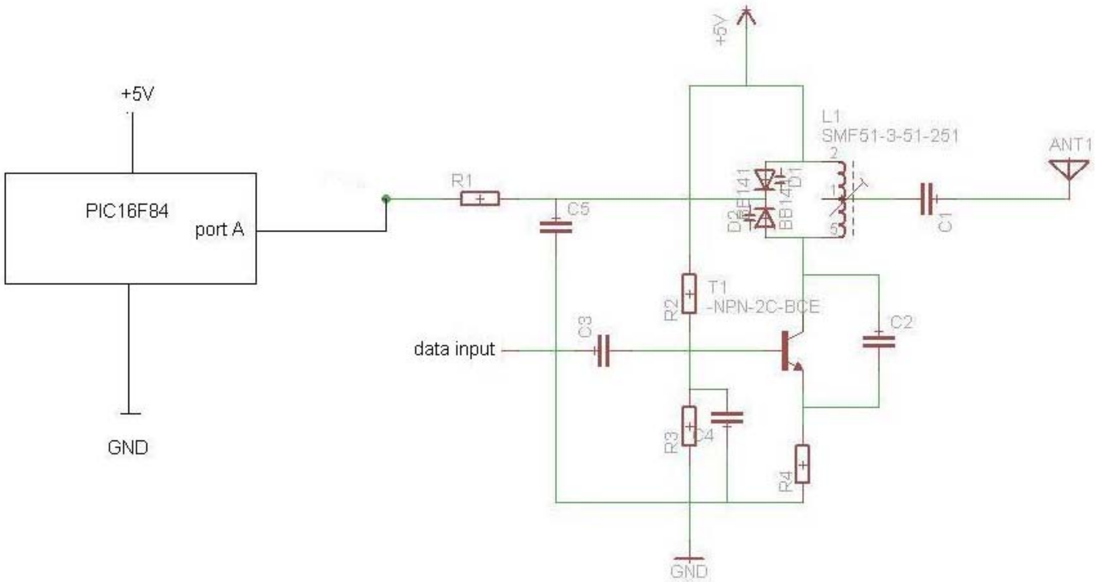

Fig. 7. Radio transmitter controlled by a R-C integrator

The R1-C5 components group represents the integrator module.

An AC source with voltage $v_{in}(t)$ inputs to an RC series circuit. The output is the voltage across the capacitor. Only **high frequencies** are considered: $\omega >> 1/RC$, so that the capacitor has insufficient time to charge up, its voltage is small, so the input voltage approximately equals the voltage across the resistor [3].

The output port program control is similar to the program shown for the figure 6 module, only the pulsing frequency is modified. The module from figure 6 is controlled with frequencies in kHz or MHz depending on the requirements, but in this case a low pulsing frequency is enough – 0.01 seconds:

```
include 16c84_10
include jlib

var bit freqbase is pin_a0
pin_a0_direction = output

forever loop
  delay_10ms( 1 )
  freqbase = high
  delay_10ms( 1 )
  freqbase = low
end loop
```

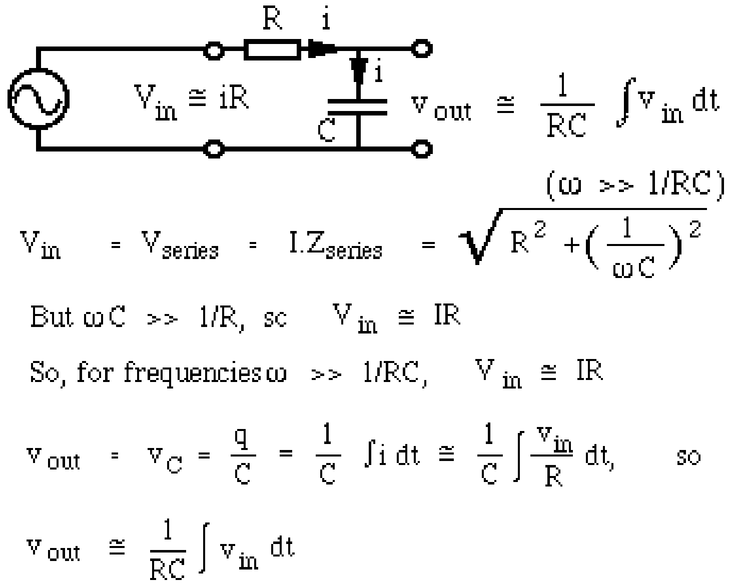

Fig. 8. Mathematical model of the integrator module [3]

By modifying the argument inside the delay_10ms instruction we can adjust how many 10ms delays the microcontroller can execute. This modifies the frequency of the output square signal which integrates into the output voltage control to the varicap diodes.

During the experiments the same high instability in controlling the output frequency was noticed due to the delays generated by the frequency divider and the high frequencies the microcontroller had to analyze. To continue the experiment, the feedback line was disconnected and the module was wrapped into wax so there would be no temperature and moisture influences.

The great advantage of this method is the possibility of defining transmitting channels located in a small range and frequencies close to each other, as presented in the following table:

The coil in the oscillator has been built and calculated to oscillate at about 401 MHz using the capacity of the two varicap diodes at zero voltage. By modifying the pulse delays we can notice the slow increase of the base frequency and the narrow band covered by the transmitter. The final stage will not show the same high instability as during the experiment presented at chapter 2. The system was highly stable during the six hours of continuous data transmitting activity even without the automatic frequency control system.

As a conclusion, this method of controlling the transmitting frequency is optimal for a high number of fixed frequency channels transmission.

Table 3: Port A pulsing and resulting frequencies

Number of 10ms delays	Resulting transmitting frequency (MHz)
9	400.0
8	400.2
7	400.35
6	400.4
5	400.52
4	400.59
3	400.68
2	400.8
1	401

Conclusions

This paper showed an efficient method for controlling the stability of frequency transmission and implementation of its control using microcontrollers. Using the JAL programming language an experimental automatic adjustment system was tested for controlling specialized PLL circuits such as LMX2306, TSA5511 or SAA1057 which was used in the PLL experiment. As the purpose of this paper was the development of a transmitting frequency controller using only a microcontroller and no other additional specialized components, the model obtained is a practical device that can be later attached to a data transmitter in order to define transmitting channels for data exchange between intelligent automatic modules such as robots or process controllers.

References

1. Marinescu, C. - *Programming Microcontrollers – Course notes*, Petroleum-Gas University of Ploiesti, 2005.
2. van Ooijen, W. - *Microcontroller programming – the high level JAL programming language*, http://www.piclist.com/techref/microchip/language/jal/doc/manual.html.
3. Wolfe, J. - *Resistor-Capacitor filters, integrators and differentiators – course notes*, University of New South Wales, Australia, 2006; http://www.physclips.unsw.edu.au/jw/RCfilters.html.
4. * * * - http://en.wikipedia.org/wiki/PLL - explaining the operation of PLL module.
5. * * * - http://www.uoguelph.ca/~antoon/gadgets/pll/pll.html - Phase-Locked Loop theory.
6. * * * - http://www.freescale.com/files/rf_if/doc/app_note/AN535.pdf - Phase-Locked Loop mathematic model.
7. * * * - http://www.nxp.com/acrobat_download/applicationnotes/AN177.pdf - Philips Semiconductors, Phase-Locked Loop theory.
8. * * * - http://www.freddospage.nl/ - Freddos Electronics commercial FM transmitters projects, 2002.
9. * * * - http://www.campusupg.ro/PLL/1057.zip - Micro controlling Transmitting Frequency – test software.
10. * * * - CadSoft Eagle Layout Editor, professional schematics and PCB designing tool, © 1988-2008 CadSoft

Controlul frecvenţei de transmisie radio cu ajutorul microcontrollerelor

Rezumat

Lucrarea analizează şi propune două metode pentru a controla digital frecvenţa de transmisie radio. Un microcontroller din familia Microcip efectuează reglajul frecvenţei de transmisie. Sunt prezentate un transmiţător cu buclă PLL şi experimentele de control direct al frecvenţei folosind circuite din familia PIC. Sunt prezentate avantaje şi dezavantaje, programe şi secvenţe de program pentru cercetări ulterioare şi proiectarea de module radio cu control digital al frecvenţei de transmisie..