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Signature :
Supervisor's Name : DR. A. B. M Shafiul Azam
Date : April 01, 2005

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DESIGN OF CARR-PURCELL GENERATOR FOR PULSE PROGRAMMER

FELIX NORMAN ANAK LAZARUS GOH

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To my Beloved family.
Especially my parent.

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ABSTRACT

A digital pulse programmer producing the standard pulse sequence required for Pulsed Nuclear Magnetic Resonance Spectroscopy is described. The pulse programmer described is capable of producing the standard pulse sequences required for pulsed NMR spectroscopy and may be easily modified to produce more specialized pulse sequences. Pulse programmer provided the two-pulse sequences for 90° – 90° and 180° - 90°. To program a Carr-Purcell series, the saturation burst generator is set to produce a single '90°' pulse, and the separation period and divisor for the '180°' pulses are selected on time base channel.

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ABSTRAK

Pemprogram Denyut Digital akan menghasilkan rangkaian denyut yang standard untuk keperluan Pulsed Nuclear Magnetic Resonance Spectroscopy. Pemprogram denyut yang dimaksudkan berupayan untuk menghasilkan rangkaian denyut yang standard bagi NMR dan mungkin mampu diubah atau di modifikasikan bagi menghasilkan lebih banyak rangkaian denyut yang khusus. Pemprogram denyut ini mampu menghasilkan dua dua rangkaian denyut untuk $90^\circ - 90^\circ$ dan $180^\circ - 90^\circ$. Bagi menghasilkan program bersiri Carr-Purcell, satu rangkaian penjana Saturation Burst diperlukan bagi menghasilkan denyut tunggal '90°', serta pemisahan tempoh dan pembahagian untuk denyut '180°'yang akan ditentukan dengan saluran pangkalan masa yang dipilih.

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CHAPTER I

INTRODUCTION

1.1 BACKGROUND

This project is commonly to design throughout a simulation, hardware and testing method on a Carr-Purcell pulse generator. The pulse that produced via this generator should be applied to the versatile pulse programmer of NMR circuit.

The pulse programmer was designed to be completely general with the capability to quickly and easily program any desired pulse sequence. So, by the Carr-Purcell method the number of 180° pulses which can be used in a given sequence is limited by the accumulation of errors in pulse length.

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1.2 PROJECT INTRODUCTION

Carr Purcell Generator is the circuit that will produces a Carr Purcell sequence of 90°-t-180°-2t-180°-2t-180° … 180° pulses. This circuit should be applied to the Versatile Pulse programmer for pulsed nuclear magnetic resonance spectroscopy circuit also known as NMR circuit.

This circuit is design to produce a sequence based on the two-pulse and multiple-pulse sequence for spin-spin relaxation Time T_2 measurements theories. To measure the spin-spin relaxation time(T_2), a 90\circ-180\circ method was also used. In this case, however, the repeat time is kept constant at a level that allows complete return to equilibrium. The time \tau in between pulses is the variable; the general idea is that the 90\circ knocks spins down and they relax a little bit up due to T_1 and deco here due to T_2^*. Then the 180\circ pulse reverses everything. The spins that had been relaxing upwards due to T_1 were sent to an equal distance below the x-y plane while still rising at the same rate, and the phase ordering of the spins in x-y has been reversed while still precessing at the same rate. Thus, another \tau later, the T_1 spin-lattice relaxation will have canceled out, and the x-y plane precession will recohere. So at the height of the spin echo, the only relaxation effect still in effect is T_2.

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1.3 OBJECTIVE

The main objective of this project is to produced the Carr-Purcell sequence of 9O°-t-180°-2t- 180°-2t-180°. . . 180° pulses. As we proceed to the next objective, we should consider whether this circuit will be able to be applied to the Burst Generator circuit and the Coincidence Circuit.

1.4 PROBLEM STATEMENT

The frequency division is produced by saturation burst generator, which then divides frequency that is inverted and to produce a further division by two. This next problem is the main problem to this project; whether this project could be compatible to another circuit before – burst generator or after- coincidence circuit.

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CHAPTER II

LITERATURE REVIEW

2.1 THEORY OF NUCLEAR MAGNETIC RESONANCE SPIN-SPIN RELAXATION

A general method is described for the calculation of the relaxation function $G(t)$ for a macroscopic nuclear magnetization perpendicular to a strong steady magnetic field, under the influence of the nuclear dipole-dipole interaction. This function is the Fourier transform of the nuclear magnetic resonance absorption line shape. Approximations are introduced, the form of which depends upon whether the short-term or the long-term development of $G(t)$ is required. A third type of approximation leads to the equation of Lowe and Norberg. The theory is applied to the case of the fluorine resonance in calcium fluoride with the steady field in the [100] direction. The first approximation gives a curve that differs only slightly from that of Lowe and Norberg over the range of t for which the latter is in good agreement with experiment. For larger t the disagreement with experiment is less severe, the characteristic oscillation of $G(t)$ being present, though with too large an amplitude. In contrast the second approximation gives a curve which though over damped provides a better description of the approach of the spin system to equilibrium. The theory may be extended to problems in which the dipolar Hamiltonian possesses explicit time dependence. In this form it is applied to the case of motional narrowing due to rapid rotation of the sample about an axis inclined at

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54.7° to the magnetic field, for which the absorption spectrum consists of a narrow central line flanked by an infinite series of sidebands spaced at intervals corresponding to the rotation frequency. It leads to a separation of the two components of the second moment of the spectrum due respectively to the generation of sidebands and to the finite width of the lines. Though the sum of these contributions is invariant to rotation they themselves are not. An assumed form for the shape of the lines leads to a line width which for rapid rotation depends inversely on the cube of the rotation frequency and is in substantial agreement with an earlier statistical theory.

2.2 INTRODUCTION TO DIGITAL PULSE PROGRAMMER

A digital pulse programmer producing the standard pulse sequences required for pulse nuclear magnetic resonance spectroscopy is described. In addition a 'saturation burst' sequence, useful in the measurement of long relaxation time in solids, is provided. Both positive and negative 4V trigger pulses are produced that are fully synchronous with a crystal-controlled time base, and the pulse programmer may be phase locked with a maximum pulse jitter of 3 ns to the oscillator of a coherent pulse spectrometer. Medium speed TTL integrated circuits are used throughout.

The pulse programmer is capable of producing the standard pulse sequences required for NMR spectroscopy and may easily be modified to produce more specialized pulse sequences. Those provided are: the two-pulse sequences for 90°-90° or 180°-180° spin-lattice relaxation time T1 measurements with a 'saturation burst' sequence for measurement of long T1 in solids; two-pulse sequences for rotating-frame spin-lattice relaxation time T1p measurements; and two-pulse and multiple-pulse sequences for spin-spin relaxation time T2 measurements.

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An internal oscillator or the RF source of a coherent spectrometer (with suitable frequency division) may be used as a time base. Medium speed TTL integrated circuits are used throughout, and the circuitry is fully synchronous with the time base, producing maximum pulse jitter of the order of 3 ns so that the programmer can be phase locked to the RF source. The output may be either positive or negative markers of 1 us duration and 4V amplitude to provide triggers for the pulse length controls of the spectrometer. The circuitry of the pulse programmer will be discussed in for segments: time base, four digit decade scaler, burst generators for special pulse sequences, and coincidence and synchronization circuits.

2.2.1 Time Base

The time base consists of a frequency standard and a decade divider. The frequency standard may be taken as some appropriate division of the oscillator frequency of a coherent spectrometer to provide phase locking to the pulse programmer, or an internal clock may be used.

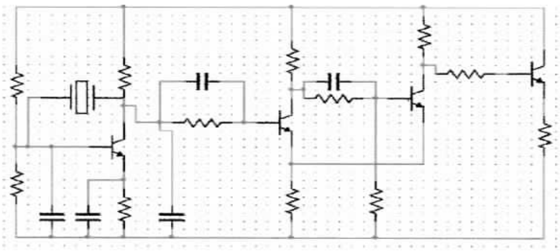

Figure 2.1: internal clock

The internal clock circuit contains a 1MHz crystal oscillator and a schmidt trigger with coupling and divider resistors selected to produce a symmetric square-wave. An emitter follower output provides impedance matching to the remaining circuitry.

Six SN7490N decade counters wired as symmetric divide-by-ten counters and three independent switched outputs labeled, ‘time base channel A, B, C’, provide

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frequencies at decade intervals from 1MHz to 1Hz, inclusive. The decade is automatically reset to zero by a coincidence circuit set to provide the desired repetition rate for the pulse sequence and by the saturation burst generator following a series of 90° pulses. These reset functions will be further discussed.

2.2.2 Decade Scaler

The decade scaler contains four of the synchronous decade counters. An SN7490N decade counter wired as a binary coded decimal (BCD) counter is decoded to decimal output by an SN7442 four-line to 10-line decoder. Visual display is provided by a Burroughs B5540 display tube driven by an SN7441AN decoder/driver. The carry output of each decade counter is synchronized with its count input to minimize accumulated delays and to allow independent resetting of the counters.

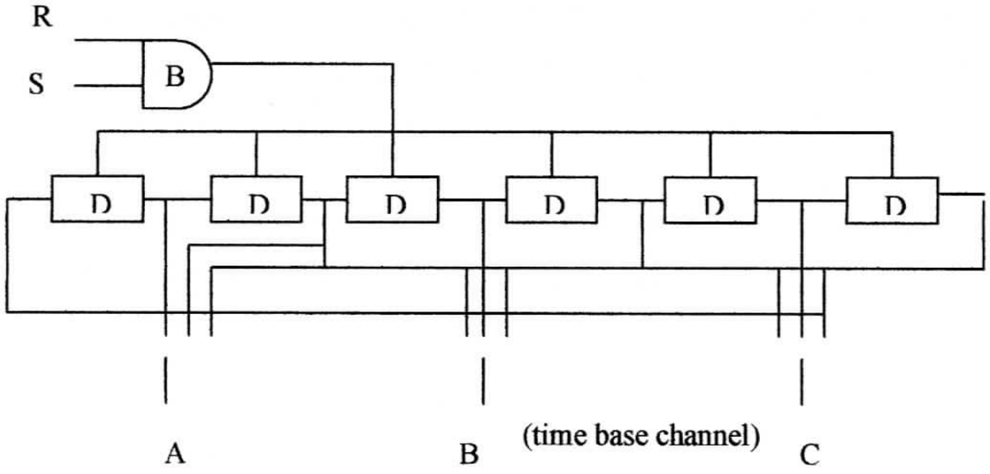

Figure 2.2: decade divider

Independently adjustable delayed pulses are produced when coincidence occurs between the switch selected decimal outputs of each decade counter. Three such coincidence channels provide pulse for: resetting time base and decade scaler.

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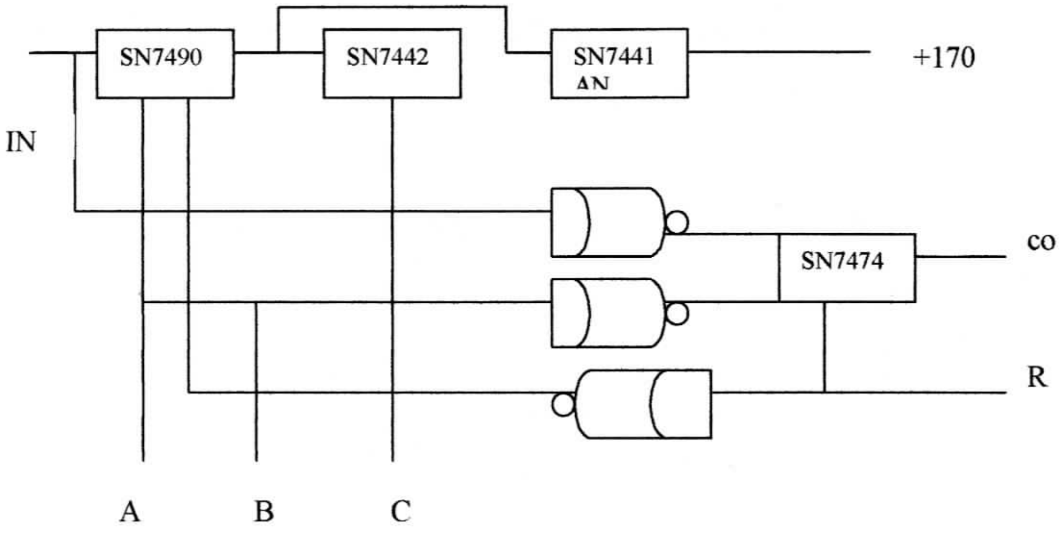

Figure 2.3: decade counter

To enable selection of a variable repetition rate for the various pulse sequences; termination of the Carr-Purcell sequence; and delayed pulse in two-pulse sequences. Four-digit ganged switches were used for each of the three coincidence channels for compact construction and ease of operation.

The use of four decade counters in the decade scaler provides four-digit precision for each of the three delayed pulses. The precision may be increased or decreased by using more or fewer decade counters.

2.2.3 Burst Generators

The saturation burst generators produces a sequence of pulses to provide a pseudo-90° pulse useful for the measurement of long relaxation times in solids. This sequence consists of 1-9 pulse of equal separation t such that $T2<t<<T1$. During this sequence the input to the decade scaler is interrupted, and the time base is reset on the last pulse in the sequence. In this way, all delayed pulses following the pseudo-

90° pulse occur at times measured from the beginning of the final pulse in the saturation burst, and no corrections for the finite extent of the sequence are required.

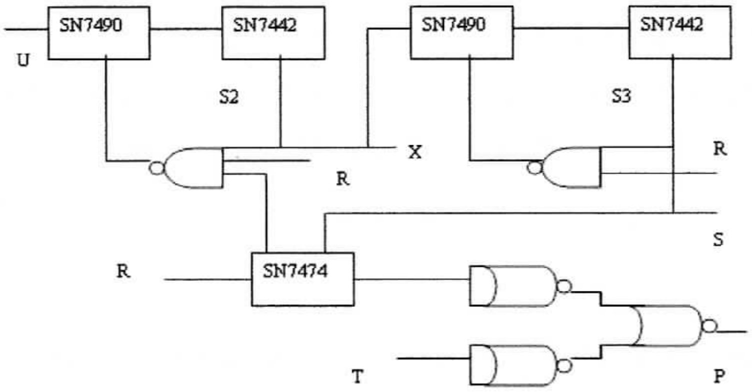

Figure 2.4: Saturation burst

The pulse separation of the burst can be selected as a multiple of time base channel A which is input to U. This input frequency is divided by an SN7490N BCD counter and SN7442N decoder. Switch S2 determines the frequency division by resetting the counter when the desired divisor has been reached. The wiper of S2 also provides the pulse for the 90° saturation burst pulses at X and is input to a second BCD counter and decoder. When the number of 90° pulses selected on S3 has been reached the second counter resets, and the sequence is terminated. During this sequence, the time base selected for the decade scaler is interrupted by an AND gate. This is formed with three NOR gates and is controlled by the Q output of an SN7474 flip-flop. When a reset pulse R resulting from the initiation of a new pulse sequence is applied to the preet input of the flip-flop, Q goes to a low level (0), and the decade scaler time base input at T is interrupted. When the last pulse in the sequence is detected at S and on the clear input of the flip-flop, Q is set to a high level (1), and the signal at T is passed to P and to the input of the decade scaler. The pulse at S also serves to reset the decade divider to zero, so that all subsequent delays are measured from the beginning of the final pulse in the saturation burst.

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2.2.4 Carr-Purcell Generator

Carr-Purcell generator is the circuit that will produce the Carr-Purcell sequence of 90°-t-180°-2t-180°-2t-180°.....180° pulses. The pulse separation t is selected by S4 as a multiple of the period of time base channel C. This frequency division is produced in the same manner as discussed. The divided frequency is inverted and applied to the clock input of an SN7474 edge triggered flip-flop (FF2) to produce a further division by two.

The pulse sequence is initiated by a reset pulse at R which sets the flip-flops and also serves as the 90° pulse. Flip-flops FF1 is preset by R so that its Q output goes to 1 enabling the AND gate (wired from three NORS) to pass subsequent 180° pulses. Flip-Flops FF2 is set by R so that the first pulse from S4 at time switches Q on FF2 from 1 to 0 producing the first 180° pulse. Subsequent pulses from S4 are divided by two in frequency to produce the desired pulse sequence. The 180° pulse string is terminated by applying a pulse at W at a preselected time.

2.2.5 Coincidence and Synchronizing

Coincidence circuit is used to select the position of each of the three delayed pulses required; W, Carr-Purcell reset; the delayed pulse in two-pulse sequences; and R, the reset pulse determining the repetition rate for all pulse sequences. Each coincidence circuit is constructed with two NOR gates and a NAND gate. Coincidence can easily be increased to a maximum of eightfold with these devices by making use of additional NOR gates and utilizing the remaining NAND inputs.

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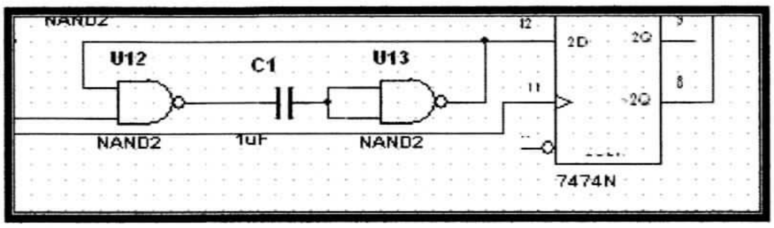

Figure 2.5: Basic design for Synchronizing Circuit

Synchronization is to remove errors that have accumulated in the preceding circuitry the output 90° and 180° pulses are synchronized with the time base clock by use of the circuit. The pulses to be synchronized with the clock are negative-going of duration approximately 50ns to one time base period, depending upon the pulse in question. These pulses are slightly delayed from the trailing edge of a clock pulse where the solid and broken lines indicate the possible extremes in duration. Such pulse are converted to negative going pulses to uniform length by gated stored-charge multivibrators formed from two NAND gates. The length t of each pulse is determined by the RC time constant of the coupling networks of these monostables and is adjusted so that 0.5us <t<1.0 us. The output of each monostable is applied to the D-input of an edge-triggered flip-flop. The output of the flip-flop is then switched by the next leading edge of the clock (~0.5 us later). The next positive leading edge of the clock restores the flip-flop to its initial condition. In this manner, a positive pulse of 1us (one clock period) duration appears at the Q output of the flip-flop, and all such pulse are delayed by approximately 0.5us from the input to the monostable. A complimentary negative-going pulse is available on the Q output of the flip-flop. Thus, each of the output pulses is synchronized to the time base clock and the maximum pulse jitter is determined by the difference in the storage times of the edge triggered flip-flop used in the synchronizing circuitry (<3 ns).

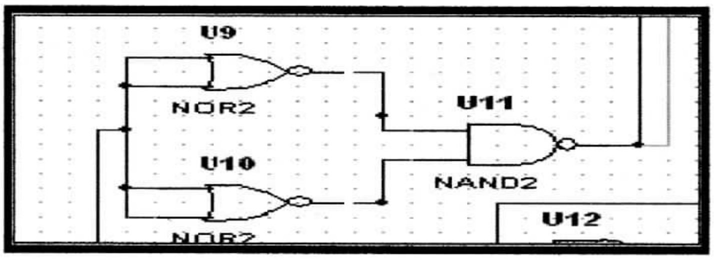

Figure 2.6: Basic design for Coincidence Circuit

CHAPTER III

METHODOLOGY

3.1 INTRODUCTION

Since this project is a piece of pulse programmer project, it is important that a through study of the project is done very carefully. After the first step is done, next step is to understand completely the circuit design including the application of the circuit and to familiarize the circuit function.

A simulating procedure will be applied to make sure that the project can proceed successfully as expected. Through this project, we will be using multisim software for simulation purpose.

Then we should be applying the circuit to a bread-board to finalize step before we apply it to the permanent printed board. The output should be match with the input of the next coincidence circuit. Finally, it will be constructed on the permanent printed board and tested. The output results will be compared with the simulation.

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