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DESIGN AND DEVELOPMENT OF A VOLTAGE DIP COMPENSATOR FOR A TRANSFORMER USING A STEPPER MOTOR WITH DIGITAL CONTROLLER

By

WAN FAIZUREEN BINTI ZAINAL ABIDIN

FINAL PROJECT REPORT

Submitted to the Department of Electrical & Electronics Engineering
in Partial Fulfilment of the Requirements
for the Degree
Bachelor of Engineering (Hons)
(Electrical & Electronics Engineering)

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CERTIFICATION OF APPROVAL

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Approved:

Assoc. Prof. Dr. K. S. Rama Rao
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

June 2007

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

Wan Faizureen Binti Zainal Abidin

ABSTRACT

The author is to design and develop a voltage dip compensator for a transformer using a stepper motor with a digital controller. The main task is to provide a mechanism for the mechanical switch of the tap changer to move. The mechanism will require a precise movement that can be controlled digitally. This report is prepared to present the design and implementation of the design for this project. In the early part of the report, the author will enlighten readers to the background of the project, the cause for needing such mechanism and the objectives of this project. Then the author will give a literature review and theory for the components used in the project. Here the theoretical result of the design is also presented. Results of circuit simulation and hardware constructed will be analysed and discussed in the next chapter. The constraints and overcoming the obstacle in completing this project will also be described. The author will conclude this report with the results of the design and knowledge gained throughout the completion of the project. Recommendations to further improve the design are presented at the end of this report.

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CHAPTER 1
INTRODUCTION

A transformer tap is a connection point along a transformer winding that allows the number of turns to be selected. By this means, a transformer with a variable turns ratio is produced, enabling voltage regulation of the secondary side. Selection of the tap is normally made via a tap changer mechanism. [1]

The author is required to design a digital controller that will manipulate the movement of a stepper motor that is physically connected to the transformer's tapping. As the output voltage of the transformer falls at an undesirable value, the motor will move, changing the tappings of the transformer changing the turns ratio and vary the input voltage so that a stable output voltage is obtained when the transformer load changes.

In completing this project, the author gained knowledge about transformer and its tapings. There are two types of tap changers; off-load and on-load. As suggested by the name, on-load tap changer, usually used for power transformer that requires no power interruptions to the load, will enable tapping even when there is load connected to the transformer. On-load tap changers may be generally classified as mechanical, or as electronic: either thyristor-assisted or solid state.

Author had also learnt briefly about peripheral interface controller (PIC). PIC is a microcontroller that has a processor and memory. They can compute and run a program responding to inputs and controlling outputs. They can process complex function and thus eliminate the use of several conventional ICs that may be able to give the same output.

For this project, the use of a stepper motor is incorporated to provide movement for the mechanism. A stepper motor is used due to its benefits that make it suitable for this project. Details on the operation and benefits of stepper motor will be discussed in the next chapter.

1.1 Problem statement

Voltage dips are one of the largest causes of disruption in the power supply system. Voltage dip may be caused by sudden change of load inrush (i.e. by inrush currents at motor start-up), short circuit inside and outside the transformer, or a thunder storm. They may result the same losses as power outage, such as loss of revenue due to unplanned process stoppage not to mention equipment damage.

Thus, it would be wise to provide a mechanism for the mechanical switch to move, so that a voltage dip can be compensated. This would also help in the event where voltage drop occurs.

The proposed tap changing mechanism requires a precise movement that can be controlled digitally. Therefore it would be appropriate to use a stepper motor controlled by PIC16F877 for this purpose. Stepper motors operate differently from other motors; rather than voltage being applied and the rotor spinning smoothly, stepper motors turn on a series of electrical pulses to the motor's windings [3]. Each pulse rotates the rotor by an exact degree.

1.2 Objective and scope of study

In this project, the author is expected to learn about microcontrollers and digital controller, PIC, programming the controller and integrate its application into the project.

On working to complete the project the author will reviewed the literature on tappings of transformer, its mechanism and perhaps learned more or less on transformer input and output voltage pattern.

The depth of understanding is only on the surface and specific on function and program of the PIC due to time limit of one year. The author is expected to come out with a program for the PIC and simulation of the motor controller circuit. After testing the open loop function of the system, the author should connect the output voltage of the transformer to the input of the PIC completing a closed loop function. The details of the project flow will be discussed on the later part of the report.

CHAPTER 2
LITERATURE REVIEW

The author is to design and develop a voltage dip compensator for a transformer tap changer. In order to do this the author will use a digital controller with PIC16F877 as the microcontroller. The purpose is to have a stable output voltage of the transformer via a voltage dip compensator by varying the position of the tap at the input coil of the transformer.

Using a concept of closed loop operation, the output of the transformer is fed back to the digital controller. The voltage is compared against a reference voltage (the chosen stable output voltage of the transformer). If the value of the output voltage is lower than the reference voltage, the input voltage is increased by changing the position of the tap changer. Vice versa if the output voltage is higher than the reference voltage the input voltage is decreased by repositioning the tap.

The findings of research and theory are discussed in the following section:

2.1 Transformer tap changer

Almost all transformers have taps on windings to adjust the ratio of transformation by changing the connecting points along the windings when the transformer is deenergized. Selection of the tap in use is made via a **tap changer** mechanism. [1, 11]

2.1.1 Voltage considerations [1]

Tap points are usually made on the high voltage, or low current, side of the winding in order to minimize the current handling requirements of the contacts. To minimize the number of windings and thus reduce the physical size of a transformer, use may be made of a 'reversing' winding, which is a portion of the main winding able to be connected in its opposite direction and thus oppose the voltage. Insulation requirements place the tap points at the low voltage end of the winding. This is near the star point in a star connected winding. In delta connected windings, the tapings are usually at the centre of the winding. In an autotransformer, the taps are usually made between the series and common windings, or as a series 'buck-boost' section of the common winding.

2.1.2 Tap changing [1]

2.1.2.1 Off-load designs

In low power, low voltage transformers, the tap point can take the form of a connection terminal, requiring a power lead to be disconnected by hand and connected to the new terminal. Alternatively, the process may be assisted by means of a rotary or slider switch.

Because different tap points are at different voltages, the two connections should not be made simultaneously, as this short-circuits a number of turns in the winding and would result in an excessive circulating current. This therefore demands that the power to the load be physically interrupted during the switchover time. Off-load tap changing is also employed in high voltage transformer designs, though it is only applicable to installations in which loss of supply can be tolerated [1].

2.1.2.2 On-load designs

Because interrupting the supply is usually unacceptable for a power transformer, these are often fitted with a more expensive and complex on-load tap-changing mechanism. On-load tap changers may be generally classified as mechanical; or as electronic, which in turn may be either thyristor or solid state controller.

- Mechanical tap changers

A mechanical tap changer physically makes the new connection before releasing the old, but avoids the high current from the short-circuited turns by temporarily placing a large diverter resistor (sometimes an inductor) in series with the short-circuited turns before breaking the original connection. This technique overcomes the problems with open or short circuit taps. The changeover nevertheless must be made rapidly to avoid overheating of the diverter. Powerful springs are wound up, usually by a low power motor, and then rapidly released to affect the tap changing operation. To avoid arcing at the contacts, the tap changers are filled with insulating transformer oil. Tapping normally takes place in a separate compartment to the main transformer tank to prevent contamination of its oil.

One possible design of on-load mechanical tap changer is shown in Figure 1. It commences operation at tap position 2, with load supplied directly via the right hand connection. Diverter resistor A is short-circuited; diverter B is unused.

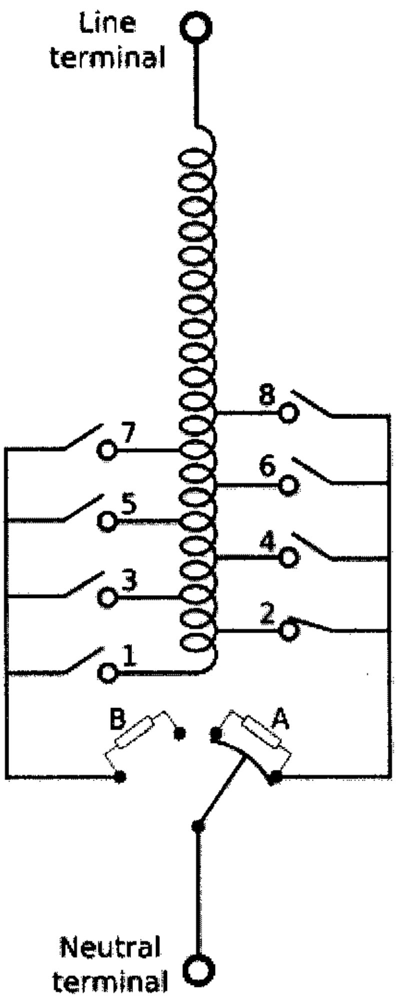


Figure 1 One possible design of a mechanical tap changer

In mechanical on-load tap changer design, changing back and forth between tap positions 2 and 3, the operation are as follows:

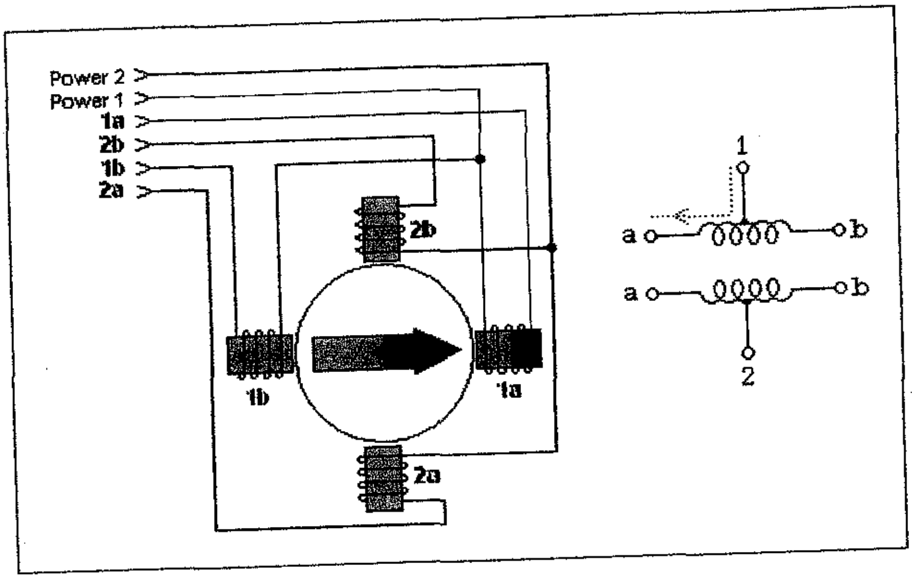


Figure 5 Conceptual model of a unipolar stepper motor

The following table describes 3 useful stepping sequences and their relative merits. The sequence pattern is represented with 4 bits; a '1' indicates an energized winding. After the last step in each sequence the sequence repeats. Stepping backwards through the sequence reverses the direction of the motor.

Table 1 Stepping sequence for unipolar stepper motor

Sequence	**Name**	**Description**
0001	Wave Drive, One Phase	Consumes the least power. Only one phase is energized at a time. Assures positional accuracy regardless of any winding imbalance in the motor.
0010		
0100		
1000		
0011	Hi-Torque, Two Phase	Hi Torque - This sequence energizes two adjacent phases, which offers an improved torque-speed product and greater holding torque.
0110		
1100		
1001		

In moving to tap 3, the following sequence occurs:

1. Switch 3 closes, an off-load operation.
2. Rotary switch turns, breaking one connection and supplying load current through diverter resistor A.
3. Rotary switch continues to turn, connecting between contacts A and B. Load now supplied via diverter resistors A and B, winding turns bridged via A and B.
4. Rotary switch continues to turn, breaking contact with diverter A. Load now supplied via diverter B alone, winding turns no longer bridged.
5. Rotary switch continues to turn, shorting diverter B. Load now supplied directly via left hand connection. Diverter A is unused.
6. Switch 2 opens, an off-load operation.

The sequence is then carried out in reverse to return to tap position 2.

- Thyristor-assisted tap changers

Thyristor-assisted tap changers use thyristors to take the on-load current whilst the main contacts change over from one tap to the next. This prevents arcing on the main contacts and can lead to a longer service life between maintenance activities. The disadvantage is that these tap changers are more complex and require a low voltage power supply for the thyristor circuitry. They also can be more costly.

- Solid state (thyristor) tap changers

These are a relatively recent development which uses thyristors both to switch the load current and to pass the load current in the steady state. Their disadvantage is that all of the non-conducting thyristors connected to the unselected taps still dissipate power due to their leakage current. This power can add up to a few kilowatts which have to be removed as heat and leads to a reduction in the overall efficiency of the transformer. They are therefore only employed on smaller power transformers.

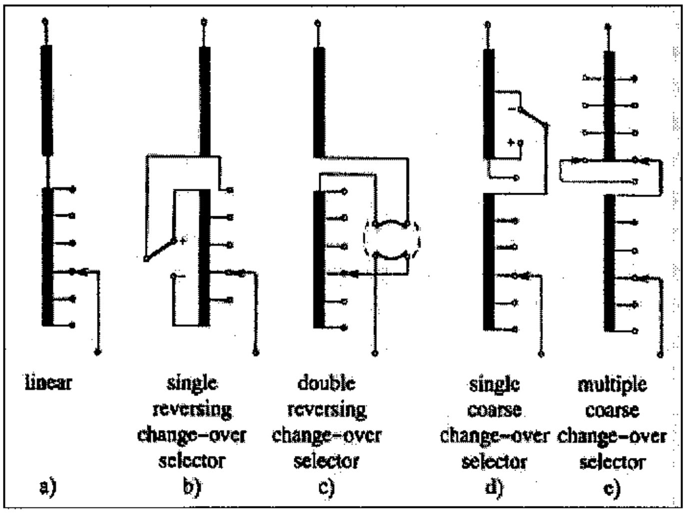


Figure 2 Basic arrangement of regulating (tap) winding

2.2 Stepper motor

Stepper motors consist of a permanent magnet rotating shaft, called the rotor, and electromagnets on the stationary portion that surrounds the motor, called the stator [3].A stepper motor has the following performance characteristics:

1. Rotation in both directions,

2. Precision angular incremental changes,

3. Repetition of accurate motion or velocity profiles,

4. A holding torque at zero speed, and

5. Capability for digital control.

A stepper motor can move in accurate angular increments known as steps in response to the application of digital pulses to an electric drive circuit from a digital controller. The number and rate of the pulses control the position and speed of the motor shaft. Generally, stepper motors are manufactured with steps per revolution of 12, 24, 72, 144, 180, and 200, resulting in shaft increments of 30, 15, 5, 2.5, 2, and 1.8 degrees per step [9].

Stepper motors are either bipolar, requiring two power sources or a switchable polarity power source, or unipolar, requiring only one power source. They are powered by dc current sources and require digital circuitry to produce the coil energizing sequences for rotation of the motor. Feedback is not always required for control, but the use of an encoder or other position sensor can ensure accuracy when it is essential. The advantage of operating without feedback is that a closed loop control system is not required. Generally, stepper motors produce less than 1 horsepower (746Watt) and are therefore frequently used in low-power position control applications [9].

The common characteristic of a stepper motor is not only just on its voltage rating. The following elements characterize a stepper motor [4]:

- Voltage: They usually have voltage ratings that is usually printed directly onto the unit, or specified in the motor's datasheet. One may exceed the voltage rating to achieve the desired torque, but doing so may produce excessive heat and/or shorten the life of the motor.
- Resistance: It is determined as the resistance-per-winding. The resistance will determine the current drawn by the motor, as well as affect the motor's torque and maximum operating speed.
- Degrees per step: This is the number of degrees the shaft will rotate for each full step. In the case of an unmarked motor, dividing the number of steps with 360 will yield degree per step value. Degrees per step is often referred to as resolution. Half step operation means double the resolutions, and cuts the angle of rotation into half.

Figure 3 illustrates one complete rotation of a stepper motor. At position 1, it can be seen that the rotor is beginning at the upper electromagnet, which is currently active (has voltage applied to it). To move the rotor clockwise (CW), the upper electromagnet is deactivated and the right electromagnet is activated, causing the rotor to move 90 degrees CW, aligning itself with the active magnet. This process is repeated in the same manner at the south and west electromagnets until once again reach the starting position.

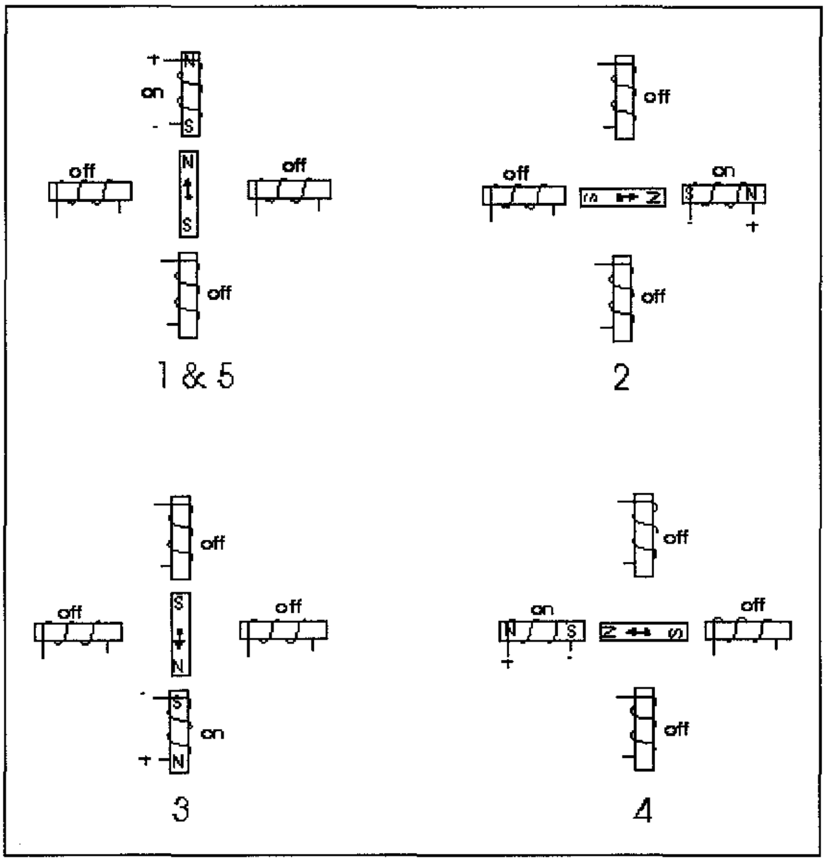


Figure 3 One complete rotation of a stepper motor.

In a "half-stepping" operation, instead of switching the next electromagnet in the rotation on one at a time, both the electromagnets are turned on simultaneously, causing an equal attraction between, thereby doubling the resolution. As show in Figure 4, in the first position only the upper electromagnet is active, and the rotor is drawn completely to it. In position 2, both the top and right electromagnets are active, causing the rotor to position itself between the two active poles. Finally, in position 3, the top magnet is deactivated and the rotor is drawn all the way right. This process can then be repeated for the entire rotation [3].

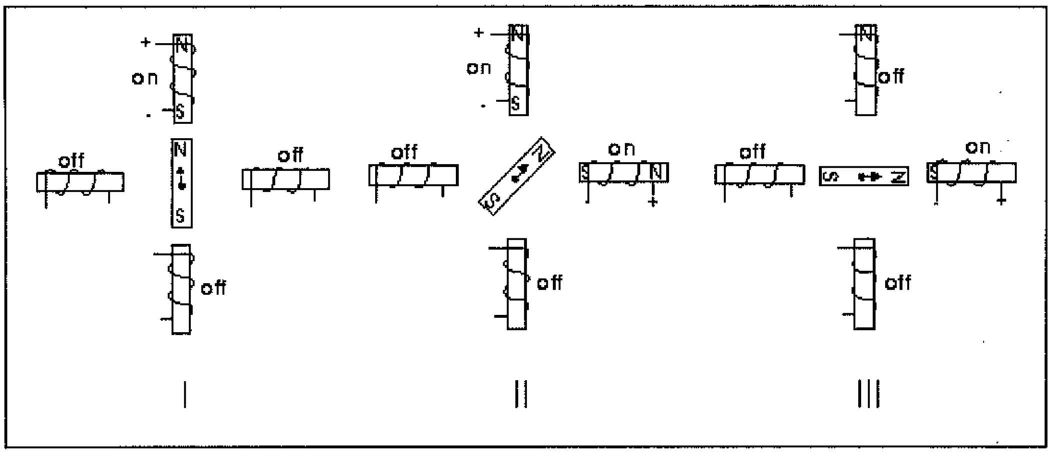


Figure 4 Half-stepping of a stepper motor

Positioning control can also be achieved by using a free spinning DC motor. But accurate and precise positioning is difficult. Even when the time for starting and stopping are set, the motor will not start or stop on the dot as the armature needs time to respond. Further more, DC motors have gradual acceleration and deceleration curves which means, stabilization is slow. Adding gears to the motor may help reduce this problem, but overshoot is still present and will throw off the anticipated stop position

Another useful characteristic of the stepper motor is that it produces the highest torque at low speeds and has holding torque, which is not present in DC motors. Holding torque allows a stepper motor to hold its position firmly when not turning. This can be useful for applications where the motor may be starting and stopping, while the force acting against the motor remains present. This eliminates the need for a mechanical brake mechanism [8].

Stepper Motors have several features which distinguish them from AC Motors, and DC Servo Motors [6].

- **Brushless** - Steppers are brushless. Motors with contact brushes create sparks, undesirable in certain environment (space missions, for example).
- **Holding Torque** - Steppers have very good low speed and holding torque. Steppers are usually rated in terms of their holding force (oz/in) and can even hold a position (to a lesser degree) without power applied, using magnetic detent

torque.

- **Open loop positioning** - Perhaps the most valuable and interesting feature of a stepper is the ability to position the shaft in fine predictable increments, without need to query the motor as to its position. Steppers can run 'open-loop' without the need for any kind of encoder to determine the shaft position. Closed loop systems that feed back position information, are known as *servo* systems. Compared to servos, steppers are very easy to control; the position of the shaft is guaranteed as long as the torque of the motor is sufficient for the load, under all its operating conditions.
- **Load Independent** - The rotation speed of a stepper is independent of load, provided it has sufficient torque to overcome slipping. The higher rpm a stepper motor is driven, the more torque it needs, so all steppers eventually poop out at some rpm and start slipping. Slipping is usually a disaster for steppers, because the position of the shaft becomes unknown. For this reason, software usually keeps the stepping rate within a maximum top rate. In applications where a known RPM is needed under a varying load, steppers can be very handy.

2.2.1 Types of stepper motor [4, 12]

A user must know the type of motor to be used to determine the type of driver and translator needed. There are two categories of stepper motors; permanent magnet (includes unipolar, bipolar and multiphase motor) and variable reluctance.

2.2.1.1 Permanent magnet stepper motor

- Unipolar stepper motor

Unipolar motors are relatively easy to control. A simple 1-of-'n' counter circuit can generate the proper stepping sequence, and drivers as simple as one translator per winding are possible with unipolar motors. Unipolar stepper motors are characterized by their center-tapped windings. A common wiring scheme is to take all the taps of the center-tapped windings and feed them with the voltage required by the motor to operate. The driver circuit would then ground each winding to energize it.

- Bipolar stepper motor

Unlike unipolar stepper motors, bipolar units require more complex driver circuitry. Bipolar motors are known for their excellent size / torque ratio, and provide more torque for their size than unipolar motors. Bipolar motors are designed with separate coils that need to be driven in either direction (the polarity needs to be reversed during operation) for proper stepping to occur. This presents a challenge for the design of a driver circuit. Bipolar stepper motors use the same binary drive pattern as a unipolar motor, only the '0' and '1' signals correspond to the polarity of the voltage applied to the coils, not simply 'on-off' signals.

2.2.1.2 Variable reluctance stepper motor

Sometimes referred to as *Hybrid* motors, variable reluctance stepper motors are the simplest to control over other types of stepper motors. Their drive sequence is simply to energize each of the windings in order, one after the other. This type of stepper motor will often have only *one* lead, which is the common lead for all the other leads. This type of motor behaves like a DC motor when the shaft is spun by hand; it turns freely and the steps are not felt. This type of stepper motor is not permanently magnetized like its unipolar and bipolar counterparts. [4][12]

2.2.2 Conceptual model of unipolar stepper motor

With centre taps of the windings wired to the positive supply, the terminals of each winding are grounded, in sequence, to attract the rotor, which is indicated by the arrow in the picture. This conceptual diagram depicts a 90 degree step per phase as shown in Figure 5. In a basic "Wave Drive" clockwise sequence, winding 1a is de-activated and winding 2a activated to advance to the next phase. The rotor is guided in this manner from one winding to the next, producing a continuous cycle. Note that if two adjacent windings are activated, the rotor is attracted mid-way between the two windings.

0001 0011 0010 0110 0100 1100 1000 1001	Half-Step	Half Step - Effectively doubles the stepping resolution of the motor, but the torque is not uniform for each step. (Since we are effectively switching between Wave Drive and Hi-Torque with each step, torque alternates each step.) This sequence reduces motor resonance which can sometimes cause a motor to stall at a particular resonant frequency. Note that this sequence is 8 steps.

2.3 Stepper motor circuit

The stepper motor selected for this project has stationary stator coils and rotating permanent magnet. Figure 3 and 4 illustrates the operation similar to the motor chosen.

Steppers don't simply respond to a clock signal, they have several windings which need to be energized in the correct sequence before the motor's shaft will rotate. Reversing the order of the sequence will cause the motor to rotate the other way. If the control signals are not sent in the correct order, the motor will not turn properly. It may simply buzz and not move, or it may actually turn, but in a rough or jerky manner. A circuit which is responsible for converting step and direction signals into winding energization patterns is called a translator. Most stepper motor control systems include a driver in addition to the translator, to handle the current drawn by the motor's windings [4].

A translator circuit shown in Figure 6, is to convert the pulses sent from the microcontroller into a sequence of signals determining its direction and number of steps. A simple two-direction translator circuit would need an exclusive-OR (XOR) and a flip-flop. The output of the translator will be sent to the driver. A motor's driver consists of current limiting resistors, diodes, and transistors as shown in Figure 7.

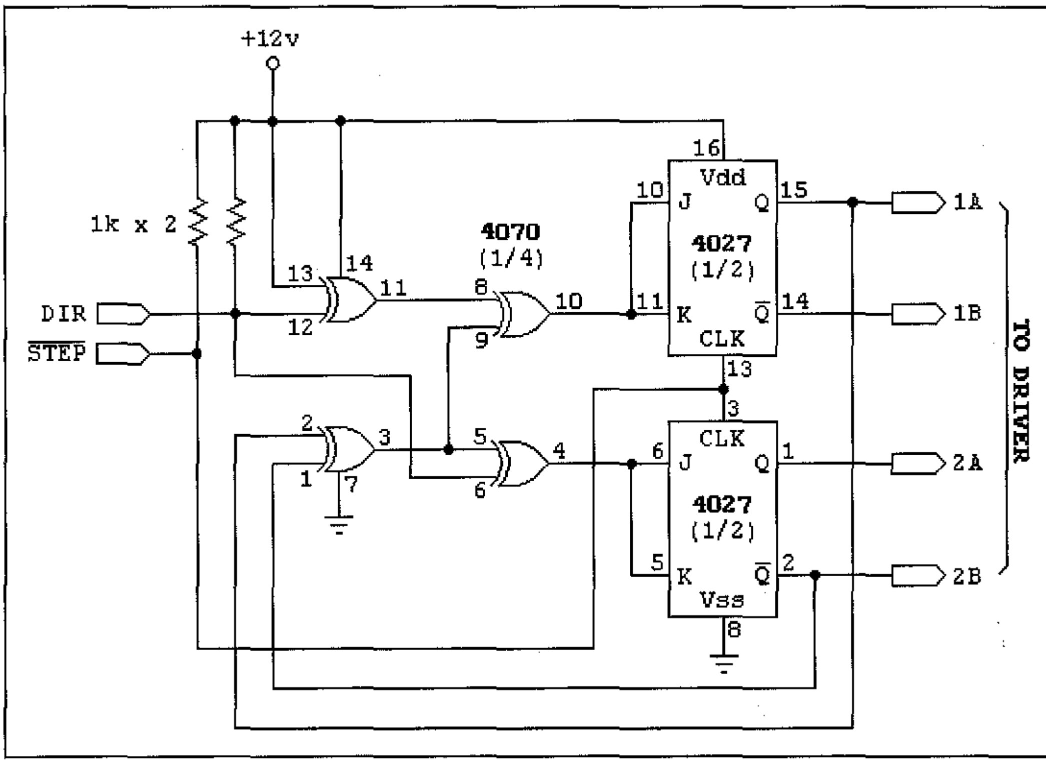


Figure 6 A simple bi-directional, two-phase drive stepper motor translator circuit

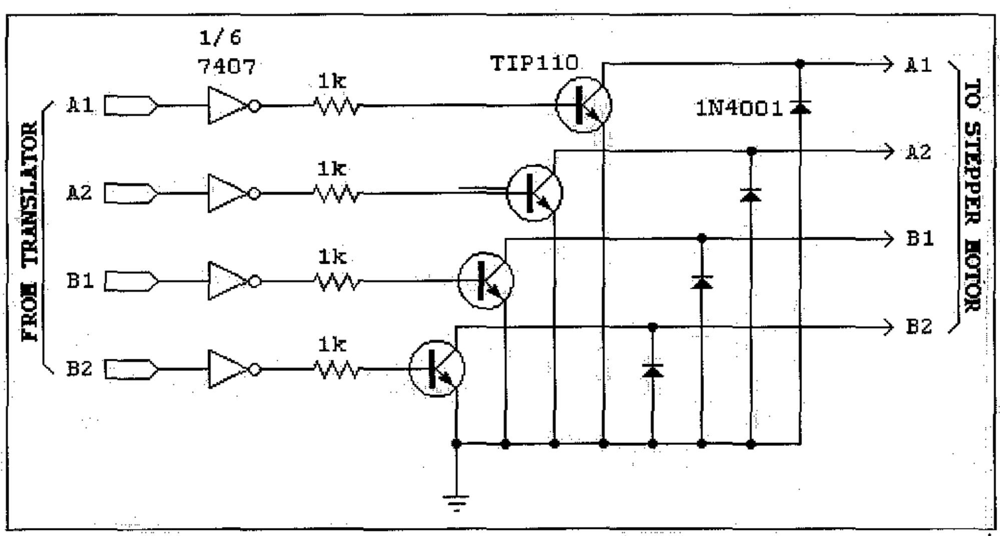


Figure 7 A Typical Unipolar Stepper Motor Driver Circuit with 4 Back EMF Protection Diodes

The transistors are used as switches in the driver must be able to allow large current that is drawn by the motor and withstand the voltage supply to motor during off condition. Diodes are used to protect the transistors. When a transistor become OFF from ON, the coil of the motor tries to continue to pass an electric current and generate high voltage that might damage the circuit.

2.4 The PIC16F877

The project requires a PIC that has an analogue input. Thus PIC16F877 is a more suitable choice compared to PIC16F84A. The Pin Diagram of PIC16F877 is as shown in Figure [5, 6, 7]:

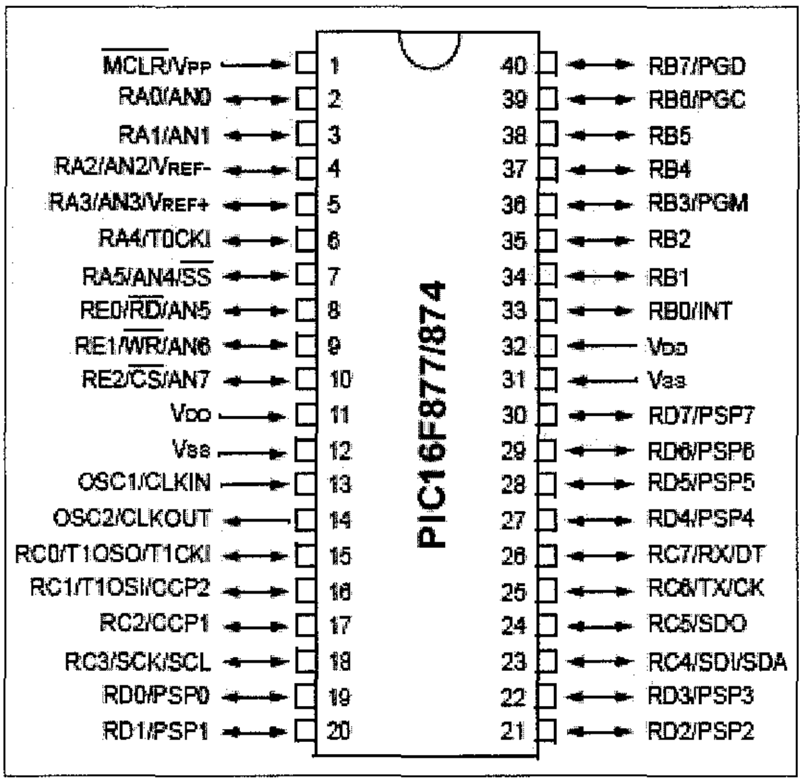


Figure 8 The PIC16F877 Pin Diagram

Some of the features of this PIC are listed as follows:

- High-Performance RISC CPU
  - Only 35 single word instructions to learn
  - All instructions are single cycle (1μs) except for program branches
  - Operating speed: DC - 20MHz clock input
  - 8 k Bytes Flash Program Memory
  - 368 Byte RAM Data Memory

- 256 Byte EEPROM Data Memory
- In-circuit serial programming

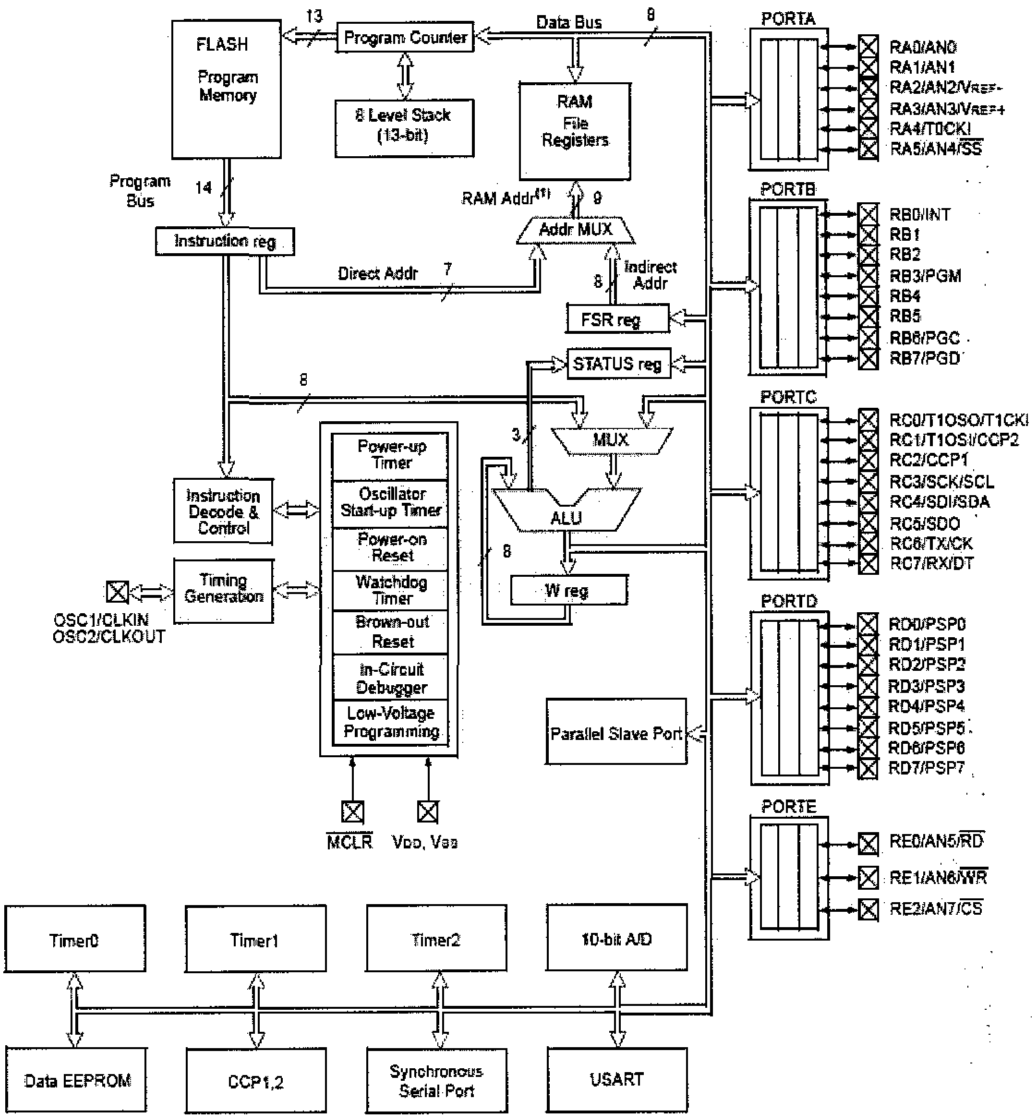
➢ Peripheral Features
  - Two 8-bit timer/counter(TMR0,TMR2) with 8-bit programmable prescalar
  - One 16 bit timer/counter(TMR1)
  - Two Capture, Compare, PWM module
  - 10-bit, 8-channel Analog-to-Digital converter
  - Synchronous Serial Port (SSP) with SPI (Master mode) and I2C (Master/Slave)
  - Universal Synchronous Asynchronous Receiver Transmitter with 9-bit address detection
  - Two Analog Comparators
  - Watchdog Timer (WDT) with separate RC oscillator

➢ Special Microcontroller Features
  - 100,000 erase/write cycle Enhanced FLASH program memory
  - 1,000,000 erase/write cycle Data EEPROM memory typical
  - Power saving SLEEP mode
  - Programmable code protection
  - Selectable Oscillator Options
  - Self-reprogrammable under software control

➢ CMOS Technology
  - Low power, high speed CMOS FLASH technology
  - Fully Static Design
  - Low Power Consumption

➢ I/O and Packages
  - 33 I/O pins with individual direction control
  - 40-pin DIP

Device	Program FLASH	Data Memory	Data EEPROM
PIC16F874	4K	192 Bytes	128 Bytes
PIC16F877	8K	368 Bytes	256 Bytes



Note 1: Higher order bits are from the STATUS register.

Figure 9 PIC16F877 Pin Diagram

Table 2 PIC16F877 Pin out Description

Pin Name	Description
OSC1/CLKIN	Oscillator crystal input/external clock source input
OSC2/CLKOUT	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{\text{MCLR}}$/VPP	Master Clear (Reset) input or programming voltage This pin is an active low RESET to the device.
 RA0/AN0 RA1/AN1 RA2/AN2/VREF- RA3/AN3/VREF+ RA4/T0CKI RA5/$\overline{\text{SS}}$/AN4	PORTA is a bi-directional I/O port. RA0 can also be analog input0. RA1 can also be analog input1. RA2 can also be analog input2 or negative analog reference voltage. RA3 can also be analog input3 or positive analog reference voltage. RA4 can also be the clock input to the Timer0 timer/ counter. Output is open drain type. RA5 can also be analog input4 or the slave select for the synchronous serial port.
 RB0/INT RB1 RB2 RB3/PGM RB4 RB5 RB6/PGC RB7/PGD	PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs RB0 can also be the external interrupt pin. RB3 can also be the low voltage programming input. Interrupt-on-change pin. Interrupt-on-change pin. Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming clock. Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming data.

CHAPTER 3
PROJECT WORK / DESIGN

In order to achieve the objective of this project, the hardware design of this hardware has been worked out to enable the stepper motor being controlled by a PIC in a positioning process and show precise movement of stepper motor.

3.1 Design of the circuit

A circuit consisting of a PIC16F877 microcontroller is built. This circuit consist of input voltage supply to the PIC (+5 Volt) connected to pin 11 and 32 of the PIC. Pin 12 and 31 are connected to the ground.

A reset button is connected to pin 1. A 4 MHz 4 pins crystal oscillator (XT oscillator) connected to pin 13. An oscillator is used to provide a clock microcontroller. A clock is needed so that the microcontroller could execute a program or program instructions.

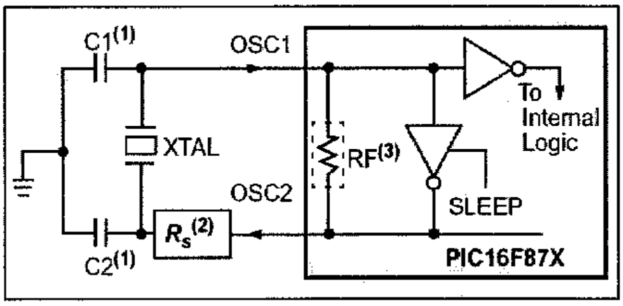


Figure 10 Schematic diagram of a XT Oscillator

There will be an analogue input at port A of the PIC. The input is taken from the secondary or the output of the transformer. The output of the PIC is two digital pulses that will send STEP (determine number of steps to be taken by the motor) and DIR (direction of stepping) signals to the translator circuit.

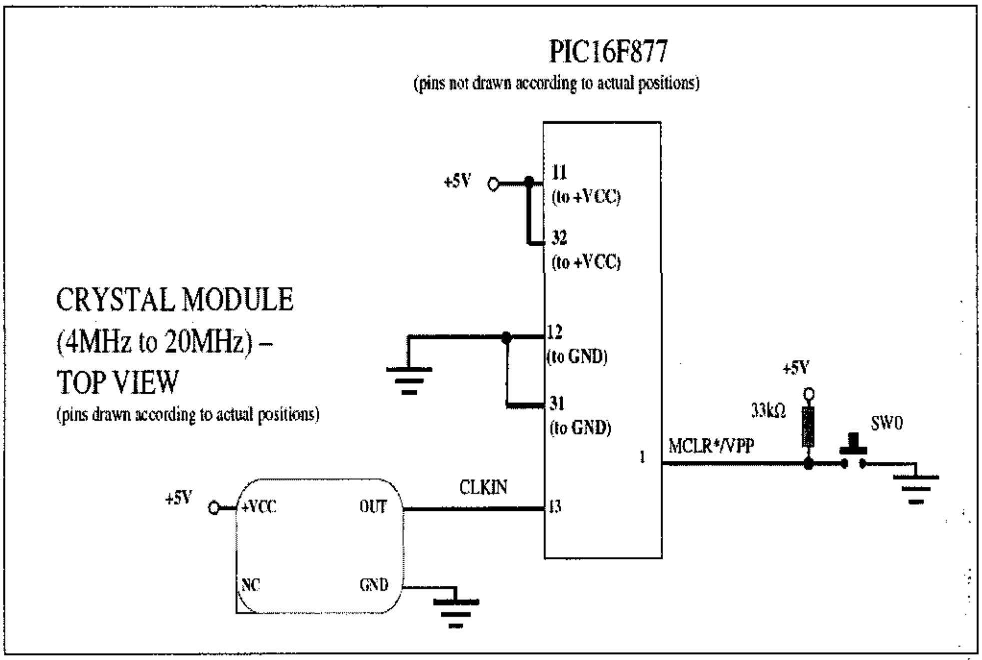


Figure 11 Basic Microcontroller System Schematic Using PIC16F877

To be connected to the output of the PIC is the translator circuit. This circuit comprises of a flip-flop, XOR IC and resistors. The schematic diagram is as illustrated in Figure 12. The motor is represented with equivalent value of resistance and inductance. The transistors are represented by switches.

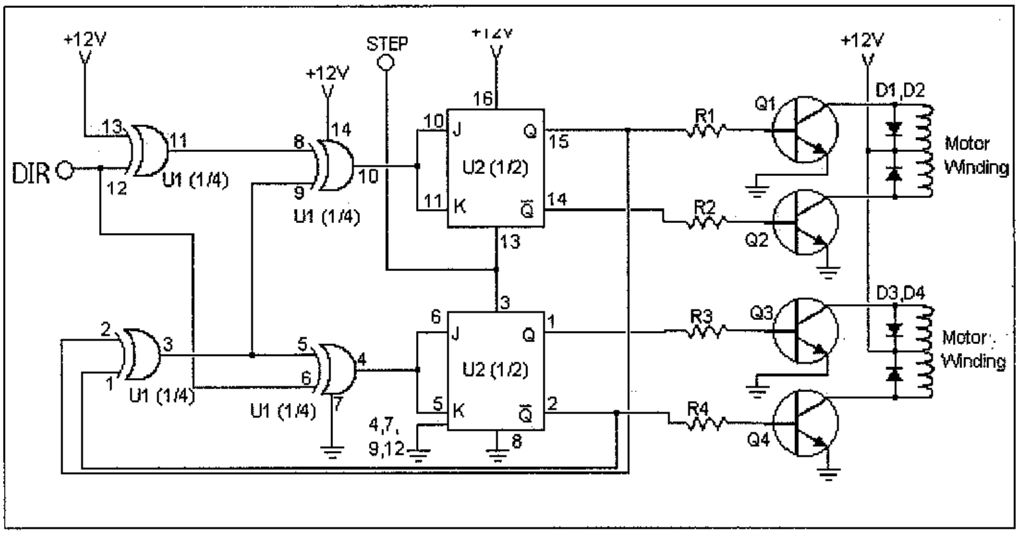


Figure 12 Schematic of a simple bidirectional two-phase driver stepper motor translator and driver circuit

The translator circuit is then connected to motor driver circuit. This circuit has four NPN transistors and 4 diodes. The diodes are used to protect the transistors from the back flow of current from the coil when the transistor becomes OFF from ON.

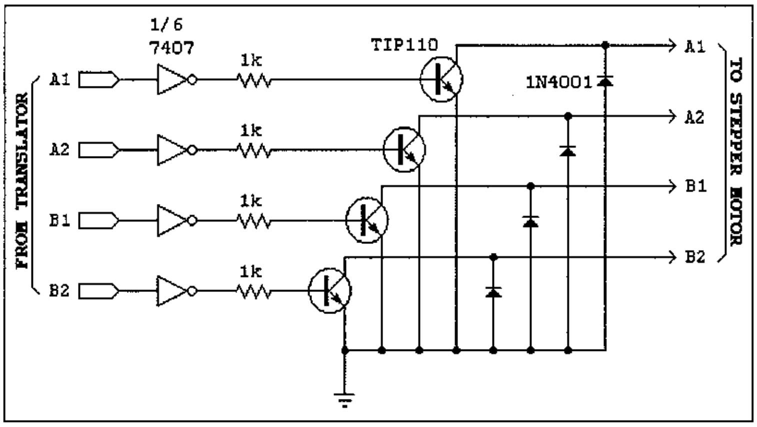


Figure 13 A Typical Unipolar Stepper Motor Driver Circuit. Note The 4 Back EMF Protection Diodes

As full step sequence is operating, two transistors will be ON at a time. The current rating of the transistor used in the motor driver is at least three times higher than the current drawn by stepper motor. The transistor must be able to withstand the voltage across its collector-emitter junction which is the motor supply voltage (12+VDC) when it is in OFF condition.

The resistors between translator and transistors are known as current limiting resistors. These resistors are used to limit the current flow to base of the transistors. If the base current is high, then it will cause higher current flow at the collector. This will then probably burn out the stepper motor if the motor is running overloaded.

As explained earlier, the diodes are used to protect the transistors as well as provide a closed loop circuit at every phase of the stepper motor when transistors are not triggered. This will cause the currents to continue to flow in the motor winding. Flow of current in the winding will dissipate the energy stored in motor's inductor as heat through the resistance in motor. The power dissipation or discharging energy in winding is needed in the system so that energizing the other windings in motor for the following step sequence will have no error. This also helps to ensure the motor has a smooth stepping sequence.

The nominal voltage for stepper motor from the driver is about 12.7V. If higher voltage is being supplied to the motor, higher torque can be obtained from the motor. But by doing so, it may produce excessive heat and/or shorten the life of the motor. The stepper motor used in the project is a four phase stepper motor. This motor has six leads. Two of them are connected to power supply and the other leads are connected to the motor driver circuit.

Basically, the schematic of the entire circuit is in Figure 14:

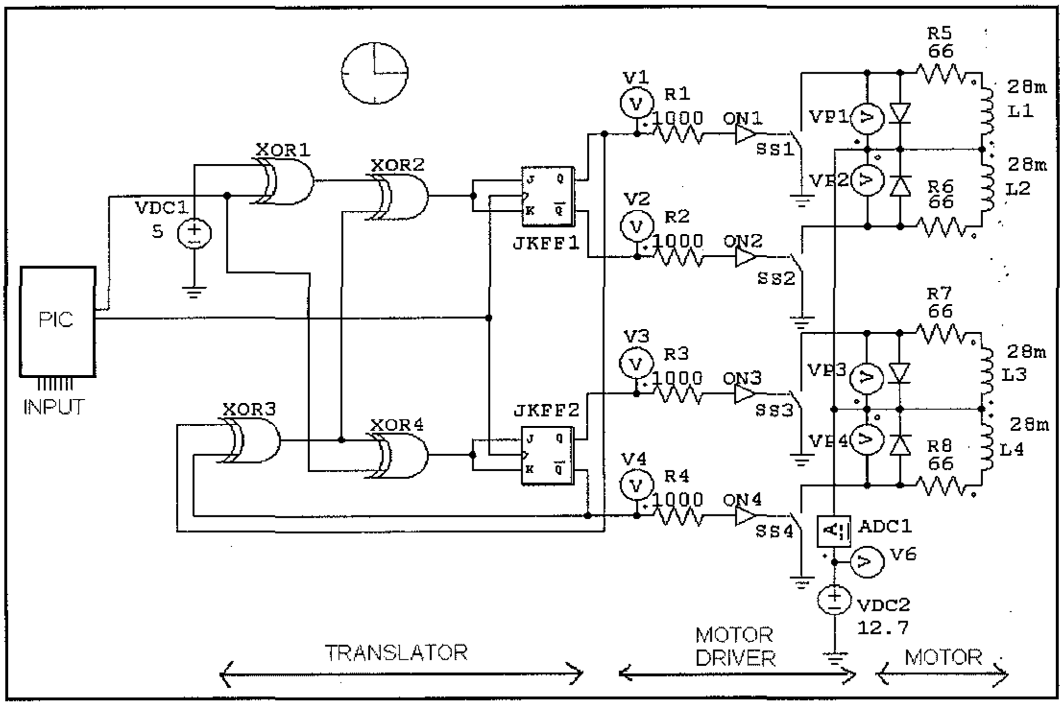


Figure 14 Stepper motor with digital controller

3.2 Software development

The program is written in C language using Custom Computer Services (CCS) The CCS compiler is specially designed to meet the special needs of the PICmicro MCU controllers. These tools allow developers to quickly design application software for these controllers in a highly readable, high-level language.

The compiler has some limitations when compared to a more traditional C compiler. The hardware limitations make many traditional C compilers ineffective. As an example of the limitations, the compilers will not permit pointers to constant arrays. This is due to the separate code/data segments in the PICmicro MCU hardware and the inability to treat ROM areas as data. On the other hand, the compilers have knowledge about the hardware limitations and do the work of deciding how best to implement the designed algorithms. The compilers can efficiently implement normal C constructs, input/output operations and bit twiddling operations.

The compiler can output 8 bit hex, 16 bit hex, and binary files. Two listing formats are available. Standard format resembles the Microchip tools and may be required by some third-party tools. The simple format is easier to read. The debug file may either be a Microchip .COD file or Advanced Transdata .MAP file. All file formats and extensions are selected via the Options|File Formats menu option in the Windows IDE [7].

Basic code must have the following [11]:

- Include the header file for the appropriate PIC
- Set the clock speed
- Set the fuses
- Set up serial communication (if applicable)
- Main function and debug/status message

3.2.1 Operation of program

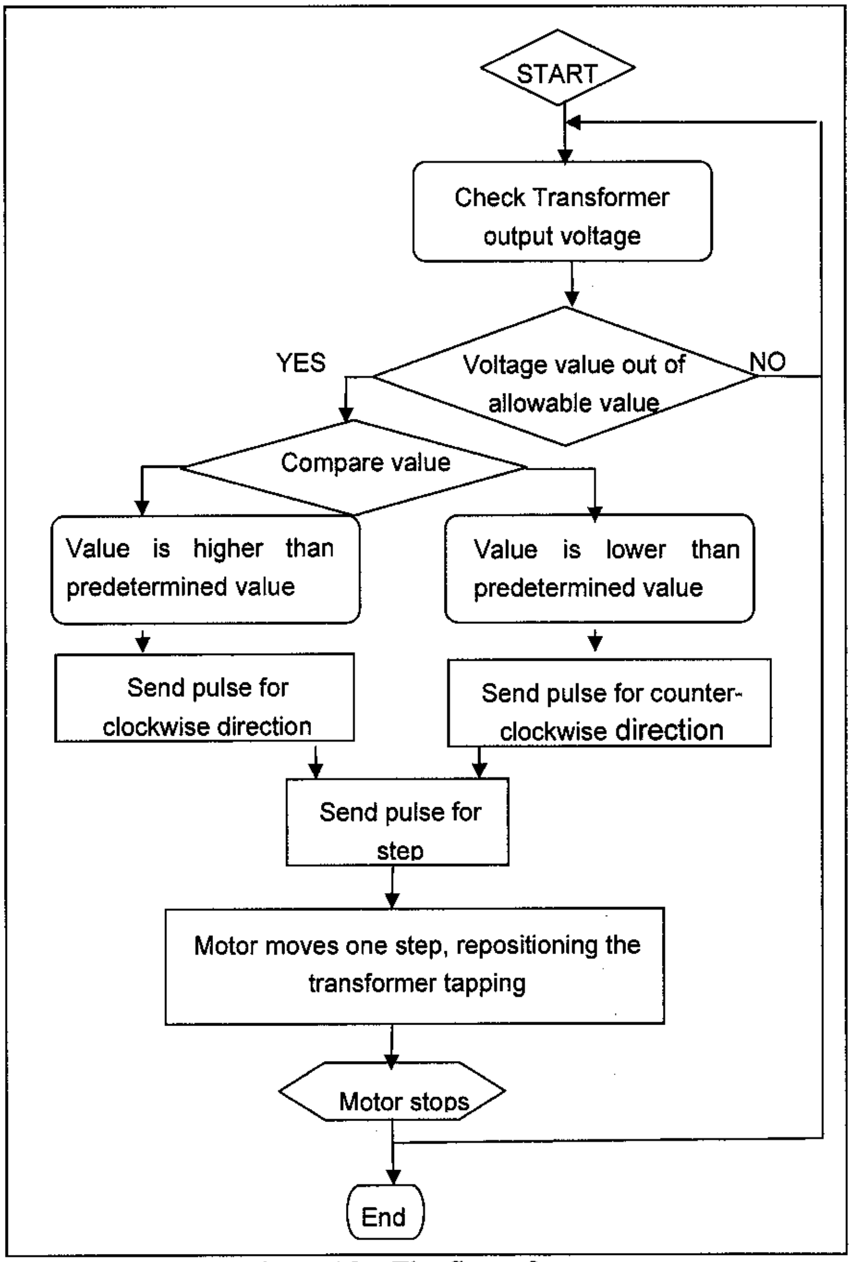


Figure 15 The flow of program

Using a concept of closed loop operation, the output of the transformer will be sent back to the digital controller. The voltage will be compared against a reference voltage (the chosen stable output voltage of the transformer). If the value of the output voltage is lower than the reference voltage, the input voltage will be increased by changing the position of the tap changer. Vice versa if the output voltage is higher than the reference voltage the input voltage will be decreased by repositioning the tap.

3.3 Hardware and circuit construction

The hardware of the project is built to illustrate the change of transformer tapping via the stepper motor.

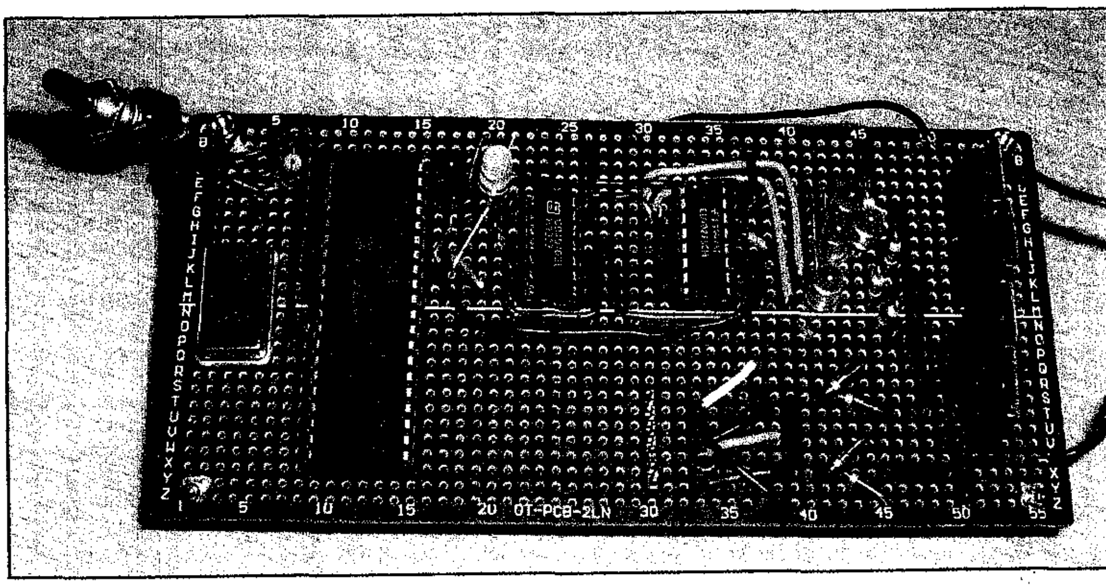


Figure 16 Circuit constructed on Vera-board

In the constructed circuit, a few LEDs are placed to indicate the signals sent by the PIC to the translator, and from translator to the driver circuit. The red LED lights up when 'Direction' signal is sent and yellow LED indicate the 'Step' signal sent to the translator. The green LEDs illuminate according to the step sequence. However the circuit is not working as it should. The output of the translator did not correspond accordingly to the signal sent by the PIC. Troubleshooting is still undertaken to tackle the problem.

The cause of problem might be the fault of the devices used and/or the chaotic construction of the circuit on the Vera-board itself. The author is constructing a similar circuit using a Printed Circuit Board (PCB). The board is expected to reduce the chances of malfunction of the circuit and is tidier.

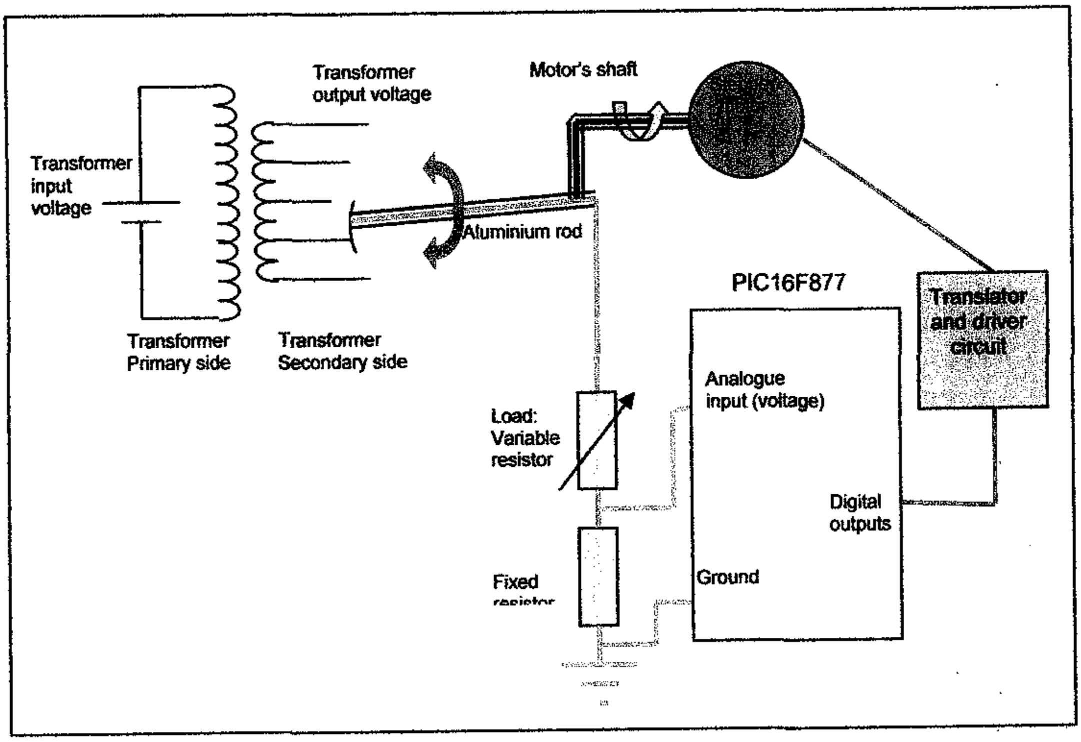


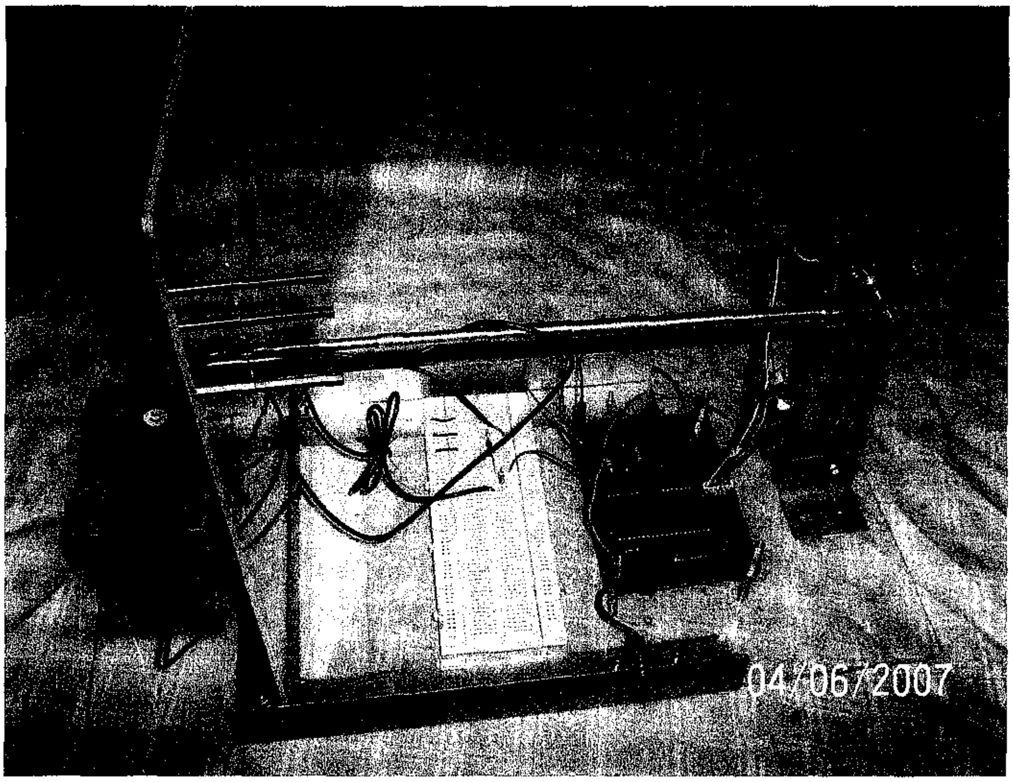
Figure 17 The sketch for the overall design

As shown in Figure 17, the secondary tap of the transformer is moved by the motor's aluminium rod arm. The output of the transformer is connected to the loads. There are two types of loads connected; fixed and variable load. The voltage across the fixed load is fed to the PIC and compared.

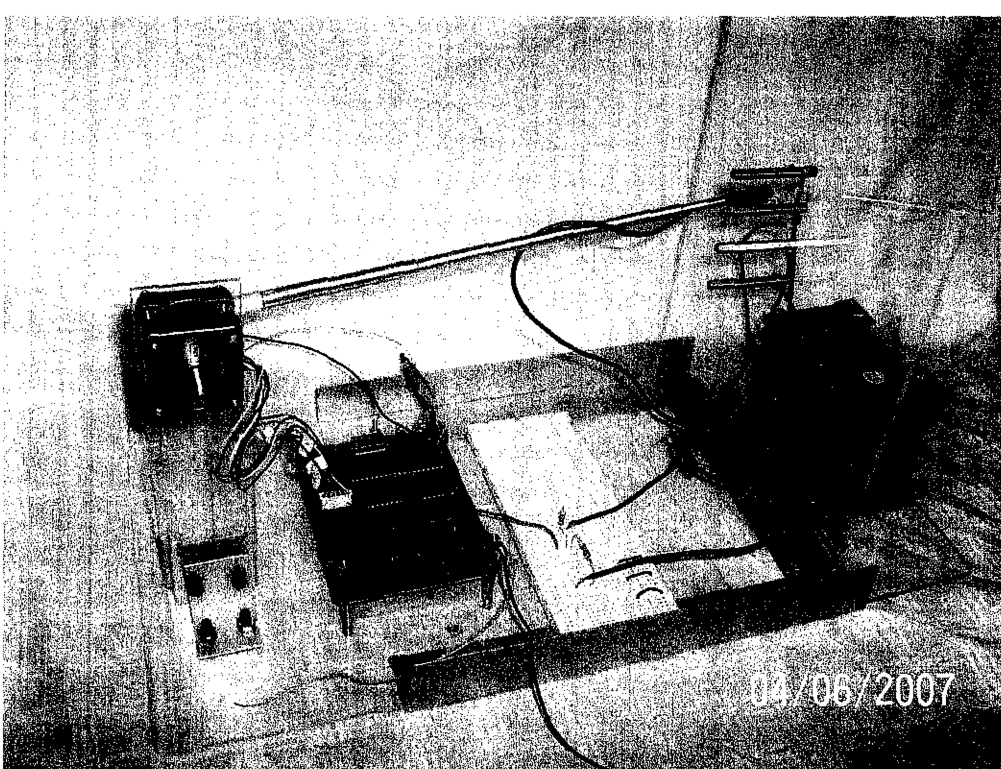
The transformer has output voltage tapping ratings of 13.4 V, 19.2 V, 26 V and 31.9 V. The current rating of the transformer is 3.2A.

When the variable load is altered, the current in the secondary side circuit changes, with a corresponding change of the voltage across the fixed resistor. The tapping of the transformer is to be positioned such that the same current is obtained on the secondary side, and thus yielding the desired voltage across the fixed resistor.

HARDWARE CONSTRUCTED



The model of a voltage dip compensator for a multi-tapped transformer using stepper motor with digital controller



CHAPTER 4

SIMULATION / PRACTICAL RESULT AND DISCUSSION

4.1 Simulation of the stepper motor controller

Simulation of the circuit was done using Multisim. The stepper motor in the circuit has been substituted by an equivalent resistance and inductance referred to its datasheet. The voltage and current waveforms behaviour can be seen in the simulation when the motor is running. The schematic diagram of the simulated circuit is as shown in Figure 18:

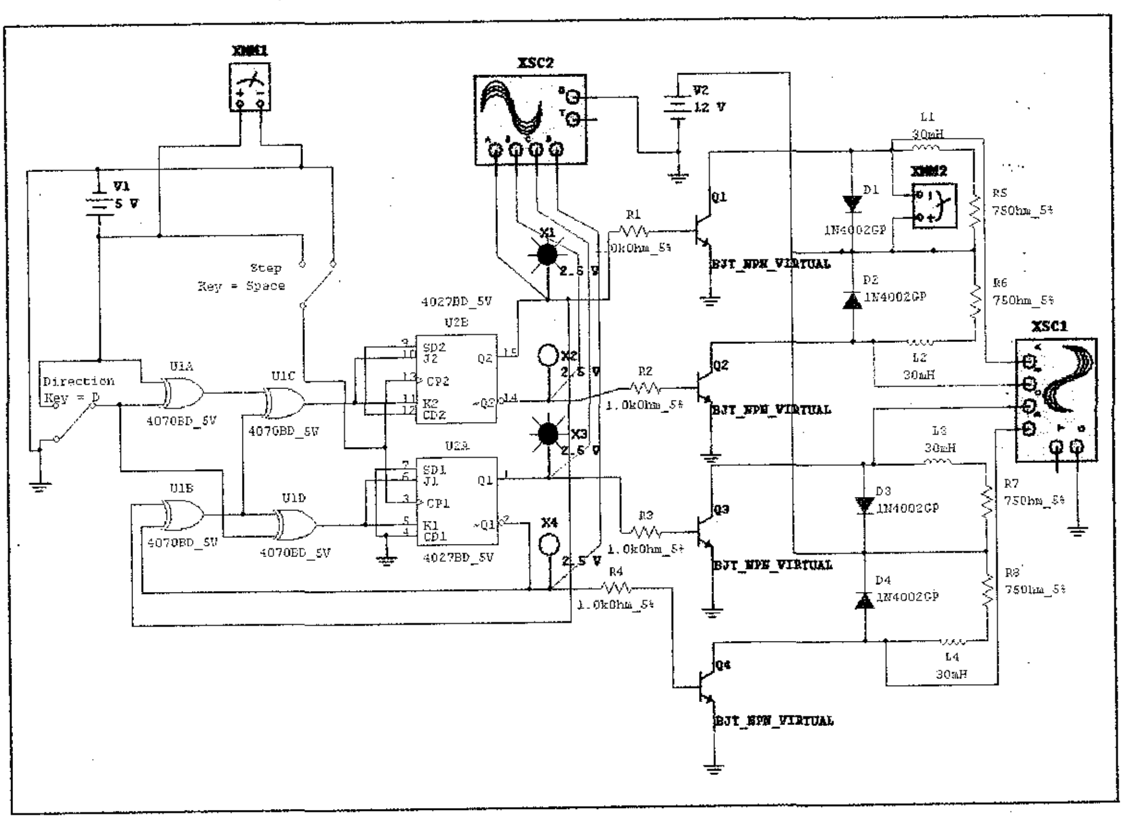


Figure 18 Schematic diagram of the simulated circuit

Figure 19 shows the waveform resulting from the translator. The translator is capable to make the dc voltage to a square wave voltage so that it can be used to trigger the motor.

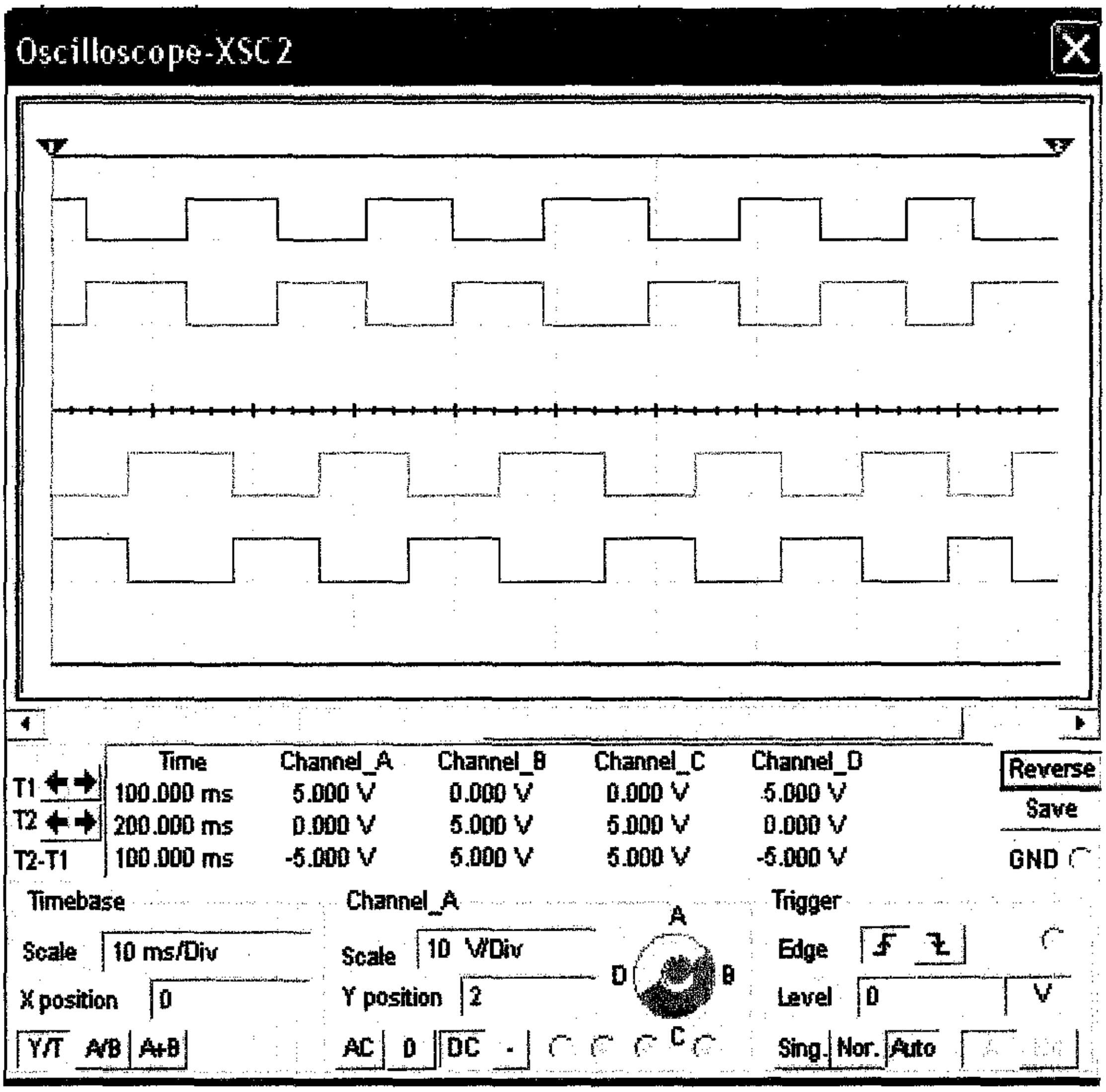


Figure 19 Translator output waveform

Figure 20 shows the waveform of voltage across each winding. These waveforms are obtained when the input 'Direction' is set to ground. As seen in the figure the wave form correspond to the step sequence.

The pulses at the input 'Step' act like the clock for the JK flip-flop to operate. Supplying constant 5V at the input 'direction' will make the shaft of motor turn in clockwise direction.

Table 3 Step sequence for full step operation

Step no.	1	2	3	4
	ON	OFF	OFF	ON
1	ON	OFF	ON	OFF
2	OFF	ON	ON	OFF
3	OFF	ON	OFF	ON
4	ON	OFF	OFF	ON
5	ON	OFF	ON	OFF

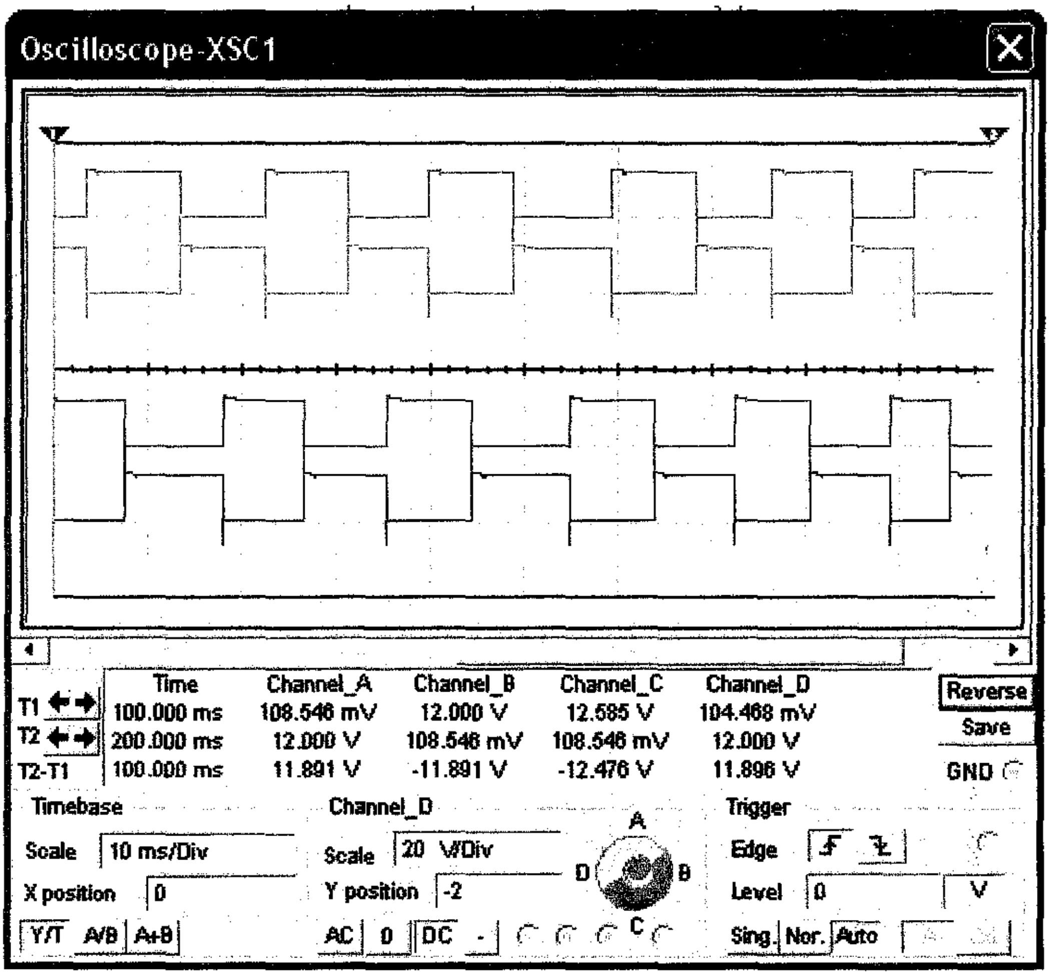


Figure 20 Waveform of voltage across each motor winding – 'Direction' is grounded

The stepping sequence that is produced by the translator in this condition (when 'Direction' is grounded) is from step number 5, 4, 3, 2, then 1 ,giving transistor ON sequence, 1-3, 1-4, 2-4, 2-3, and 1-3; and the sequence repeat again. When the 'Direction' is supply with constant 5V, the stepping sequence will be in the reverse direction.

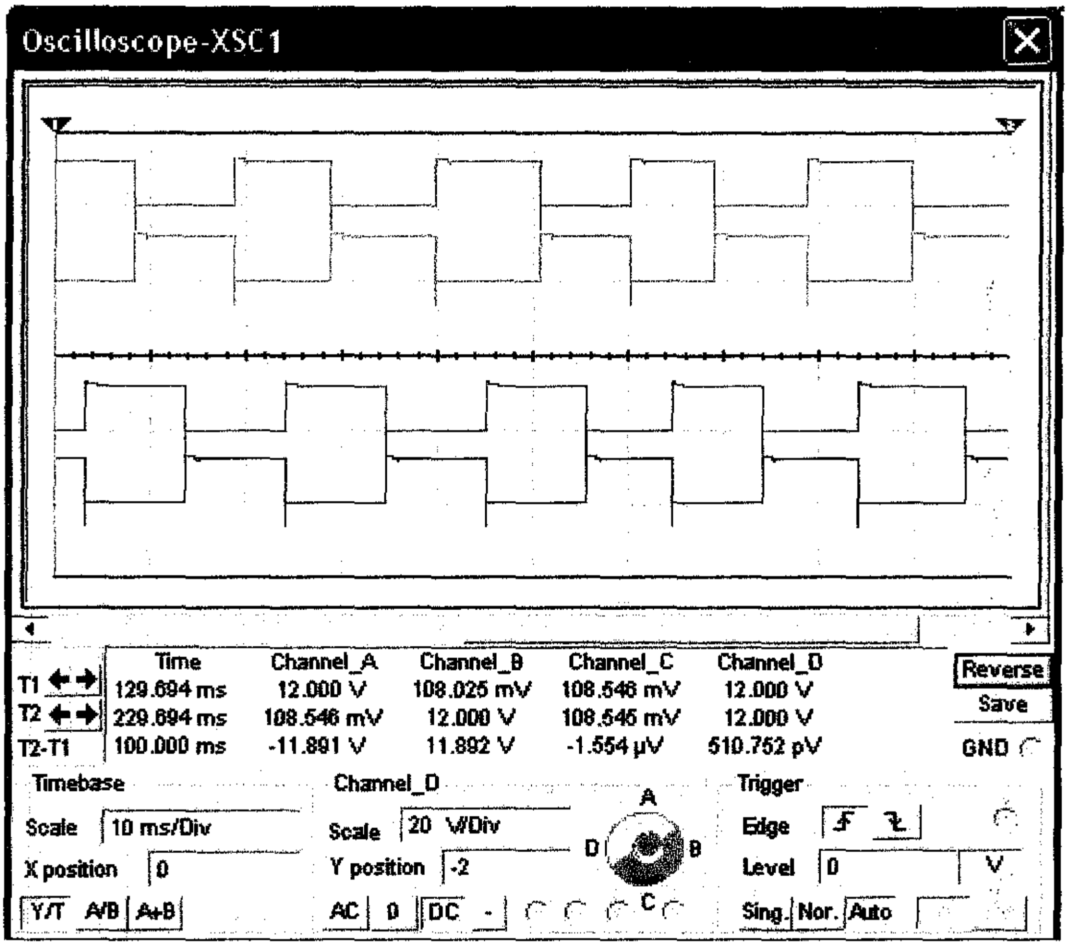


Figure 21 Waveform of voltage across each motor winding – 'Direction' is supplied with 5V

There will be current overshoots at the starts of each step. This is because the current used to energize the motor winding at the beginning of every step. The coils will need more current to start rotating the shaft because of rotor inertia.

4.2 Discussion

A stepper motor controller presented before is used to show the accuracy of stepper motor positioning. Since the motor will be connected to an aluminium rod (act as the arm for tapping), there will be some friction losses on the roller. So, after some movements or processes, there will be a small error and the pointer used to run a little bit out of position. Thus calibration must be done from time to time.

Important points to be considered when experimenting with the hardware.

1. The components used in the circuit must be checked carefully and selected. More attention is to be paid on the rating of the transistors and able to withstand the amount of current drawn by the stepper motor. They must be able to withstand voltage higher than the supply voltage of motor.
2. The supply voltage to the motor must be limited to rated voltage; otherwise it will shorten the life of motor. The voltage supply to PIC and flip flop must be checked first before supplying to them. A higher voltage will burn the IC.
3. Power to the motor must be turned off after use without leaving it for a long time. This will prevent the motor heating from continuous energization of the coils in the motor.
4. The current limiting resistors must be added to the motor drive circuit to prevent the motor from drawing excessive current when overloaded. This will not cause the motor to be over heated and damage the motor winding.
5. Aluminium rod used must be light enough to prevent high hold torque forced on the motor. The rod must also be properly insulated to prevent short circuit of the transformer tap.
6. Transformer tapping points must be easily contacted.
7. In real application, the tapings must be done in an arch free environment. A separate compartment within the transformer, and insulated with transformer oil would be a suitable.

Other obstacles during the implementation of the project is troubleshooting. Each element as stated earlier must be at the acceptable rated voltage and current. Each element must be in a very good condition. Angle of contact for the transformer tapping model must also be correct to ensure contact and minimize the arch length.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

1. A digital controller is designed and constructed using PIC16F877 to control the position of a stepper motor on a transformer tapping to compensate voltage dip of a transformer.
2. The digital controller provides the translator circuit with two pulses, each to control the direction and stepping of the motor. The translator than provide a square wave voltage to the motor driver.
3. At the start of each step, high current is flowing in the motor's winding.
4. In the control of speed program, the motor can not start at very high speed.
5. Stepper motor can do the positioning very well with a digital controller. PIC that is used as a controller in this project can be programmed to compare analog input against a digital predetermined value and send digital output signal.

5.2 Recommendations

1. More studies and design must be done to provide a smooth mechanism to the taping. This mechanism must provide spark free connection at the taping.
2. Add diverter resistor - breaking one connection and supplying load current through diverter resistor

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APPENDIX

PIC16F877 DATASHEET

CD4070BC (Quad 2-Input EXCLUSIVE-OR Gate) DATASHEET

CD4027BC (Dual J-K Master/Slave Flip-Flop with Set and Reset) DATASHEET

STEPPER MOTOR DATASHEET

TAPPED TRANSFORMER 3.2A SELECTION GUIDE

PIC16F87X

28/40-Pin 8-Bit CMOS FLASH Microcontrollers

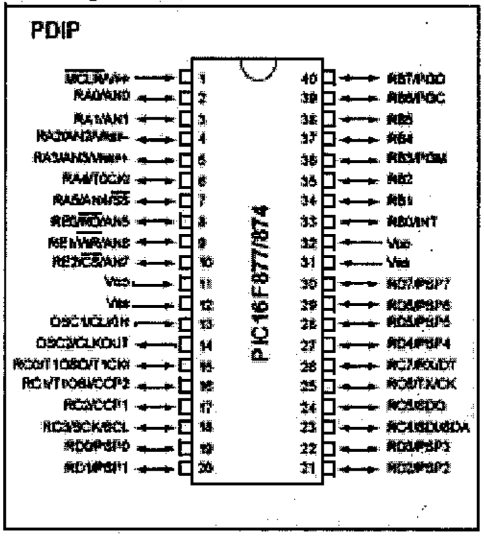
Devices Included in this Data Sheet:

- PIC16F873
- PIC16F874
- PIC16F876
- PIC16F877

Microcontroller Core Features:

- High performance RISC CPU
- Only 35 single word instructions to learn
- All single cycle instructions except for program branches which are two cycle
- Operating speed: DC - 20 MHz clock input
  DC - 200 ns instruction cycle
- Up to 8K x 14 words of FLASH Program Memory, Up to 368 x 8 bytes of Data Memory (RAM) Up to 256 x 8 bytes of EEPROM Data Memory
- Pinout compatible to the PIC16C73B/74B/76/77
- Interrupt capability (up to 14 sources)
- Eight level deep hardware stack
- Direct, indirect and relative addressing modes
- Power-on Reset (POR)
- Power-up Timer (PWRT) and Oscillator Start-up Timer (OST)
- Watchdog Timer (WDT) with its own on-chip RC oscillator for reliable operation
- Programmable code protection
- Power saving SLEEP mode
- Selectable oscillator options
- Low power, high speed CMOS FLASH/EEPROM technology
- Fully static design
- In-Circuit Serial Programming™ (ICSP) via two pins
- Single 5V In-Circuit Serial Programming capability
- In-Circuit Debugging via two pins
- Processor read/write access to program memory
- Wide operating voltage range: 2.0V to 5.5V
- High Sink/Source Current: 25 mA
- Commercial, Industrial and Extended temperature ranges
- Low-power consumption:
  - < 0.6 mA typical @ 3V, 4 MHz
  - 20 μA typical @ 3V, 32 kHz
  - < 1 μA typical standby current

Pin Diagram



Peripheral Features:

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler, can be incremented during SLEEP via external crystal/clock
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules
  - Capture is 16-bit, max. resolution is 12.5 ns
  - Compare is 16-bit, max. resolution is 200 ns
  - PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter
- Synchronous Serial Port (SSP) with SPI™ (Master mode) and I^2C™ (Master/Slave)
- Universal Synchronous Asynchronous Receiver Transmitter (USART/SCI) with 9-bit address detection
- Parallel Slave Port (PSP) 8-bits wide, with external $\overline{RD}$, $\overline{WR}$ and $\overline{CS}$ controls (40/44-pin only)
- Brown-out detection circuitry for Brown-out Reset (BOR)

1.0 DEVICE OVERVIEW

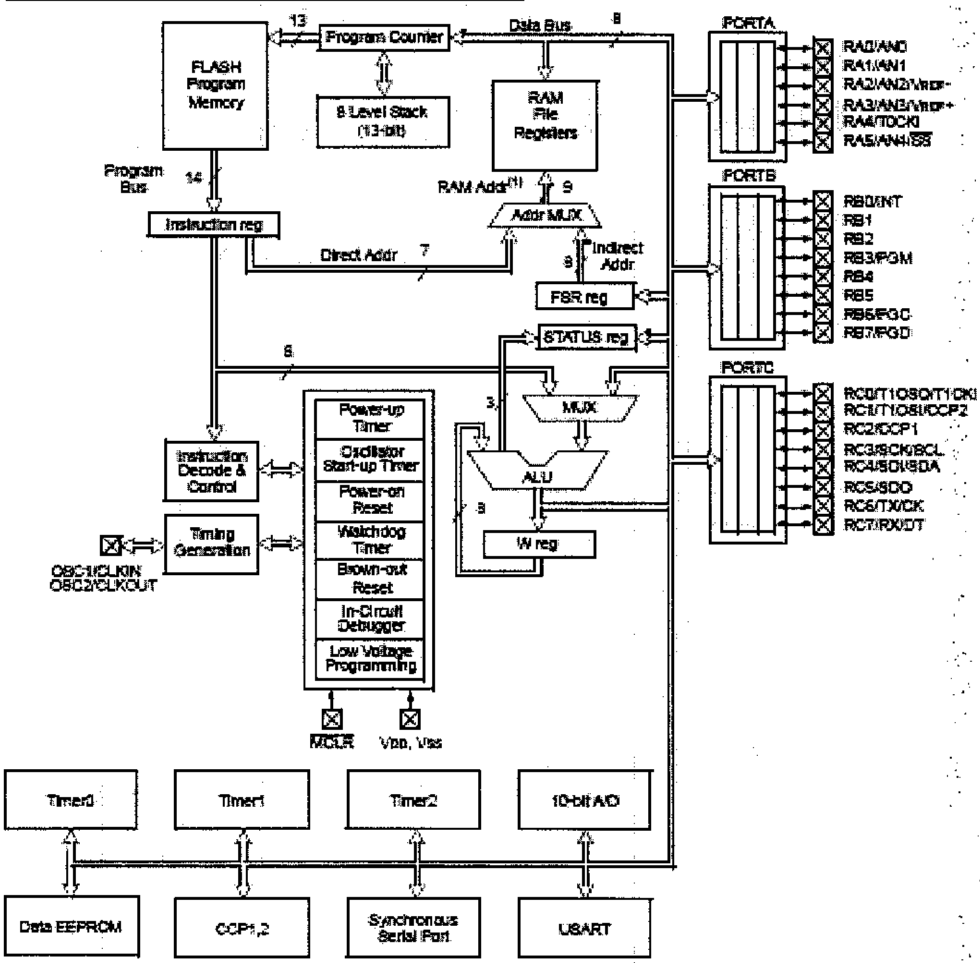
This document contains device specific information. Additional information may be found in the PICmicro™ Mid-Range Reference Manual (DS33023), which may be obtained from your local Microchip Sales Representative or downloaded from the Microchip website. The Reference Manual should be considered a complementary document to this data sheet, and is highly recommended reading for a better understanding of the device architecture and operation of the peripheral modules.

There are four devices (PIC16F873, PIC16F874, PIC16F876 and PIC16F877) covered by this data sheet. The PIC16F876/873 devices come in 28-pin packages and the PIC16F877/874 devices come in 40-pin packages. The Parallel Slave Port is not implemented on the 28-pin devices.

The following device block diagrams are sorted by pin number; 28-pin for Figure 1-1 and 40-pin for Figure 1-2. The 28-pin and 40-pin pinouts are listed in Table 1-1 and Table 1-2, respectively.

FIGURE 1-1: PIC16F873 AND PIC16F876 BLOCK DIAGRAM

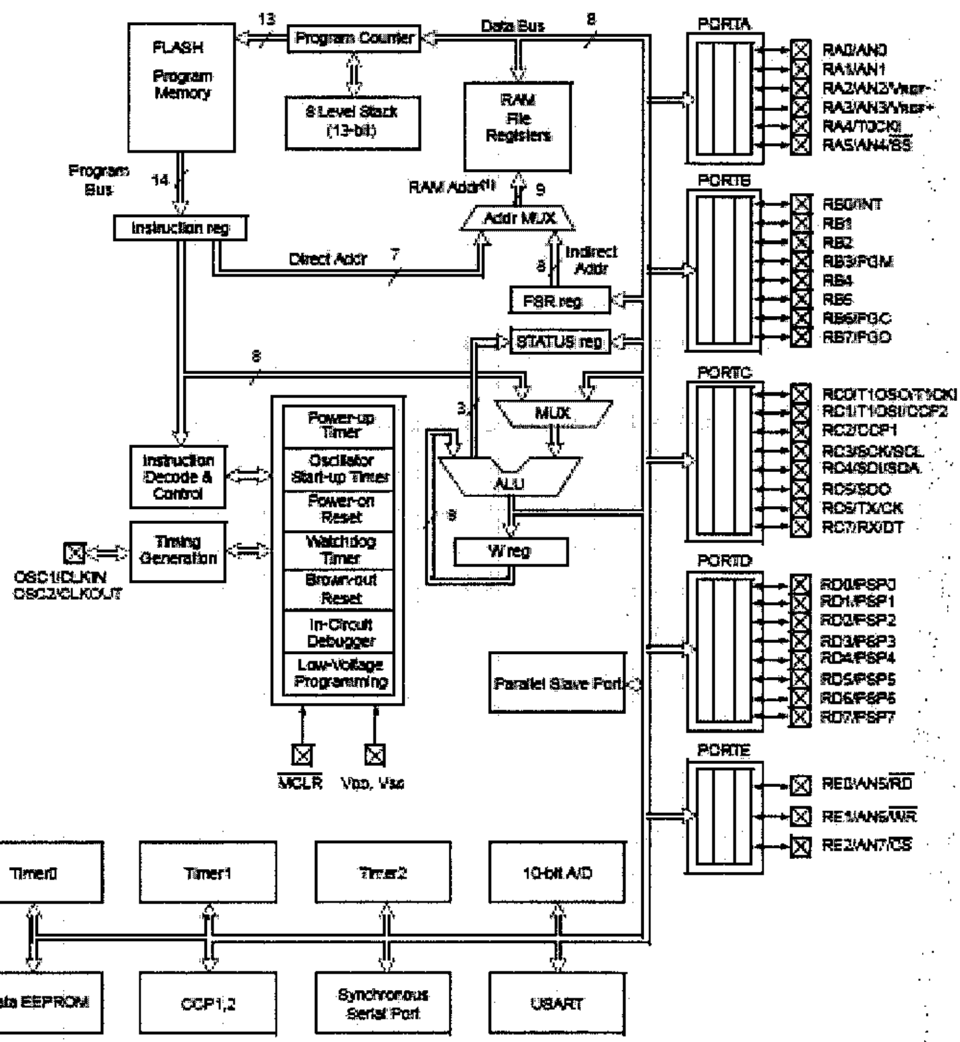
Device	Program FLASH	Data Memory	Data EEPROM
PIC16F873	4K	192 Bytes	128 Bytes
PIC16F876	8K	368 Bytes	256 Bytes



Note 1: Higher order bits are from the STATUS register.

FIGURE 1-2: PIC16F874 AND PIC16F877 BLOCK DIAGRAM

Device	Program FLASH	Data Memory	Data EEPROM
PIC16F874	4K	192 Bytes	128 Bytes
PIC16F877	8K	368 Bytes	256 Bytes



Note 1: Higher order bits are from the STATUS register.

TABLE 1-2: PIC16F874 AND PIC16F877 PINOUT DESCRIPTION

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
OSC1/CLKIN	13	14	30	I	ST/CMOS(4)	Oscillator crystal input/external clock source input.
OSC2/CLKOUT	14	15	31	O	—	Oscillator crystal output. Connects to crystal or resonator in crystal oscillator mode. In RC mode, OSC2 pin outputs CLKOUT which has 1/4 the frequency of OSC1, and denotes the instruction cycle rate.
$\overline{MCLR}$/VPP	1	2	18	I/P	ST	Master Clear (Reset) input or programming voltage input. This pin is an active low RESET to the device.
						PORTA is a bi-directional I/O port.
RA0/AN0	2	3	19	I/O	TTL	RA0 can also be analog input0.
RA1/AN1	3	4	20	I/O	TTL	RA1 can also be analog input1.
RA2/AN2/VREF-	4	5	21	I/O	TTL	RA2 can also be analog input2 or negative analog reference voltage.
RA3/AN3/VREF+	5	6	22	I/O	TTL	RA3 can also be analog input3 or positive analog reference voltage.
RA4/T0CKI	6	7	23	I/O	ST	RA4 can also be the clock input to the Timer0 timer/counter. Output is open drain type.
RA5/$\overline{SS}$/AN4	7	8	24	I/O	TTL	RA5 can also be analog input4 or the slave select for the synchronous serial port.
						PORTB is a bi-directional I/O port. PORTB can be software programmed for internal weak pull-up on all inputs.
RB0/INT	33	36	8	I/O	TTL/ST(1)	RB0 can also be the external interrupt pin.
RB1	34	37	9	I/O	TTL	
RB2	35	38	10	I/O	TTL	
RB3/PGM	36	39	11	I/O	TTL	RB3 can also be the low voltage programming input.
RB4	37	41	14	I/O	TTL	Interrupt-on-change pin.
RB5	38	42	15	I/O	TTL	Interrupt-on-change pin.
RB6/PGC	39	43	16	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming clock.
RB7/PGD	40	44	17	I/O	TTL/ST(2)	Interrupt-on-change pin or In-Circuit Debugger pin. Serial programming data.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as an external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

TABLE 1-2: PIC16F874 AND PIC16F877 PINOUT DESCRIPTION (CONTINUED)

Pin Name	DIP Pin#	PLCC Pin#	QFP Pin#	I/O/P Type	Buffer Type	Description
						PORTC is a bi-directional I/O port.
RC0/T1OSO/T1CKI	15	16	32	I/O	ST	RC0 can also be the Timer1 oscillator output or a Timer1 clock input.
RC1/T1OSI/CCP2	16	18	35	I/O	ST	RC1 can also be the Timer1 oscillator input or Capture2 input/Compare2 output/PWM2 output.
RC2/CCP1	17	19	36	I/O	ST	RC2 can also be the Capture1 input/Compare1 output/PWM1 output.
RC3/SCK/SCL	18	20	37	I/O	ST	RC3 can also be the synchronous serial clock input/output for both SPI and I^2C modes.
RC4/SDI/SDA	23	25	42	I/O	ST	RC4 can also be the SPI Data In (SPI mode) or data I/O (I^2C mode).
RC5/SDO	24	26	43	I/O	ST	RC5 can also be the SPI Data Out (SPI mode).
RC6/TX/CK	25	27	44	I/O	ST	RC6 can also be the USART Asynchronous Transmit or Synchronous Clock.
RC7/RX/DT	26	29	1	I/O	ST	RC7 can also be the USART Asynchronous Receive or Synchronous Data.
						PORTD is a bi-directional I/O port or parallel slave port when interfacing to a microprocessor bus.
RD0/PSP0	19	21	38	I/O	ST/TTL(3)	
RD1/PSP1	20	22	39	I/O	ST/TTL(3)	
RD2/PSP2	21	23	40	I/O	ST/TTL(3)	
RD3/PSP3	22	24	41	I/O	ST/TTL(3)	
RD4/PSP4	27	30	2	I/O	ST/TTL(3)	
RD5/PSP5	28	31	3	I/O	ST/TTL(3)	
RD6/PSP6	29	32	4	I/O	ST/TTL(3)	
RD7/PSP7	30	33	5	I/O	ST/TTL(3)	
						PORTE is a bi-directional I/O port.
RE0/$\overline{RD}$/AN5	8	9	25	I/O	ST/TTL(3)	RE0 can also be read control for the parallel slave port, or analog input5.
RE1/$\overline{WR}$/AN6	9	10	26	I/O	ST/TTL(3)	RE1 can also be write control for the parallel slave port, or analog input6.
RE2/$\overline{CS}$/AN7	10	11	27	I/O	ST/TTL(3)	RE2 can also be select control for the parallel slave port, or analog input7.
VSS	12,31	13,34	6,29	P	—	Ground reference for logic and I/O pins.
VDD	11,32	12,35	7,28	P	—	Positive supply for logic and I/O pins.
NC	—	1,17,28,40	12,13,33,34		—	These pins are not internally connected. These pins should be left unconnected.

Legend: I = input O = output I/O = input/output P = power
— = Not used TTL = TTL input ST = Schmitt Trigger input

Note 1: This buffer is a Schmitt Trigger input when configured as an external interrupt.
2: This buffer is a Schmitt Trigger input when used in Serial Programming mode.
3: This buffer is a Schmitt Trigger input when configured as general purpose I/O and a TTL input when used in the Parallel Slave Port mode (for interfacing to a microprocessor bus).
4: This buffer is a Schmitt Trigger input when configured in RC oscillator mode and a CMOS input otherwise.

TEXAS INSTRUMENTS

Data sheet acquired from Harris Semiconductor
SCHS055

January 1998

CD4070B, CD4077B

CMOS Quad Exclusive-OR and Exclusive-NOR Gate

Features

- High-Voltage Types (20V Rating)
- CD4070B - Quad Exclusive-OR Gate
- CD4077B - Quad Exclusive-NOR Gate
- Medium Speed Operation
  - t_{PHL}, t_{PLH} = 65ns (Typ) at V_{DD} = 10V, C_L = 50pF
- 100% Tested for Quiescent Current at 20V
- Standardized Symmetrical Output Characteristics
- 5V, 10V and 15V Parametric Ratings
- Maximum Input Current of 1μA at 18V Over Full Package Temperature Range
  - 100nA at 18V and 25°C
- Noise Margin (Over Full Package Temperature Range)
  - 1V at V_{DD} = 5V, 2V at V_{DD} = 10V, 2.5V at V_{DD} = 15V
- Meets All Requirements of JEDEC Standard No. 13B, "Standard Specifications for Description of 'B' Series CMOS Devices"

Applications

- Logical Comparators
- Adders/Subtractors
- Parity Generators and Checkers

Description

The Harris CD4070B contains four independent Exclusive-OR gates. The Harris CD4077B contains four independent Exclusive-NOR gates.

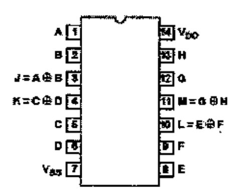
The CD4070B and CD4077B provide the system designer with a means for direct implementation of the Exclusive-OR and Exclusive-NOR functions, respectively.

Ordering Information

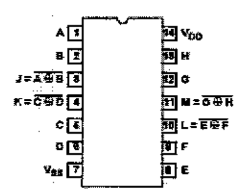
PART NUMBER	TEMP. RANGE (°C)	PACKAGE	PKG. NO.
CD4070BE	-55 to 125	14 Ld PDIP	E14.3
CD4077BE	-55 to 125	14 Ld PDIP	E14.3
CD4070BF	-55 to 125	14 Ld CERDIP	F14.3
CD4077BF	-55 to 125	14 Ld CERDIP	F14.3
CD4070BM	-55 to 125	14 Ld SOIC	M14.15
CD4077BM	-55 to 125	14 Ld SOIC	M14.15

Pinouts

CD4070B
(PDIP, CERDIP, SOIC)
TOP VIEW



CD4077B
(PDIP, CERDIP, SOIC)
TOP VIEW

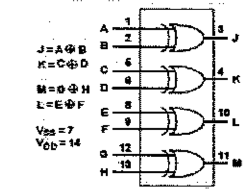


CAUTION: These devices are sensitive to electrostatic discharge. Users should follow proper IC Handling Procedures.

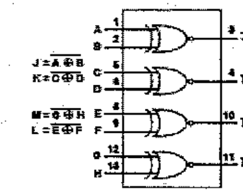
File Number 910.1

Functional Diagrams

CD4070B



CD4077B



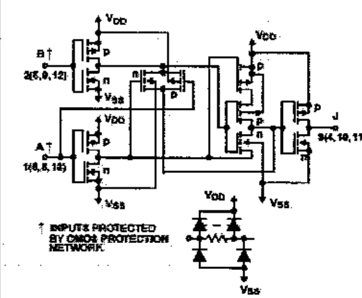


FIGURE 1. SCHEMATIC DIAGRAM FOR CD4070B (1 OF 4 IDENTICAL GATES)

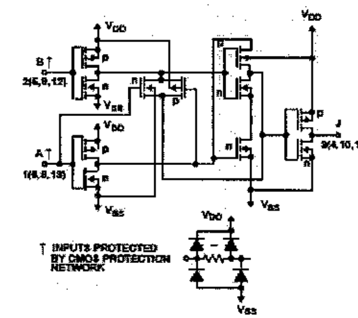


FIGURE 2. SCHEMATIC DIAGRAM FOR CD4077B (1 OF 4 IDENTICAL GATES)

CD4070B TRUTH TABLE (1 OF 4 GATES)

A	B	J
0	0	0
1	0	1
0	1	1
1	1	0

NOTE:
1 = High Level
0 = Low Level
J = A⊕B

CD4077B TRUTH TABLE (1 OF 4 GATES)

A	B	J
0	0	1
1	0	0
0	1	0
1	1	1

NOTE:
1 = High Level
0 = Low Level
J = $\overline{A \oplus B}$

FAIRCHILD SEMICONDUCTOR™

October 1987
Revised March 2002

CD4027BC
Dual J-K Master/Slave Flip-Flop with Set and Reset

General Description

The CD4027BC dual J-K flip-flops are monolithic complementary MOS (CMOS) integrated circuits constructed with N- and P-channel enhancement mode transistors. Each flip-flop has independent J, K, set, reset, and clock inputs and buffered Q and $\overline{Q}$ outputs. These flip-flops are edge sensitive to the clock input and change state on the positive-going transition of the clock pulses. Set or reset is independent of the clock and is accomplished by a high level on the respective input.

All inputs are protected against damage due to static discharge by diode clamps to V_{DD} and V_{SS}.

Features

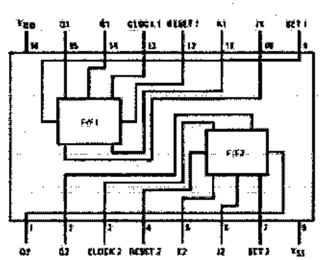
- Wide supply voltage range: 3.0V to 15V
- High noise immunity: 0.45 V_{DD} (typ.)
- Low power TTL compatibility: Fan out of 2 driving 74L or 1 driving 74LS
- Low power: 50 nW (typ.)
- Medium speed operation: 12 MHz (typ.) with 10V supply

Ordering Code:

Order Number	Package Number	Package Description
CD4027BCM	M16A	16-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow
CD4027BCN	N16E	16-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300" Wide

Devices also available in Tape and Reel. Specify by appending the suffix letter "X" to the ordering code.

Connection Diagram



Top View

Truth Table

Inputs t_{n-1} (Note 1)						Outputs t_n (Note 2)	
CL (Note 3)	J	K	S	R	Q	Q	$\overline{Q}$
⎯⌐	I	X	O	O	O	I	O
⎯⌐	X	O	O	O	I	I	O
⎯⌐	O	X	O	O	O	O	I
⎯⌐	X	I	O	O	I	O	I
⌐⎯	X	X	O	O	X	(No Change)	
X	X	X	I	O	X	I	O
X	X	X	O	I	X	O	I
X	X	X	I	I	X	I	I

I = HIGH Level
O = LOW Level
X = Don't Care
⎯⌐ = LOW-to-HIGH
⌐⎯ = HIGH-to-LOW

Note 1: t_{n-1} refers to the time interval prior to the positive clock pulse transition

Note 2: t_n refers to the time intervals after the positive clock pulse transition

Note 3: Level Change

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FAIRCHILD SEMICONDUCTOR™

October 1987
Revised April 2002

CD4070BC
Quad 2-Input EXCLUSIVE-OR Gate

General Description

The CD4070BC employs complementary MOS (CMOS) transistors to achieve wide power supply operating range, low power consumption, and high noise margin, the CD4070BC provide basic functions used in the implementation of digital integrated circuit systems. The N- and P-channel enhancement mode transistors provide a symmetrical circuit with output swing essentially equal to the supply voltage. No DC power other than that caused by leakage current is consumed during static condition. All inputs are protected from damage due to static discharge by diode clamps to V_{DD} and V_{SS}.

Features

- Wide supply voltage range: 3.0V to 15V
- High noise immunity: 0.45 V_{DD} typ.
- Low power TTL compatibility: Fan out of 2 driving 74L or 1 driving 74LS
- Pin compatible to CD4030A

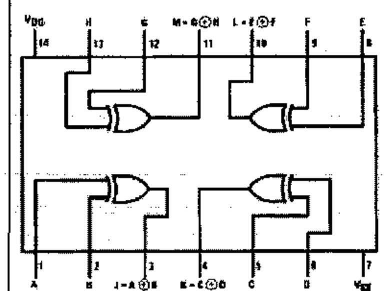
Equivalent to MM74C86 and MC14070B

Ordering Code:

Order Number	Package Number	Package Description
CD4070BCM	M14A	14-Lead Small Outline Integrated Circuit (SOIC), JEDEC MS-012, 0.150" Narrow
CD4070BCN	N14A	14-Lead Plastic Dual-In-Line Package (PDIP), JEDEC MS-001, 0.300" Wide

Devices also available in Tape and Reel. Specify by appending the suffix letter "X" to the ordering code.

Connection Diagram



Top View

Truth Table

Inputs		Outputs
A	B	Y
L	L	L
L	H	H
H	L	H
H	H	L

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STEPPER MOTOR DATASHEET

1200001553

Issued / Herausgegeben / Publicado / Publication 09/2001 **V9728**
Publicatto / Udgivet / Afgegeven / Utgiven

Instruction Leaflet
Bedienungsanleitung
Hojas de instrucciones
Feuille d'instructions
Foglio d'instruzioni
Betjeningsvejledning
Instructies
Instruktionsfolder

Hybrid Stepping Motors (GB)

Hybrid-Schrittmotoren (D)

Motores híbridos paso a paso (E)

Moteurs pas à pas hybrides (F)

Motori ibridi passo-passo (I)

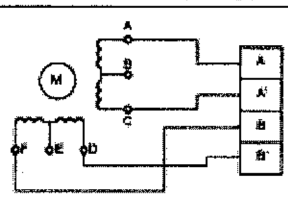
Hybride stepmotorer (DK)

Hybride stappenmotor (NL)

Hybridstegmotorer (SE)

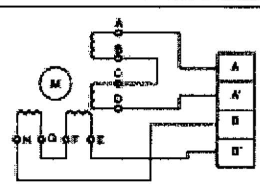
Figures / Abbildung / Figura / Figurer / Afbeeldingen

①



(GB) Connection diagrams
(E) Esquemas de conexión
(I) Schemi di inserzione
(NL) Aansluitdiagrammen
(D) Anschluß der Schrittmotoren
(F) Diagrammes de raccordement
(DK) Koblingsdiagram
(SE) Kopplingsschema

②



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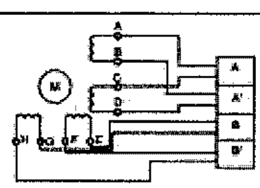


GB — RS Stock No.

440-420 to 440-470
191-8299 to 191-8384

Step	A	B	A'	B'
1	on	on		
2		on	on	
3			on	on
4	on			on

6 Wire Motors (refer to figure 1)

	Position					
	A	B	C	D	E	F
RS stock no.						
440-420	White	Brown	Red	Yellow	Brown	Blue
440-436	White	Brown	Red	Yellow	Brown	Blue
191-8299	White	Brown	Red	Yellow	Brown	Blue
191-8306	White	Brown	Red	Yellow	Brown	Blue
	Wire Colours					

8 Wire motors (refer to figures 2 &3)

	Position							
	A	B	C	D	E	F	G	H
RS stock no.								
440-442	Red	Red/White	Black/White	Black	Yellow	Yellow/White	Green/White	Green
440-458	Red	Red/White	Black/White	Black	Yellow	Yellow/White	Green/White	Green
440-464	Red	Red/White	Black/White	Black	Yellow	Yellow/White	Green/White	Green
440-470	Red	Red/White	Black/White	Black	Yellow	Yellow/White	Green/White	Green
191-8328	Red	Red/White	Black/White	Black	Yellow	Yellow/White	Green/White	Green
191-8334	Red	Red/White	Black/White	Black	Yellow	Yellow/White	Green/White	Green
191-8340	Red	Red/White	Black/White	Black	Yellow	Yellow/White	Green/White	Green
191-8356	Red	Red/White	Black/White	Black	Yellow	Yellow/White	Green/White	Green
191-8362	Red	Red/White	Black/White	Black	Yellow	Yellow/White	Green/White	Green
191-8378	Red	Red/White	Black/White	Black	Yellow	Yellow/White	Green/White	Green
191-8384	Red	Red/White	Black/White	Black	Yellow	Yellow/White	Green/White	Green
	Wire Colours							

Technical Specification

RS stock no.	440-420	440-436	440-442	440-458	440-464	440-470
Rated voltage (V)	5	12	5	12	3	2.5
Rated current (I)	0.5	0.16	1	0.6	2	4.5
Resistance (Ω)	10	75	5	20	1.5	0.56
Inductance (mH)	6	36	9	32	4.5	2.6
Detent torque (mNm)	5	4	30	30	40	100
Holding torque (mNm)	70	70	500	500	1274	2450
Step angle accuracy (%)	5	5	5	5	5	5
Step angle	1.8	1.8	1.8	1.8	1.8	1.8
Insulation class	B	B	B	B	B	B
NEMA frame size	17	17	23	23	40	40
Rear shaft	No	Yes	No	Yes	Yes	No

RS Voorraadnummer	191-8299	191-8306	191-8328	191-8334	191-8340	191-8356	191-8362	191-8378	191-8384
Nominale spanning	12	15	5	12	12	12	5,4	3,4	6
Nominale stroomsterkte	0,4	0,4	1	0,4	0,46	0,6	1,4	2,65	1,6
Weerstand	30	37,5	5	30	25	20	3,6	1,3	3,4
Inductiviteit	15	22	5,7	30	40	35	7,0	2,5	5
Klinkmoment	3,5	3,5	14,8	14,8	29,6	29,6	56,5	77,6	77,6
Houdmoment	100	100	260	260	500	500	882	1200	1200
Nauwkeurigheid staphoek	5	5	5	5	5	5	5	5	5
Staphoek	1,8	1,8	1,8	1,8	1,8	1,8	1,8	1,8	1,8
Isolatieklasse	B	B	B	B	B	B	B	B	B
NEMA frame-afmeting	17	17	23	23	23	23	23	23	23
Achteras	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee	Nee

RS Components accepteert geen aansprakelijkheid met betrekking tot enige verantwoordelijkheid of enig verlies (door welke oorzaak dan ook en al of niet te wijten aan nalatigheid van de zijde van RS Components) die zou kunnen ontstaan in verband met het gebruik van gegevens die in de technische documentatie van RS Components zijn opgenomen.

SE — RS Lagernummer

440-420 - 440-470
191-8299 - 191-8384

Steg	A	B	A'	B'
1	on (PÅ)	on (PÅ)		
2		on (PÅ)	on (PÅ)	
3			on (PÅ)	on (PÅ)
4	on (PÅ)			on (PÅ)

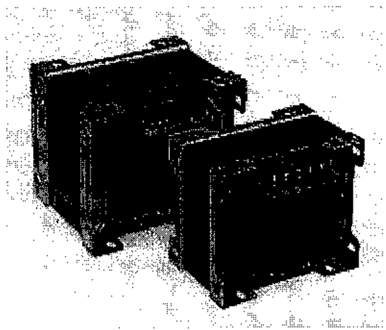
6 Anslutna Motorer (se figur 1)

	Position					
	A	B	C	D	E	F
RS Lagernummer						
440-420	Vit	Brun	Röd	Gul	Brun	Blå
440-436	Vit	Brun	Röd	Gul	Brun	Blå
191-8299	Vit	Brun	Röd	Gul	Brun	Blå
191-8306	Vit	Brun	Röd	Gul	Brun	Blå
	Ledningsfärger					

8 Anslutna motorer (se figurerna 2 &3)

	Position							
	A	B	C	D	E	F	G	H
RS Lagernummer								
440-442	Röd	Röd/Vit	Svart/Vit	Svart	Gul	Gul/Vit	Grön/Vit	Grön
440-458	Röd	Röd/Vit	Svart/Vit	Svart	Gul	Gul/Vit	Grön/Vit	Grön
440-464	Röd	Röd/Vit	Svart/Vit	Svart	Gul	Gul/Vit	Grön/Vit	Grön
440-470	Röd	Röd/Vit	Svart/Vit	Svart	Gul	Gul/Vit	Grön/Vit	Grön
191-8328	Röd	Röd/Vit	Svart/Vit	Svart	Gul	Gul/Vit	Grön/Vit	Grön
191-8334	Röd	Röd/Vit	Svart/Vit	Svart	Gul	Gul/Vit	Grön/Vit	Grön
191-8340	Röd	Röd/Vit	Svart/Vit	Svart	Gul	Gul/Vit	Grön/Vit	Grön
191-8356	Röd	Röd/Vit	Svart/Vit	Svart	Gul	Gul/Vit	Grön/Vit	Grön
191-8362	Röd	Röd/Vit	Svart/Vit	Svart	Gul	Gul/Vit	Grön/Vit	Grön
191-8378	Röd	Röd/Vit	Svart/Vit	Svart	Gul	Gul/Vit	Grön/Vit	Grön
191-8384	Röd	Röd/Vit	Svart/Vit	Svart	Gul	Gul/Vit	Grön/Vit	Grön
	Ledningsfärger							

RS TAPPED TRANSFORMER 3.2A



RS Stock No.	211-0654
RoHS Status	Add to my RoHS notification list
Manufacturer	WALSALL TRANSFORMERS
Manufacturer's part number	WT1295
Name	Frame mount transformer,3.2A o/p

3.2A/4A/10A Secondary Options Transformers

Chassis mounting frame construction low voltage mains transformers with a single 230V ac 50/60Hz primary winding and multi-tapped secondary winding.

- Double section bobbin construction
- Fully shrouded bobbins
- Full varnish impregnation
- Multi-hole frame fixing
- Solder tag terminations
- 100% electrical and flash tested
- Tested in accordance with BS3535 and EN 60 742

Selection guide

stock no.	regulation	*max. output	output voltage tappings V ac
	% typ.	current (A)	
211-0654	10	3·2	0-13·4-19·2-26·0-31·9
211-0660	10	4·0	0-6-9-12-18-24
211-0676	7	10·0	0-4·5-6-9-12-15-18-20-24

* Maximum current through any part of the winding

dimensions

stock no.	dimensions			fixing centres	wt.
	L.	W.	H.		kg
211-0654	99	76	83	63·5 x 47 x 2BA	1·98
211-0660	89	68	75	57 x 43·5 x 2BA	1·6
211-0676	100	92	82	72 x 70 x M5	2·8