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Industrial Power Control by Integral Cycle Switching Without Generating Harmonics

K. Aparnau [a], K. Chandrasekhara [b]

[a] *M. Tech Student Electrical Power System, crit college Anantapur, Andhra Pradesh, India*
[b] *M. Tech Student Electrical Power System, crit college Anantapur, Andhra Pradesh, India*

A B S T R A C T

The project is designed to achieve integral cycle switching, a method to remove whole cycle, cycles or portions of cycles of an AC signal. It is a well-known and old method of controlling AC power, especially across linear loads such as heaters used in electric furnace. However the concept of achieving the cycle switching of voltage waveform by use of Arduino can be very precise as per the program written in assembly language so that the actual time-average voltage or current experienced at the load is proportionately lower than the whole signal if applied to the load. In place of a linear load to be used in the output, a series motor or lamp can be used to verify the output. One side effect of utilizing this scheme is an imbalance in the input current or voltage waveform as the cycles are switched on and off across the load. In this project we are using comparator for zero crossing detection which is fed as an interrupt to Arduino. Here the Arduino delivers the output based on the interrupt received as the reference for generating triggering pulses. Using these pulses, we drive the opto-isolators for triggering the triac to achieve integral cycle control as per the input switches interfaced to the Arduino. A lamp is provided in this project in place of a motor for demonstration purpose. Further this project can be enhanced by using feedback mechanism to automatically maintain desired output to the load by appropriate cycle switching.

Keywords: AC, HDC

INTRODUCTION

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This project is intended to attain vital cycle switching – a technique to get rid of complete cycle, cycles or fractions of cycles of an AC signal. It is a renowned and aged technique of managing AC power, principally across linear loads for instance heaters brought into play in electric oven. However, the concept of achieving the cycle switching of voltage waveform by the use of Arduino can be very precise as per the program written in assembly language so that the actual time-average voltage or current experienced at the load is proportionately lower than the whole signal if applied to the load. In this project, we are using a comparator for zero crossing detection which is fed as an interrupt to the Arduino . Here, the Arduino delivers the output based on the interrupt received as the reference for generating triggering pulses. Using these pulses, we drive the opto-isolators for triggering the triac to achieve integral cycle control as per the input switches interfaced to the Arduino. In place of a linear load to be used in the output, a series motor or lamp can be used to verify the output. One side effect of utilizing this scheme is an imbalance in the input current or voltage waveform as the cycles are switched on and off across the load.

A lamp is provided in this project in place of a motor for demonstration purpose. The project output with a lamp appears to be a simple project of lamp flickering.

2.1 Introduction

An embedded system is a system which is going to do a predefined specified task is the embedded system and is even defined as combination of both software and hardware. A general-purpose definition of embedded systems is that they are devices used to control, monitor or assist the operation of equipment, machinery or plant. "Embedded" reflects the fact that they are an integral part of the system. At the other extreme a general-purpose computer may be used to control the operation of a large complex processing plant, and its presence will be obvious.

All embedded systems are including computers or microprocessors. Some of these computers are however very simple systems as compared with a personal computer. The very simplest embedded systems are capable of performing only a single function or set of functions to meet a single predetermined purpose. In more complex systems an application program that enables the embedded system to be used for a particular purpose in a specific application determines the functioning of the embedded system. The ability to have programs means that the same embedded system can be used for a variety of different purposes. In some cases a microprocessor may be designed in such a way that application software for a particular purpose can be added to the basic software in a second process, after which it is not possible to make further changes. The applications software on such processors is sometimes referred to as firmware.

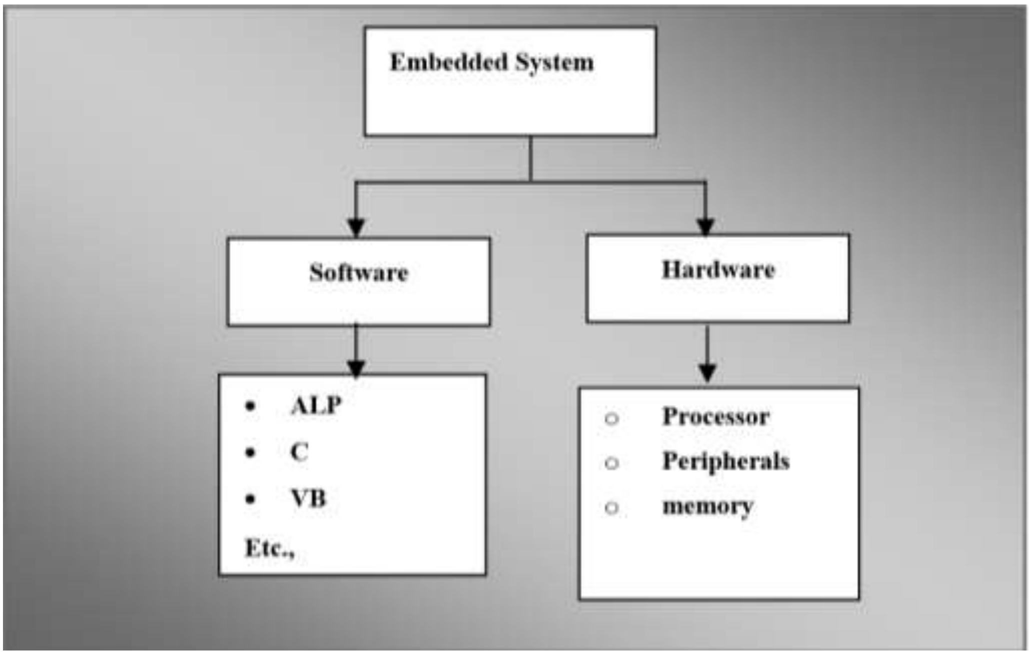


Fig 2.1 Block diagram of Embedded System

The simplest devices consist of a single microprocessor (often called a "chip"), which may itself be packaged with other chips in a hybrid system or Application Specific Integrated Circuit (ASIC). Its input comes from a detector or sensor and its output goes to a switch or activator which (for example) may start or stop the operation of a machine or, by operating a valve, may control the flow of fuel to an engine. As the embedded system is the combination of both software and hardware Software deals with the languages like ALP, C, and VB etc., and Hardware deals with Processors, Peripherals, and Memory.

Memory: It is used to store data or address.

Peripherals: These are the external devices connected

Micro Processor (μp):

A silicon chip that contains a CPU. In the world of personal computers, the terms microprocessor and CPU are used interchangeably. At the heart of all personal computers and most workstations sits a microprocessor. Microprocessors also control the logic of almost all digital devices, from clock radios to fuel-injection systems for automobiles.

.Clock speed: Given in megahertz (MHz), the clock speed determines how many instructions per second the processor can execute.

In both cases, the higher the value, the more powerful the CPU. For example, a 32-bit microprocessor that runs at 50MHz is more powerful than a 16-bit microprocessor that runs at 25MHz. In addition to bandwidth and clock speed, microprocessors are classified as being either RISC (reduced instruction set computer) or CISC (complex instruction set computer).

A microprocessor has three basic elements, as shown above. The ALU performs all arithmetic computations, such as addition, subtraction and logic operations (AND, OR, etc). It is controlled by the Control Unit and receives its data from the Register Array. The Register Array is a set of registers used for storing data. These registers can be accessed by the ALU very quickly. Some registers have specific functions - we will deal with these later. The Control Unit controls the entire process. It provides the timing and a control signal for getting data into and out of the registers and the ALU and it synchronizes the execution of instructions (we will deal with instruction execution at a later date).

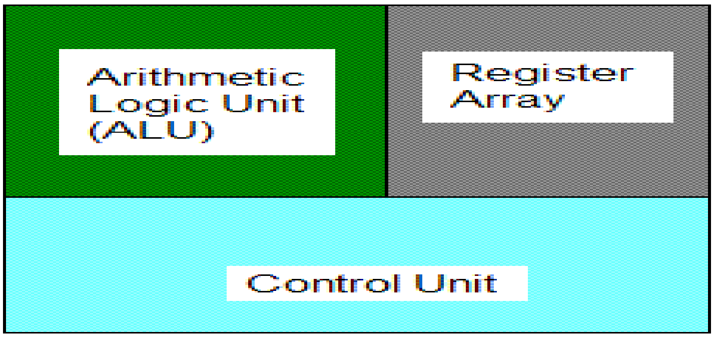


Fig: 2.2 Three Basic Elements of a Microprocessor

2.2 Micro Controller (μc)

A microcontroller is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form of NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications.

2.3 Digital Signal Processors

Digital Signal Processors is one which performs scientific and mathematical operation. Digital Signal Processor chips - specialized microprocessors with architectures designed specifically for the types of operations required in digital signal processing. Like a general-purpose microprocessor, a DSP is a programmable device, with its own native instruction code. DSP chips are capable of carrying out millions of floating point operations per second, and like their better-known general-purpose cousins, faster and more powerful versions are continually being introduced. DSPs can also be embedded within complex "system-on-chip" devices, often containing both analog and digital circuitry.

2.3.1 Application Specific Integrated Circuit (ASIC)

ASIC is a combination of digital and analog circuits packed into an IC to achieve the desired control/computation function

ASIC typically contains

- CPU cores for computation and control
- Peripherals to control timing critical functions
- Memories to store data and program
- Analog circuits to provide clocks and interface to the real world which is analogue in nature

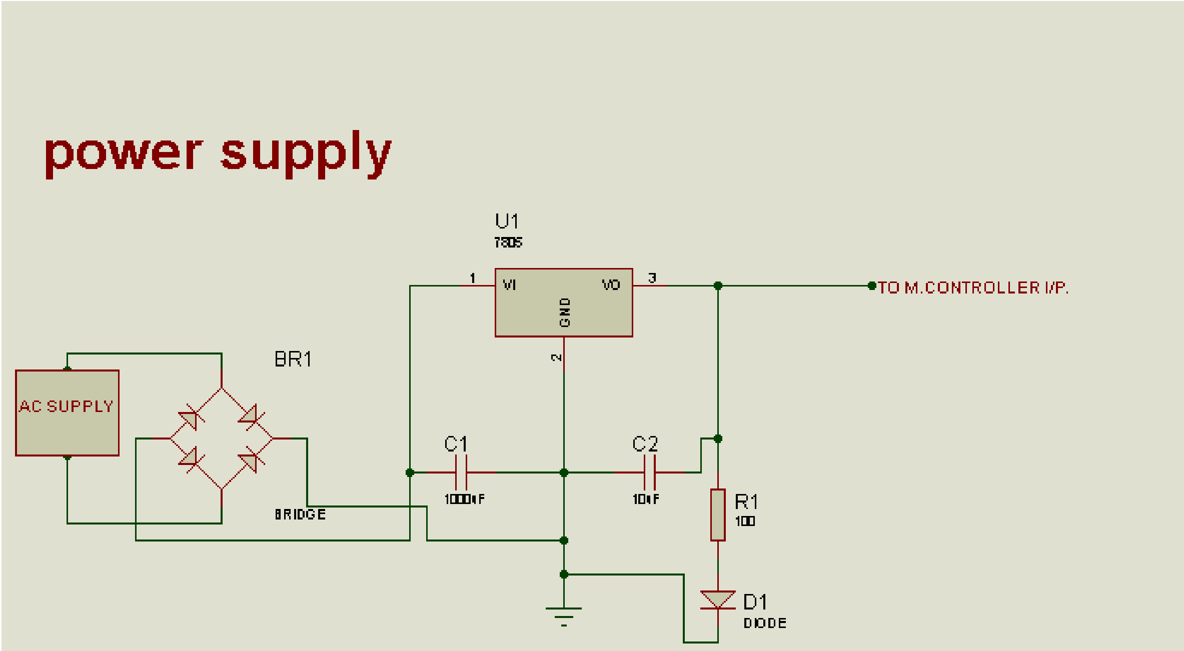
SYSTEM DESIGN

3.1 POWER SUPPLY

Block diagram

Fig 3.1 Power Supply

Circuit diagram



Transformer

A transformer is a device that transfers electrical energy from one circuit to another through inductively coupled conductors the transformer's coils. A varying current in the first or *primary* winding creates a varying magnetic flux in the transformer's core, and thus a varying magnetic field through the *secondary* winding. This varying magnetic field induces a varying electromotive force (EMF) or "voltage" in the secondary winding. This effect is called mutual induction.

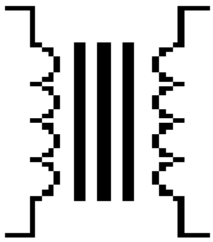


Fig 3.3 Transformer Symbol

Basic Principle

A transformer makes use of Faraday's law and the ferromagnetic properties of an iron core to efficiently raise or lower AC voltages. It of course cannot increase power so that if the voltage is raised, the current is proportionally lowered and vice versa.

From Faraday's Law

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

For ideal transformer

The voltage ratio is equal to the turns ratio, and power in equals power out.

From conservation of energy

$$P_P = V_P I_P = V_S I_S = P_S$$

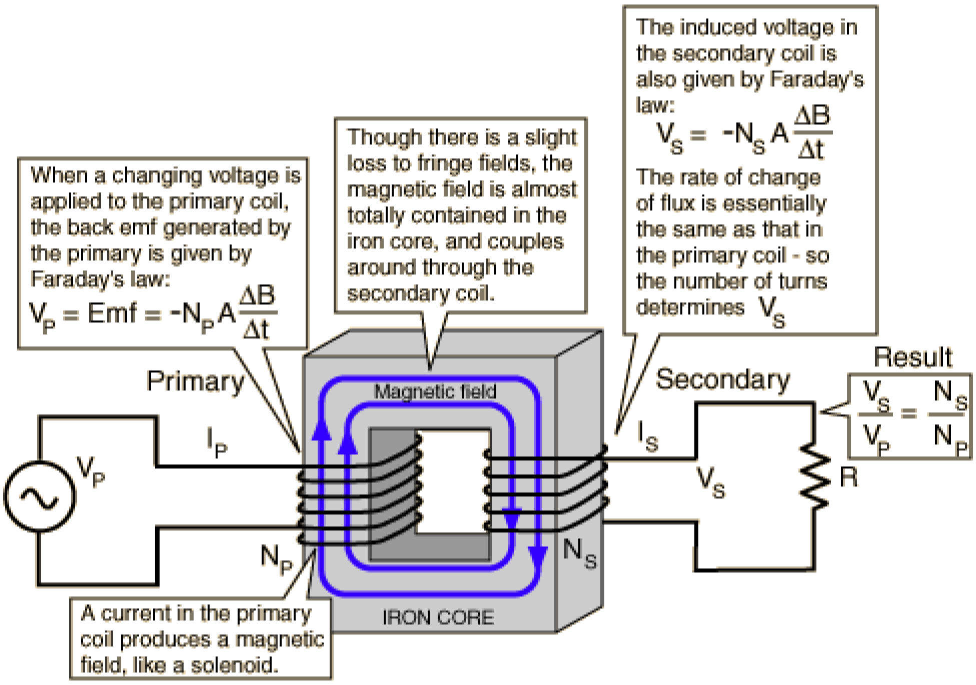


Fig 3.4 Basic Principle

3.2 Transformer Working

A transformer consists of two coils (often called 'windings') linked by an iron core, as shown in figure below. There is no electrical connection between the coils, instead they are linked by a magnetic field created in the core.

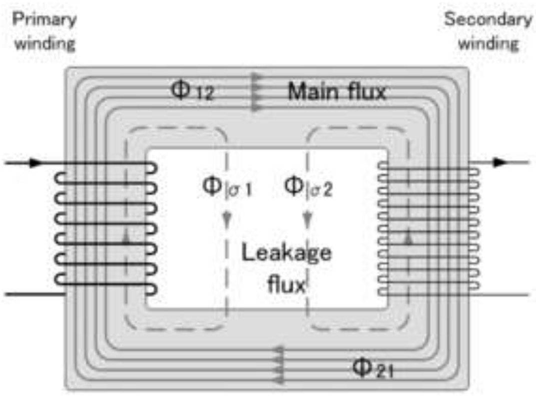


Fig 3.3 Basic Transformer

Transformers are used to convert electricity from one voltage to another with minimal loss of power. They only work with AC (alternating current) because they require a changing magnetic field to be created in their core. Transformers can increase voltage (step-up) as well as reduce voltage (step-down). Alternating current flowing in the primary (input) coil creates a continually changing magnetic field in the iron core. This field also passes through the secondary (output) coil and the changing strength of the magnetic field induces an alternating voltage in the secondary coil. If the secondary coil is connected to a load the induced voltage will make an induced current flow. The correct term for the induced voltage is 'induced electromotive force' which is usually abbreviated to induced e.m.f.

The iron core is laminated to prevent 'eddy currents' flowing in the core. These are currents produced by the alternating magnetic field inducing a small voltage in the core, just like that induced in the secondary coil. Eddy currents waste power by needlessly heating up the core but they are reduced to a negligible amount by laminating the iron because this increases the electrical resistance of the core without affecting its magnetic properties.

Transformers have two great advantages over other methods of changing voltage:

1. They provide total electrical isolation between the input and output, so they can be safely used to reduce the high voltage of the mains supply.

2. Almost no power is wasted in a transformer. They have a high efficiency (power out / power in) of 95% or more.

Classification of Transformer:

- Step-Up Transformer
- Step-Down Transformer

Step-Down Transformer:

Step down transformers are designed to reduce electrical voltage. Their primary voltage is greater than their secondary voltage. This kind of transformer "steps down" the voltage applied to it. For instance, a step down transformer is needed to use a 110v product in a country with a 220v supply. Step down transformers convert electrical voltage from one level or phase configuration usually down to a lower level. They can include features for electrical isolation, power distribution, and control and instrumentation applications. Step down transformers typically rely on the principle of magnetic induction between coils to convert voltage and/or current levels. Step down transformers are made from two or more coils of insulated wire wound around a core made of iron. When voltage is applied to one coil (frequently called the primary or input) it magnetizes the iron core, which induces a voltage in the other coil, (frequently called the secondary or output). The turn's ratio of the two sets of windings determines the amount of voltage transformation.

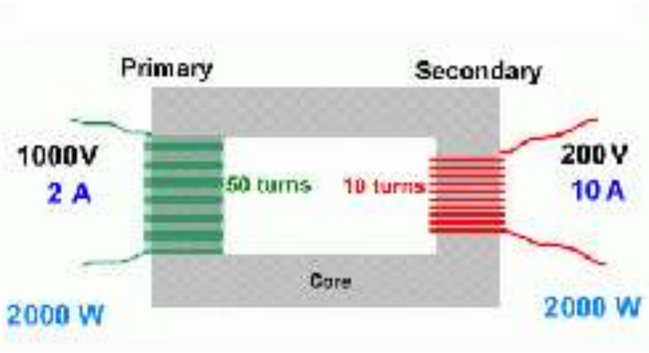


Fig 3.3 Step-Down Transformer

An example of this would be: 100 turns on the primary and 50 turns on the secondary, a ratio of 2 to 1.

Step down transformers can be considered nothing more than a voltage ratio device.

With step down transformers the voltage ratio between primary and secondary will mirror the "turn's ratio" (except for single phase smaller than 1KVA which have compensated secondary). A practical application of this 2 to 1 turn's ratio would be a 480 to 240 voltage step down. Note that if the input were 440 volts then the output would be 220 volts. The ratio between input and output voltage will stay constant. Transformers should not be operated at voltages higher than the nameplate rating, but may be operated at lower voltages than rated. Because of this it is possible to do some non-standard applications using standard transformers. Single phase step down transformers 1 KVA and larger may also be reverse connected to step-down or step-up voltages. (Note: single phase step up or step down transformers sized less than 1 KVA should not be reverse connected because the secondary windings have additional turns to overcome a voltage drop when the load is applied. If reverse connected, the output voltage will be less than desired.)

CONCLUSION

In this way, we can control the power by using integral cycle switching. We understand how to remove cycle from main input. We get output without any distortion. We can see our output with integral cycle switching.

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