

MODELLING AND SIMULATION OF A DIGITAL PHASE METER FOR PHASE CHANGES MONITORING IN POWER SUPPLY

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ABSTRACT

Sequel to the recent import restrictions in Nigeria, particularly in the face of the much fancied deregulation of certain sectors of the economy, the power industry inclusive, Engineers are expected to look inwards and see what could be done in the development of our engineering infrastructure. Effort is therefore made in this paper to model from first principles and design for implementation phase angle meters for use in the power sector of the economy to ensure reliable power supply. A sincere effort has been made and a phase angle changing meter has been realized that is suitable for monitoring phase angle changes in the power Network.

1. INTRODUCTION

In the power industry or any control system, meters are the last bus stop as far as control and automation are concerned. They either warn the operator in advance to take action before an automatic operation takes place in the system or inform the operator what happened in the system before an automatic operation took place.

The fact is that meters are the 'eyes' of operators in control rooms without which the operators are blind to what happens in the system. No wonder then that operators sit (as a tradition) face to face with the control panel in order to observe meters on twenty four hours basis.

In a typical power network, there are various types of meters, but the phase meter that measures phase angle changes in power supply in degrees is of concern in this work. The earlier meters used in power systems operation and control came in various names, sizes and modes of operation, but their outputs are basically analog in nature. These meters are bulky in size and have the disadvantage of parallax errors in reading their output. Also their moving parts depreciate in efficiency with time.

However, with the development of digital technology, meters of portable sizes, longer life and assured accuracy have been produced at cheaper costs for use in the power industry. It is on this basis that the development and design of Digital phase meter is conceived and carried out.

In this paper, therefore, a typical phase meter for use in a power company is modeled and produced. The realized design is simulated between angles 0-360 degrees and simulated results are presented and discussed. A close

observation of the pulses show that whereas the pulse width increases with increase in phase angle difference for positive angles, it decrease for increase in magnitude of the negative phase angle differences [1]

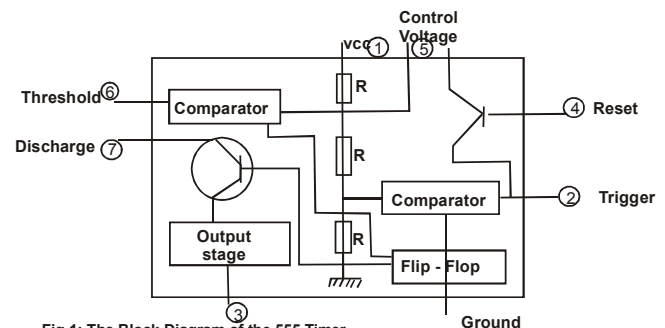
The power industry cannot do without Phase Angle Meters because their readings inform certain decisions towards stable and durable power supply to consumers. They are very suitable for the development of the power industry.

2. THE SYSTEM DESIGN

The design of this phase meter will take volumes if every detail of it is to be considered. On this basis, the description of the components of this design will be so compressed that both space and time will be on our part.

2.1. COUNTERS

Counters are used to count the pulses as they are generated from the clock input, as is the case in R-S or J-K Flip-flops. These pulse are decoded at the output of the counter. The counter is composed of memory elements of flip-flops and combination circuits and is used in timing, control and sequencing circuits. Counters are of various types. In this design, we used the 555 TIMER (ASTABLE MULTIVIBRATOR), which comprises 23 transistors, 2 diodes, and 16 resistors. However, the circuit can be reduced to the functional block diagram as shown (Figure 1) with 2 comparators, 1 flip-flop, 2 control transistors and a high current output stage [1,2].



2.2 THE INPUT

The inputs to the system are ac voltage signals. The components of the input consist of two, identical transformers T which step down the ac voltage (240V) to the desired level, usually (12V a.c) which can be handled

by the comparators. These reduced ac voltage signals are now fed into two identical connectors. The outputs of these connectors which are also ac signals are then fed into the inverting inputs of two identical comparators, as shown in Figure 2.

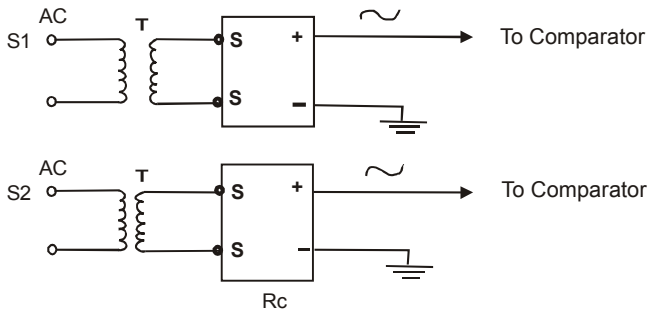


Figure 2: The Input

2.2.1 The Regulated Power Supply

For the sake of economy, the input to the regulated power supply is tapped from any of the transformers of the input system of Figure 2, however, it is brought out here separately for purposes of clarity, as shown in Figure 3.

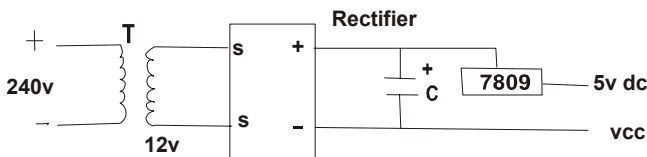


Figure 3: Regulated Power Supply

This unit consists of a 240/12v transformer (step down), which supplies a rectifier. The output of the rectifier has a capacitor of 100 mf connected across it. The function of the capacitor is to keep the negative cycle of the ac voltage at a high position. The signal then passes through a 5V regulator (7805) which regulates the signal to 5Vdc. This 5Vdc (vcc) is then to drive the logic gates in the main circuit. A bridge rectifier was used for the rectification, [3].

2.3 THE ADC

The ADC (Analog to Digital Converter) is a component of the system comprising two comparators and two logic gates. Use is made of operational amplifiers as the comparator for this component and the logic is one Exclusive-OR-gate and one AND gate, Figure 4.

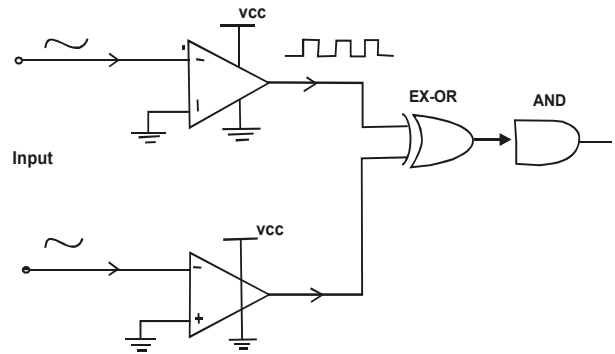


Figure 4: ADC (Analog-to-Digital converter) circuit

We see that the inputs to the comparators are sinusoidal and they are converted to square waves at the output before entering the Exclusive-OR-gate.

The op amp connection is in the inverting mode as shown in the diagram. The Exclusive-OR-gate produces an output I only if there is a discrepancy in the occurrence of the outputs of the comparators. Otherwise, the output will be 0. Then comes the AND gate which combines the input from the Exclusive OR gate with a clock pulse to give an output. The clock pulse is I each time so it is the other signal that determines the output.

2.4 THE SAMPLING AND COUNTING CIRCUITS

2.4.1 The Line Decoder

We have already given some attention to counters (Figure 1) where we used the 40171c counter. The line Decoder is a two-circuit arrangement in a single package, three of these ICS (4518) are used in cascade in this design and their outputs are fed into three seven segment decoder as shown in Figure 5.

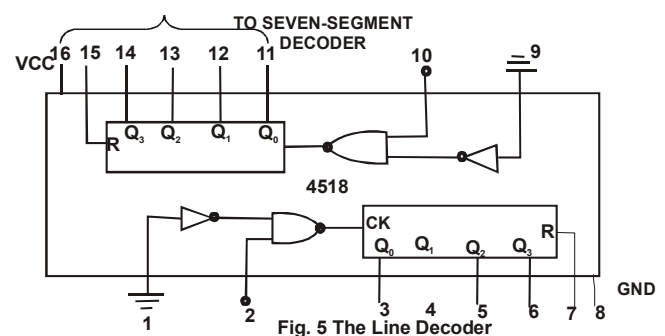


Fig. 5 The Line Decoder

Note: Pin 5 is clocked (connected) to pin I in the practical connection, Pin 2 is the clock input pin.

2.4.2 The Seven Segment Decoder

The Binary coded Decimal BCD – to – Seven Segment decoder/driver is shown in Figure 6. This is the IC that decodes the binary (0-9) into the segments that are supposed to be on for each corresponding input number. We used the 7447 IC which has the active – low output. So, when a 4 digit binary input is applied through the

input pins ABCD, it is decoded into the segment as shown Table 1.

Table 1: Truth Table for Seven Segment Decoder

	D	C	B	A	F	g	a	b	c	d	e
1	0	0	0	0	1	0	1	1	1	1	1
2	1	0	0	0	1	0	0	0	1	1	0
3	0	0	0	1	0	1	1	1	0	1	1
4	3	0	0	1	1	0	1	1	1	1	0
5	4	0	1	0	0	1	1	0	1	1	0
6	5	0	1	0	1	1	1	1	0	1	1
7	6	0	1	1	0	1	1	0	0	1	1
8	7	0	1	1	1	0	0	1	1	0	0
9	8	1	0	0	0	1	1	1	1	1	1
	9	1	0	0	1	1	1	1	1	0	0

Figure 6: The Seven Segment Decoder/Driver

2.4.3 The NAND Gate

The function of the NAND Gate is to ensure that the phase difference does not exceed 180° (or enter the -ve angle). The inputs to the NAND gate are 1s only if the difference between the two ac signals is 180° . Then, its output becomes 0 (inverted) and this de-enables the AND gate of the entire design, so that 180° will be displayed until the phase difference departs that figure (becomes less) and the count begins in a digital form.

2.5 THE DISPLAY UNIT

This section takes us to final part of the design. The display unit comprises the light emitting Diodes (LEDs) and the seven segment Display which enable us to read the output in a digital form.

2.5.1 THE LEDs

The LEDs are the type of diodes, which glow when a high input (1) is applied to their legs and go off when a low input (0) is applied. For each seven segment display part, there are seven legs of LEDs connected to it. Figures 7a and b show common cathode/Anode connection of LEDs.

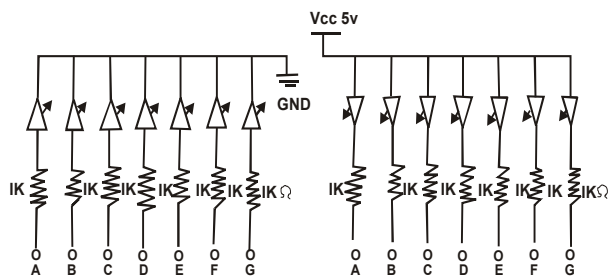


Fig 7 (a) Common Cathode (b) Common Anode Connection

2.5.2 The Seven Segment Display

We can develop one part (say just digit 1) of the seven segment display to show the internal connections.

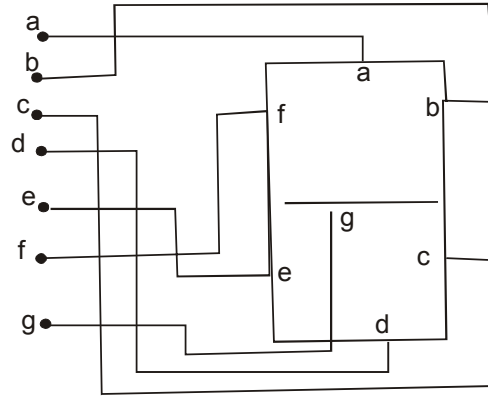


Figure 8: The internal connection of the seven segment display

Having come this far, we can now collect these components together in a block diagram form to model the complete layout of the design, see Figure 9.

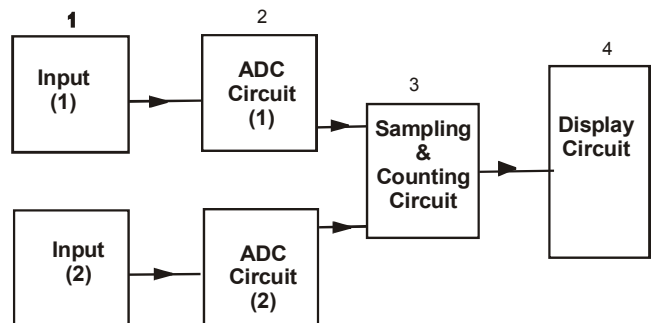


Figure 9: Block Diagram Representation of the Design

- Where: Block 1 House → the Regulated power supply
- Block 2 House → the analog-to-digital converter ccts
- Block 3 House → the counter 4017, the line decoder 4518, the seven segment decoder 7447, the NAND gate
- Block 4 House → the LEDs. The seven segment display

3. THE OUTPUT

The theoretical output was simulated from the comparators and the Exclusive OR gate circuit (Figure 4). The two out of the three parameters of the signal to the comparators are fixed at 5 volts, 60hz respectively while the phase angle is varied. Individually, the comparators produce square waves before getting to the exclusive OR gate.

The output of the EX-OR is 1 only when there is a discrepancy between the two input signals, otherwise it will be 0. Hence, the phase difference between the two signals is got from the output of the EX OR gate. For instance, chart 1 shows the output when the phase difference between the two signals is 10° . These are sharp square spikes of amplitude 5 volts. This chart and the subsequent ones are magnified to the tune of 5 volts/20ms i.e. 0.25v/ms, the magnification factor. When the phase angles were raised to 30° and 45° , the outputs depicted in

charts 2 and 3 respectively were recorded. The spikes are still sharp but progressively wider than when the phase angles were 60° , 90° , 120° and 160° respectively. Noteworthy is the fact that the output flattens to the origin at the angles of 180° and 360° , signifying that such angle differences cannot exist. Also, it is important to note that as the differences in the phase angles becomes bigger, the on-time of the EX-OR Gate also becomes bigger and these inform the progressive widening of the spikes.

4. METER TEST RESULTS

On completion of the design, the meter was tested with the conventional three Phase supply. One of the two signal inputs in the design is grounded and tied to the power source (ie S_2). The leg then becomes the neural leg for the probe leads.

The results are as outlined below:

$$\begin{array}{lcl}
 R\emptyset \longrightarrow & \text{Neutral} & = 122^\circ \\
 Y\emptyset \longrightarrow & \text{Neutral} & = 111^\circ \\
 B\emptyset \longrightarrow & \text{Neutral} & = 127^\circ
 \end{array}$$

Now, since the Neutral (zero) is the reference point for all the phases, we can have;

$$\begin{array}{lcl}
 \text{Phase angle difference b/w } R\emptyset & \text{and } Y\emptyset & \\
 \text{as } 122^\circ - 111^\circ & = & 11^\circ \\
 \text{Phase angle difference b/w } Y\emptyset & \text{and } B\emptyset & \\
 \text{as } 111^\circ - 127^\circ & = & -16^\circ = 16^\circ \\
 \text{Phase angle difference b/w } B\emptyset & \text{and } R\emptyset & \\
 \text{as } 127 - 122 = & & 5^\circ
 \end{array}$$

These results are recorded in Table 2 and they are revealing some good point. For example, we can see that a load line was created along the leading diagonal showing a state of imbalance in the system. Also, this looks like two equal arrows in opposite directions, pulling away from the center.

These two affects put stress on equipment like transformers and three phase machines and lead to their quick exit from the circuit.

Table 2: Meter Test Results

Phase to Neutral	Reading (Degrees)	Angler Difference Between			Remarks
		R	Y	B	
R	122		11	5	This test was carried out b/w 1105 hrs and 1110 hrs on a mid week day in Onitsha.
Y	111	11		16	
B	127	5	16		

5. CONCLUSION

The design of Digital Phase Meter has been presented in this paper. The realized results indicate that this meter is useful in the power sector of the economy and can be produced locally.

It is our view therefore, that this work should not be allowed to rotten and a strong case is hereby made for commercialization. Government Agencies, power and allied industries are by this paper approached for mass production of this design which can help them in monitoring phase changes in their various power supplies. This meter is intended to be used in control rooms of power companies. It has the advantage of eliminating parallax errors introduced by the use of analogue meters.

6. REFERENCES

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Presenter: The paper is presented by V.C. Echedom.