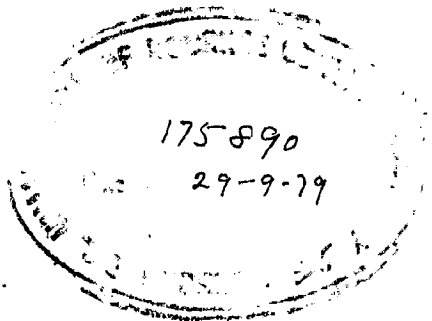# ELECTRONIC TESTING OF INTEGRATING METERS

A DISSERTATION

Submitted in partial fulfilment
of the requirements for the award of the Degree
of
MASTER OF ENGINEERING
in
ELECTRICAL ENGINEERING
(MEASUREMENT AND INSTRUMENTATION)

By

AJAY KUMAR SAXENA

DEPARTMENT OF ELECTRICAL ENGINEERING
UNIVERSITY OF ROORKEE
ROORKEE, (INDIA)
MARCH 1979

C E R T I F I C A T E

Certified that the dissertation entitled, 'ELECTRONIC TESTING OF INTEGRATING METERS', which is being submitted by Ajay Kumar Saxena in partial fulfilment for the award of the degree of Master of Engineering in Electrical Engineering (Measurement and Instrumentation) of the University of Roorkee, Roorkee, is a record of bonafide work carried out by him under my supervision and guidance. The matter embodied in this dissertation has not been submitted for the award of any other Degree or Diploma.

This is further certified that he has worked for 14 months from Jan., 78 to March, 79 for preparing this dissertation at this University.

(H. K. VERMA)
Reader in Electrical Engg.,
Department of Electrical Engg.,
University of Roorkee,
Roorkee.

Dated March 22 , 1979.

A C K N O W L E D G E M E N T

_A_B_S_T_R_A_C_T_

Electronics is fast appearing in every field of
engineering, and in fact of the human life. Testing of
integrating meters (energy meters) has also not been left
untouched by electronics. Considerable work has been done
by researchers in electronic testing of integrating meters,
and to some extent the same has been adopted by the manu-
facturers. The work done so far has been reviewed here
critically. To bring out clearly the advantages and limi-
tations of electronic testing methods as also computer
testing, an account of the conventional methods has also
been included.

A testing scheme using digital electronic circuits
and another one based on the use of a microprocessor has
been developed by the author and successfully used for
testing induction type energy meters. Principles of these
schemes, as also the details of the hardware and software
(for the latter scheme only) are presented here. Conclu-
sions on the work done have been drawn and some suggestions
for future work have been given at the end.

_C_O_N_T_E_N_T_S_

* * * * *

CHAPTER - 1

IN TRODUCTION

1.1 Integrating Meter Testing

Integrating meters are the meters which measure and register, either the total quantity of electricity in ampere-hours, or the total amount of energy, in kilowatt-hours, supplied to a circuit over a given period of time. Whereas the former is a d.c. instrument, the latter is of a.c. or d.c. type. Out of these meters, the a.c. energy meter is the most widely used one[1]. As its single largest application it is used for determining the energy consumed by electricity consumers. As such the dissertation is aimed at the testing of a.c. type integrating meters (energy meters) only.

Because of the variation of voltage, frequency, friction and temperature the meters are prone to become eroneous[2]. Integrating meter testing involves not only finding the actual errors but also includes the adjustments to bring the meter within permissible limits of error. The adjustments in the electromechanical (induction type) energy meters[3] are done by

(i)   a light-load compensator either in the form of a non-magnetic, conducting plate in the main air gap or in the form of a seperate shading coil on each outer limb of the voltage magnet.

(ii)   a shading device employed for the power factor or quadrature adjustment.

(iii)   a braking system by moving either the brake magnet itself or a shading coil on it.

These three adjustments are carried out in a definite order chosen so that each new setting has but little effect on those preceding it.

Limits of error for various integrating meters have been laid down in Indian Standard Specification no. 722. The scopes of various parts of this standard are as follows -

(i)   IS : 722 (Part II) - 1962 - Single-phase 2-wire whole-current watthour meter.

(ii)   IS : 722 (Part III) - 1966 : - Three-phase whole-current and transformer-operated meters, and single-phase two-wire transformer-operated meters.

(iii)   IS : 722 (Part IV) - 1961 - Three-phase kilowatt hour meters with maximum demand indicator.

(iv)   IS : 722 (Part V) - 1965 - Volt Ampere Hour meters for restricted power factor range.

(v)   IS : 722 (Part VI) - 1968 - Reactive volt Ampere Hour meters.

As an example of the limits of error laid down in these Standards, those for single-phase 2-wire whole-current watthour meter are reproduced in Appendix A.

Three basic methods of error determination (discussed at length in the following Chapters) are -

(i)   Use of dials on the meter for checking against a
        precission dial testing instrument.

(ii)   Comparison of the speed of the rotor of the meter
        under test with that of a precission rotating sub-
        standard meter.

(iii)   Time check of the speed of the rotor of the meter
        using suitable indicating instruments and a stop
        watch.

Out of these, the comparision method is most commonly
used as it eliminates the need for holding the loads on the
two meters constant.

Interest and attention of test engineers has shifted
to electronic testing in the past two decades. Electronic
testing, incorporating counting computation and display using
electronic components, has higher potential of accuracy because
of reduced share of human operator. Such testing may be done
by a number of methods. Most of the techniques used consist
of an application of analog principles and this results in
low resolution and noise contamination unless filtering is
used.

More elaborate design consists of hybrid digital-
analog systems, which involve rectification of pulses produced
by magnetic or optical transducer giving a train of pulses
with a freq. proportional to the angular velocity. Filtering
is still necessary.

Digital designs requiring only digital processing have followed the previous ones. These designs involve the measurement of angular distance over a given time by counting the number of uniformly spaced signals produced from rotation of the meter disc. The count, being equivalent to integration over a given time, gives angular velocity. Filtering is not required but the designs are limited by the angular resolution of the disc and slow sampling time.

1.2 Overview of the Dissertation

Chapter 2 of the dissertation deals with conventional testing of a.c. type integrating meters to have an idea of the prevailing methods of testing. Testing of 3-phase meters, reactive meters, kilowatt demand indicators, KVAh and KVA demand indicators is briefly discussed. Chapter 3 reviews electronic and computer methods of testing. In Chapter 4 some new schemes incorporating varied amounts of automation have been proposed. Chapter 5 is devoted to an electronic test set-up which has been successfully designed and developed by the author. Chapter 6 presents a novel method of testing meters using a microprocessor. In the last chapter conclusions on the present work and suggestions for future work are given.

CHAPTER - 2

CONVENTIONAL TESTING

Before going into details of electronic testing it
is essential to have an understanding of the conventional
methods of integrating meters! testing. Keeping this in view
prevailing methods of testing integrating meters have been
discussed in this Chapter. Advantages and disadvantages
of those methods have also been discussed in detail.

2.1. Scope of Meter Testing

The purpose of meter testing is the determination of
errors of supply meters under approved conditions and by
approved methods with a view to submitting these meters for
certification. This includes not only the actual testing of
the meters, but also the verification of the substandards
used in connection therewith. The work of a testing station
is not, however, confined within these limits. Most supply
undertakings have in operation the systems of charging that
necessitate the measurement of electrical quantities other
than kwh, and the instruments used for these measurements -
demand indicators, KVArh and KVA meters - must be checked
for accuracy.

2.2. Range of Tests

A typical scheme of tests for a.c. energy meters
would consist of tests -

(a)   at the lowest current at which the accuracy is
        guaranteed (usually 5 percent of marked current);

(b)   at one intermediate current;

(c)   at the highest current at which the accuracy is
        guaranteed;

(d)   at marked current, 0.5 power factor lagging,

(e)   at the starting current (usually 0.5 percent of
        marked current), to ensure that the meter will run
        continuously at this current;

(f)   at zero current, with 10 percent excess voltage
        applied to the voltage circuit, to ensure that the
        meter does not creep under these conditions.

        All the tests except (f) are carried out at normal
voltage. Test (a), (b), (c) and (e) performed at unity power
factor.

2.3 Methods of Testing

        The three methods of test specified from which a
choice can be made are as given below.

Method A

        Long-period dial tests, using substandard rotating
        meters.

Method B

        (a) Short time tests using substandard rotating
            meters.

        (b) one long period dial test.

Method C

      (a) Tests by substandard indicating instruments
      and time measurement

      (b) One long-period dial test

2.3.1 Long-Period Dial Tests

It is the most important test as whichever of the three methods of testing is chosen, it cannot be dispensed with. In this method the actual advance of the register of the meter is obsërved for the passage of a measured amount of energy through it. Each of the four tests (a) - (d), desdribed in Section 2.2, is carried out as a comparision between the movement of the dials of the test meter and the recorded rotations of the disc of the rotating substandard. The two meters are started simultaneously on the required load and, after a suitable time interval, stopped simultaneously. The regulation of the duration of the test load to an exact number of t seconds is obtained by means of a flexible cord in the voltage circuit of the meter. A flashing device actuated by a standard clock is better for this purpose than a stopwatch. The duration of the test must correspond to not less than ten revolutions of the pointer of the last (or lowest reading) dial.

Advantages -

(a)   Complete elimination of errors due to starting
        or stopping of the substandards or stop watches.

(b)   No need of any necessity for holding the load
        absolutely constant.

(c)   Complete verification of the accuracy of the meter
        as an integrating instrument because the verification
        of substandard meter is done by measuring energy in
        terms of power and time.

(d)   Errors due to self heating can be determined by this
        test. For this purpose, after the end of such a test,
        short time test at full load is performed.

Disadvantages

(a)   Large period of time required for a single test - and
        thus for the complete set of tests.

(b)   Not a suitable method if adjustments to the meters
        have to be made during testing.

2.3.2   Short-time Test against Rotating Substandard

        In this method energy corresponding to a stipulated
integral number of revolutions of the rotor of the test meter
is measured by means of a substandard meter which registers
revolutions and fractions of a revolution of its moving
element.

        Number of revolutions of the rotor of the test meter
is stipulated, and when the substandard meter registers in
rotor revolutions and fractions thereof, the advance of the
substandard corresponding to the stipulated revolutions of
the test meter is calculated.

Let r = counted revolutions of the meter under test

        R = counted revolutions of the substandard meter

        k_h = watthour constant of the meter under test

        K_h = watthour constant of the substandard meter

        R_o = revolutions of the substandard meter, if the test meter was hundred percent accurate.

$$= \frac{r \; k_h}{K_h} \quad \text{(since then } R_o \; K_h = r \; k_h \text{)}$$

Percentage error is thus

$$\frac{\text{Calculated revolutions - observed revolutions}}{\text{Observed revolutions}} \times 100$$

The test is normally, carried out for between 5 and 100 complete revolutions of the disc of the test meter. As the disc may make some hundreds of revolutions for one revolution of even the last dial of the meter, the time for this test is of the order of two minutes, as compared with something of the order of an hour for a long-period dial test.

Advantages -

(a)   The adjustments to the test meter and repetition of the test are possible without an excessive waste of time.

(b)   Avoidance of load holding.

(c)   Elimination of errors due to starting and stopping.

(d)   Constancy of test load is not essential and hence only one observer is required.

Main disadvantage of the test is that the short
period of the test at each load prevents the meter from
reaching a steady temperature at that load.

2.3.3. Test by substandard indicating Instruments and Time Measurement

In this method the actual ratio of speed to watts
is compared with that for which the gearing constant is suited.
The value of power in the test circuit, actual, or nominal at
a declared pressure, is measured by substandard indicating
instruments, and the accuracy of the performance of the meter
is assessed by the measurement of time interval required for
a stipulated number of revolutions of the rotor of the meter.
In the practical application of this method the time actually
required for the execution of a definite exact integral
number of revolutions of the meter rotor with a stipulated
load is compared with the nominal time which corresponds to
the gearing constant.

If watthour constant of the meter $= k_h$, then correct
time required in any condition is given as

$$seconds = \frac{K_h \times revolutions \times 3600}{volts \times amperes}$$

From this the time required for three different loads (at a
stipulated voltage) may be calculated. If the three observed
timings agree with their corresponding calculated (correct)
values the meter is correct.

If the correct time is T_1 and the observed time T for N revolutions, the actual rotor speed is N/T and the correct speed is N/T_1. The difference in these speeds expressed as a fraction of the correct speed is

$$\frac{N \left(\frac{1}{T} - \frac{1}{T_1} \right)}{N/T_1} = \frac{T_1 - T}{T}$$

The percentage error would then be

$$\frac{T_1 - T}{T} \times 100,$$

the meter being fast if $T < T_1$

If the errors are the same at the three test loads these errors are merely of calibration, and either the inherent speed/load characteristic of the meter may be altered to suit the gearing constant or the gearing constant may be altered to suit the actual characteristic.

Notable advantage of this method is the superior accuracy of standard wattmeters in comparision with rotating standards.

Disadvantages

(a)   Ceaseless vigilance is required to maintain the load constant at its stipulated value during the test.

(b)   Careful regulation of the load throughout the test period by an observer additional to the one who actually measures the time interval.

2.4 Stroboscopic Testing

The stroboscopic method of testing is most useful when large batches of metres of similar rating are to be handled and adjusted rapidly. A beam of light is directed perpendicularly at the edge of the disc of the substandard meter (Fig. 2.1). This edge has teeth which alternately intercept and pass the beam. When the beam, is passing through a space between teeth, it activates the photoelectric cell whose output is amplified to flash a neon lamp placed near the disc of the test meter. This disc is marked with regularly spaced black spots. These spots appear to standstill if the meter speeds are the same, as should be the case if both are accurate or have the same error and both have the same watthour constant. If the meter speed is too high, the apparent motion of the disc will be forward at a rate corresponding to the meter error relative to the substandard, and vice-versa.

The adjustment of the test meter consists in setting the position of the brake magnets so that the disc appears to be stationary. This method has been refined for the determination of actual meter errors by direct indication. The substandard is provided with a specially calibrated brake magnet adjusting device, geared to a dial indicating deviations from correct speed in percentages fast and slow. The speed of the substandard is adjusted to exact correspondence with that of the test meter, and the error of this meter is read off directly on the special dial.

LIGHT SOURCE

LENSE

SUBSTANDARD METER DISC

TEST METER DISC

INDEX POINTS

LENSE

POWER SUPPLY

AMPLIFIER

NEON LAMP

PHOTO-ELECTRIC CELL
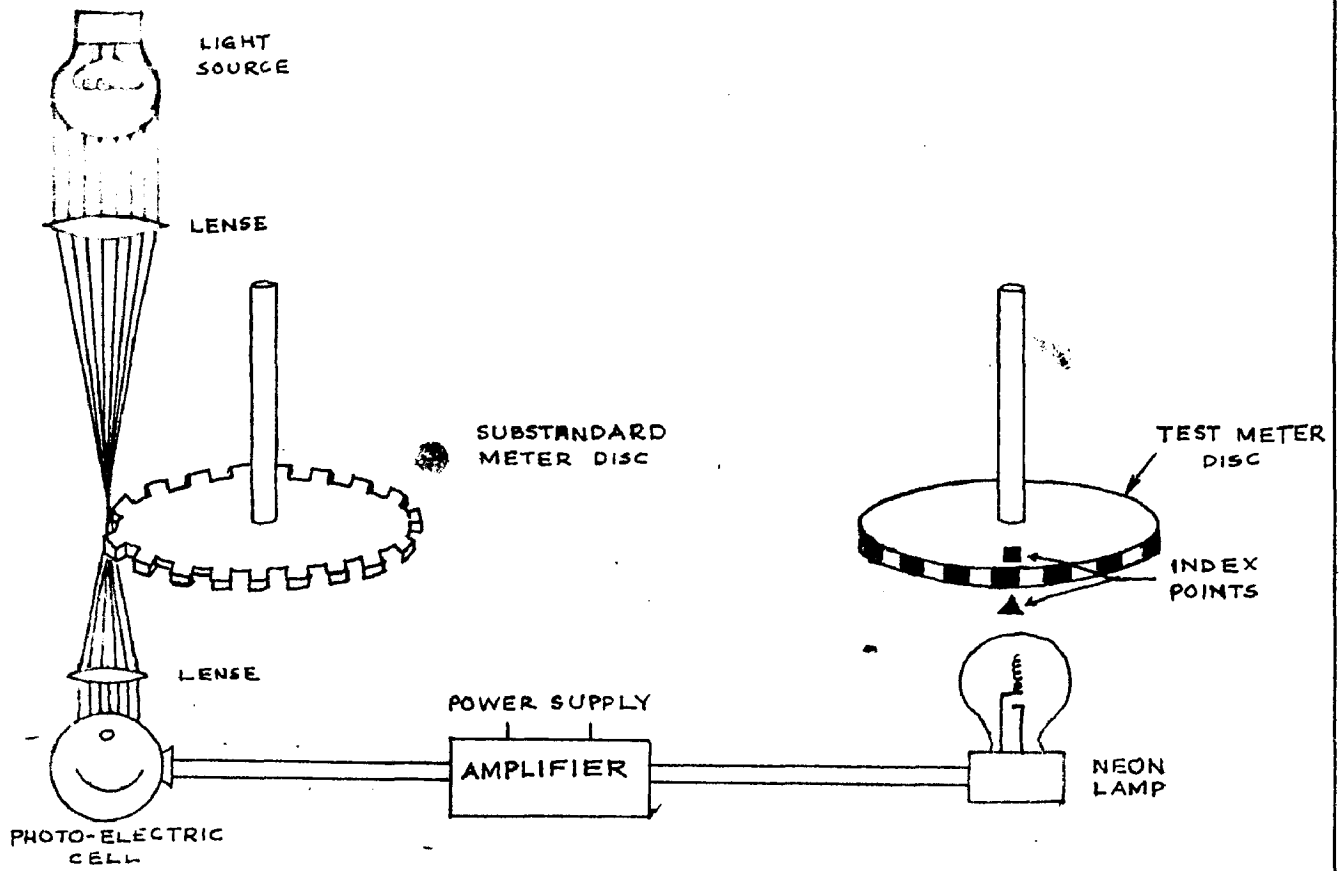
FIG. 2·1: STROBOSCOPIC METHOD OF TESTING

FROM PHASE SHIFTER

A

3-WIRE SUBSTANDARD METER
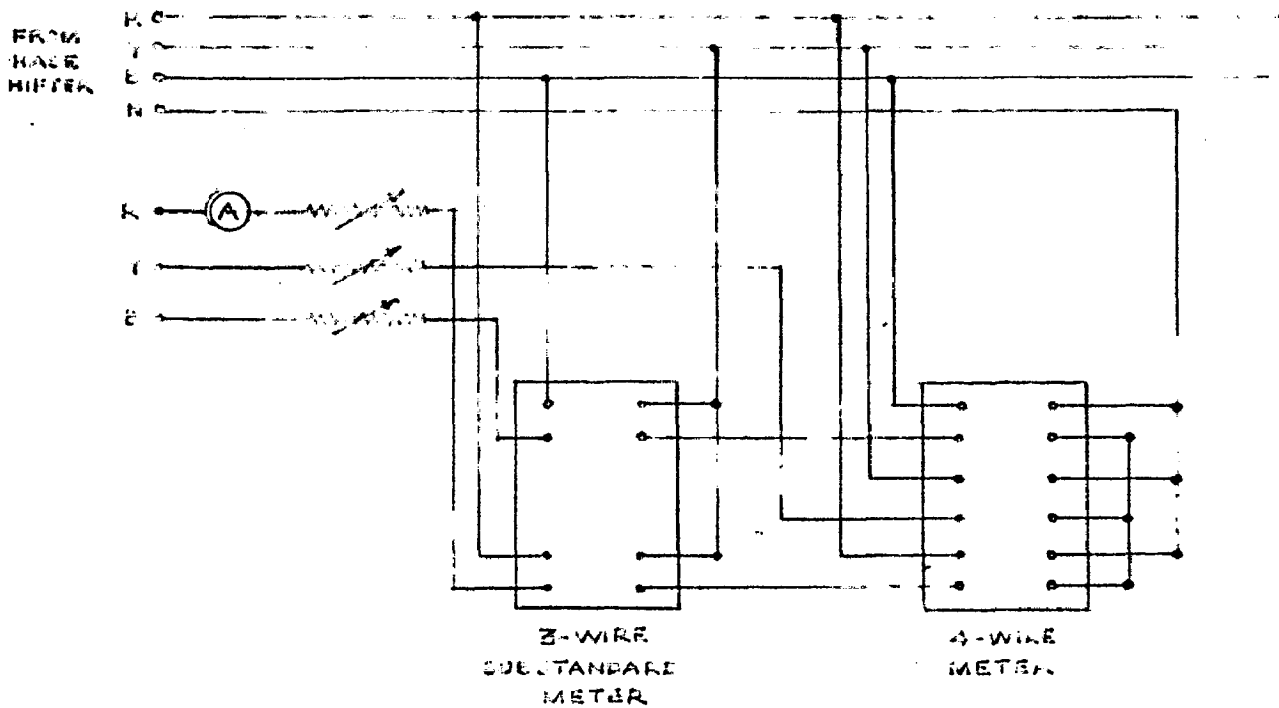
4-WIRE METER

FIG. 2.2: TESTING 3-PHASE 4-WIRE METERS

Advantages

(a)   Error is indicated at once.

(b)   The method affords a means of adjusting the meter
        during the run and thus substantially shortens the
        time required for testing.

(c)   It also eliminates many opportunities for mistakes
        in calibration and in recording the sign of the error.

(d)   Measurements of the time intervals and personal error
        incident thereto are avoided.

(e)   The method is accurate as the setting of the brake
        magnet is made with certainty.

One of the important limitations of the test is
that it is inherently suitable for test loads not less than
half the rated full load of the meter. At the lower
loads the disc speeds are so small that this method becomes
unreliable or fails entirely to give its characteristic
phantom differential speed effect. Some manufacturers have
adapted the method to low load testing by temporarily substi-
tuting, for the ordinary brake magnets of the substandard and
test meters, special low flux magnets which increase the
meter speeds tenfold.

2.5 Creep Test

Energy meters are tested for creep with its current
circuit open and with 110 percent of the rated voltage applied
to its voltage circuit under these conditions the disc of the
meter should not make more than one revolution.

2.6 Low Power Factor Tests

There may be difference between the errors of an a.c. meter at full rated VA at 0.5 power factor and at the same watt load at unity power factor. To check this a.c. meters are tested at full rated VA and 0.5 power factor lagging. A tolerance of 10 percent is allowed in the power factor for this test.

2.7 Verification of Substandards

Meter testing regulations require that all the meters submitted for certification shall be determined by substandard instruments which are themselves periodically tested, either directly or indirectly. The approved apparatus for any testing station is listed below:-

Standard Apparatus : D.C. potentiometer, standard cells, voltage dividers and resistance standards for current measurements.

Ship's chronometer or pendulum clock.

Substandard Apparatus : Indicating wattmeters, ammeters, voltmeters, rotating meters, stopwatches or other timing devices.

Current, voltage and phase control apparatus.

Verification of substandards is briefly discussed below -

2.7.1. Verification of Indicating Substandards -

The verification of a substandard indicating meter consists essentially in comparing the true with the indicated

values of the quantity purpoted to fbe measured by the
instrument approximately at stipulated points of the scale.
There are two ways in which this comparision may be made.
First, the quantity to be measured may be adjusted to such
a value that the pointer of the instrument deflects exactly
to a position on the scale representing the value of the
quantity measured, its true value then being measured by the
standard potentiometer. Otherwise the value of the quantity
measured may be adjusted to be exactly equal to the nominal
value required by means of the potentiometer, and the actual
instrument reading in this condition observed.

2.7.2. Verification of Time Substandards

Substandard stopwatches can be verified for accuracy
very easily by a standard instrument with a seconds dial. A
comparision of the stopwatch reading with the advance of the
standard chronometer or clock over a period of 5 minutes
reveals any error of the order of the maximum of 0.15 per
cent, permissible with certainty. In practice any stopwatch
exhibiting an error of more than 0.1 per cent, that is, an
actual error of 0.3 seconds in 5 minutes, is subjected for
examination and regulation. The indicated error of a stop-
watch is inclusive of the error of starting and stopping, and
this will vary with the observer.

If the standard clock is not fitted with a seconds
hand, stop watches must be tested by the counting of pendulum
swings. To make this tedious process convenient and less

liable to error the standard clock is fitted with an optical device. In this a shutter attached to the pendulum bob allows a light flash to pass from a lamp, through the operature in the shutter, every time it reaches one extreme limit of its swing. By means of a suitable mirror the indicating flash is made visible at a test bench. The position of the lamp is required to be accurately adjusted by trial, so that the flash is given at the extreme point of the travel. Any error in this position will result either in no flash being obtained or in the flash being double. After making the adjustment once, the integrity of the flash is a very good indication of correctness of swing of the standard clock.

2.7.3. Verifying Substandard Integrating Meters

As in two of the three approved methods of testing the meters are tested by comparision with substandard integrating meters, these must itself be verified by indicating substandards. Testing of substandard D.C.meters is similar to that of ordinary supply meters using indicating instruments and stopwatches.

A special technique, in addition to the testing by indicating substandards is used for the testing of A.C. substandard meters. In this the time during which a load of measured power passes the meter is regulated automatically by a standard clock. The automatic time control is obtained either by special contacts fitted to the 'scape' wheel shaft

of the clock or by light flashes received by a photo-electric
cell and transmitted electrically to an impulse relay. The
voltage circuit of the meter is closed and opened by a
contactor relay controlled indirectly by the clock, so that
the voltage circuit current of the meter flows during a time
interval which is exactly equal to a prescribed number of
seconds. The advance of the register in revolutions and
fractions of a revolution of the moving element is compared
with the energy corresponding to the measured constant test
power flowing for the time period controlled by the standard
clock.

This method of testing avoids two sources of error:
first, the inherent error of a stopwatch, and secondly, the
observers error in either starting and stopping the meter
in a dial advance test.

2.8 Testing 3-Phase Meters

Every 3-phase meter must be tested in 3-phase circuit.
Three-phase 4-wire meters may be tested in 3-wire circuits
which supply the testing currents, in which case the total
power in the phantom test load can be measured either by two
wattmeters or by a 2-element polyphase wattmeter; alternati-
vely, tests can be made by substandard 2-element meters. With
this method of testing 4-wire meters the common terminal of
the three voltage circuits is connected to the neutral of
the voltage supply. The sedimentary connections for testing
a 4-wire supply meter by a 3-wire substandard are shown in
Fig. 2.2.

The technique of testing 3-phase meters by substandard integrating meters, by either short or long-period method, differs in no way from that of the testing of single phase meters other than that of setting the test loads to the required magnitude and to the balanced condition. When, however, 3-phase meters are tested by means of indicating substandards, the maintenance of a steady load during testing is not so straight forward. If the power in the phantom 3-phase test load is measured by a single polyphase substandard wattmeter, small adjustments can be made to one of the three variable loading resistances to maintain the required indication of the wattmeter, as these small adjustments do not cause sensible departure from the balanced condition of the load. If, however, the total power in the phantom load is measured by two substandard wattmeters it is by no means easy to maintain an absolutely constant value of this total power by adjustment of a loading resistance, if the supply voltage is not quite steady, because with a star connected load, such adjustment will alter the power indicated by each wattmeter. It is practically impossible to maintain a 3-phase test load, supplied by a varying voltage, at an absolutely constant value by adjustment if the total power is indicated by two wattmeters, because one observer cannot keep the indications of wattmeters under continual observation.

In addition to the usual tests with a balanced load, every polyphase meter must be tested for balance of elements. In such a test both voltage circuits are tested in the normal way and full load current is passed through each element in turn. These tests are carried out at power factors of unity and 0.5 lagging, thä later power factor being subject to a tolerance of 10 per cent. It is to be noted that, in the balance test, unity and 0.5 power factors refer to the single-phase load actually producing torque in the meter when a star connected test load is used, the balance test is conveniently carried out with one line supply to the load interrupted, as shown in Fig. 2.3.

2.9 Testing Reactive Meters

As the only meters requiring certification are those which register kwh, there is no officially approved procedure for testing the accuracy of a meter which either registers KVArh or which is a component of a meter registering KVAh. If substandard instruments indicating 3-phase VAr were available, the testing of reactive meters would be similar to the testing of 3-phase energy meters. A polyphase substandard watt-meter or Wh meter can be made to indicate 3-phase VAr by supplying its voltage circuits from a bank of two voltage transformers arranged in open delta[4].

The normal tests of a reactive meter are carried out at zero power factor when the VAr equal to the VA. In addition, the behaviour of the meter with rated VA unity power
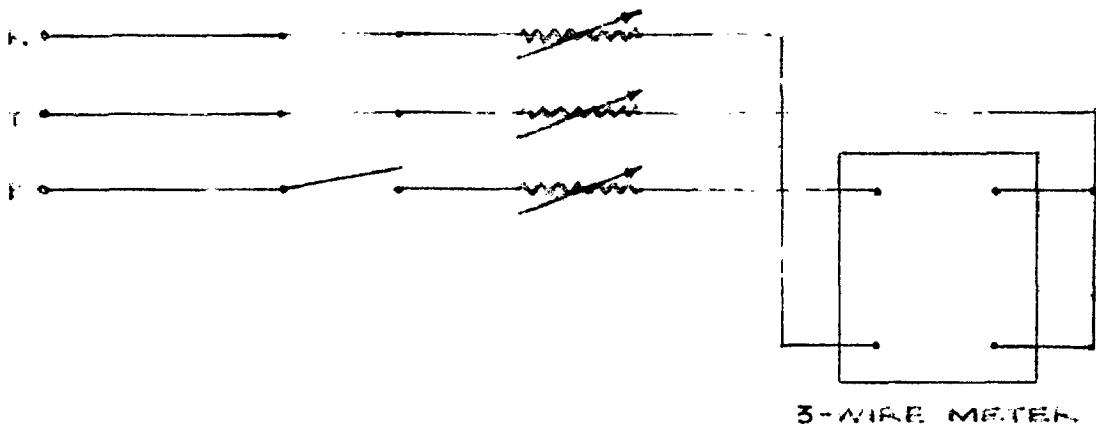
FIG. 2·3 : BALANCE TEST FOR 3-PHASE METER

3-WIRE METER
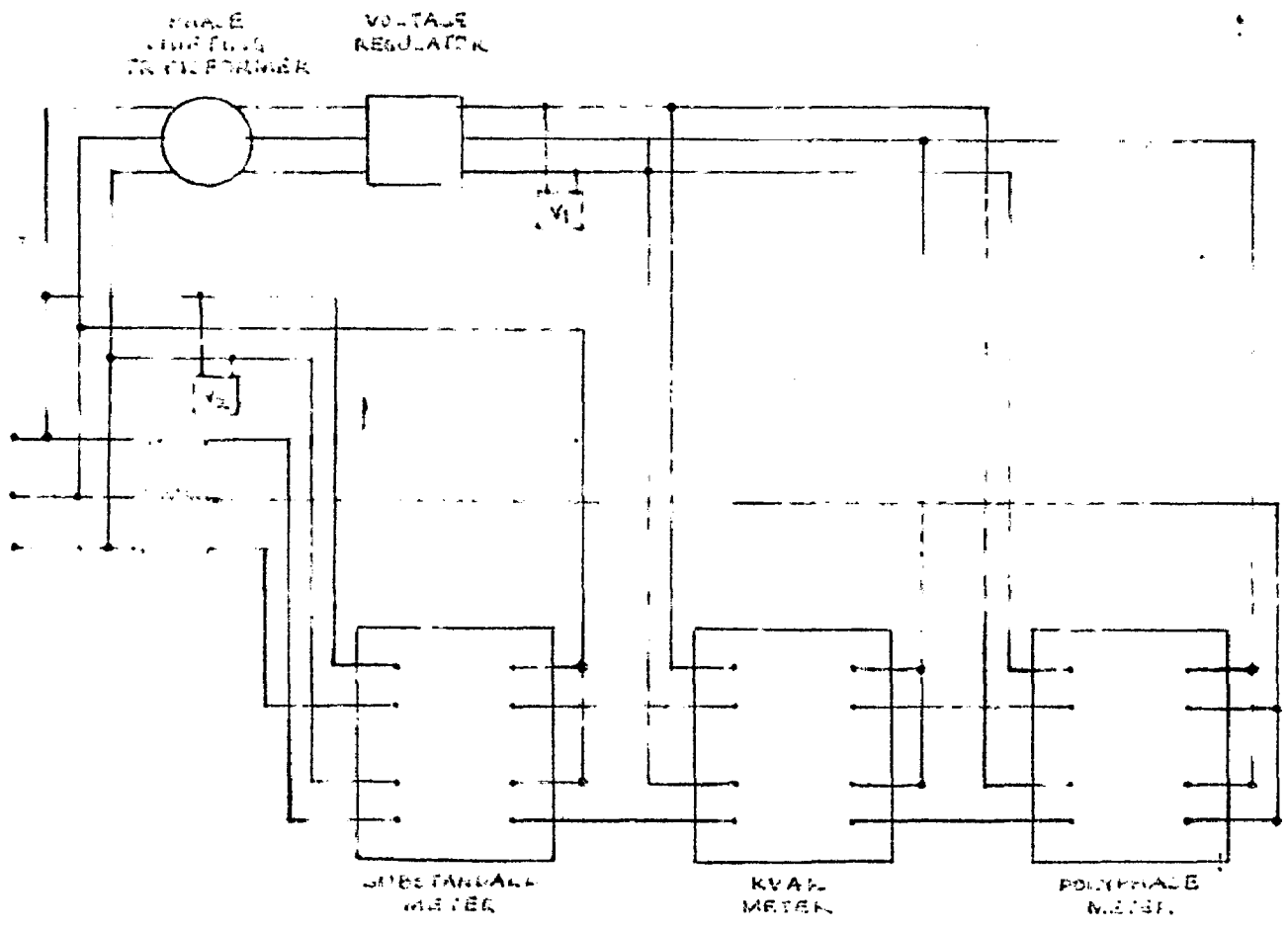
FIG. 2·4 : TESTING KVAR METERS

factor and zero VAr is observed and a test is made with an intermediate lagging power factor. The test for balance of the elements of a polyphase reactive meter is made with normal voltage excitation and with current in each element singly.

If there are no means available for the measurement of VAr or VArh directly by substandard instruments, indirect methods are used. A straightforward indirect method of obtaining 3-phase VAr is to obtain the watts by actual measurement and VAr from ammeter and voltmeter readings. This method is combersome and undesirable as it involves simultaneous readings of three ammeters, three voltmeters and one or two wattmeters, together with an awkward calculation. Moreover, this method is only fundamentally accurate with a balanced load, but the error with small unbalance is practically negligible.

Another indirect method of obtaining the VAr measure of a balanced 3-phase test load is from the readings of two single-phase wattmeters used to measure the power. $\sqrt{3}$ times the difference of these readings will give the 3-phase VAr if both currents and voltages are accurately balanced. The disadvantage of this method is that the accuracy of the VAr measure so obtained depends so much upon the balance of the currents and voltages.

Third method involves the use of a phase - shifting transformer. The VAr value is obtained indirectly from the reading of a substandard wattmeter. The reactive meter to be

tested is connected in an ordinary 3-phase double circuit, which the voltage supply is derived from the secondary circuit of a phase-shifting transformer. A polyphase substandard meter is included in the circuit.

Neither of these three indirect methods can be considered as anything more than a makeshift. The only satisfactory way to test a reactive meter is by reactive substandards, and the most satisfactory available substandards for this purpose are ordinary substandard wattmeters or integrating meters used with substandard voltage compensators. The accuracy of such substandards will, of course, depend upon exactness of balance of the supply voltages, and if unbalance errors of the substandards are similar in magnitude and phase to those caused by voltage unbalance in the reactive meter, the test will indicate the accuracy of the meter in balanced voltage conditions. No test of a reactive meter can be considered conclusive till single-phase internally compensated reactive substandards are available of an accuracy at standard frequency, comparable with that of a substandard wattmeter.

2.10 Testing Kilowatt Demand Indicators

The accuracy of the Merz demand indicator, provided the associated meter is free from error, will depend upon the accuracy of the gearing ratio controlling the advancement of the pointer and the accuracy of the averaging periods. When the averaging periods are controlled by an external time

switch, this switch can be checked for accuracy seperately, and the accuracy of the demand indicator gearing can be tested by a procedure similar to a long-period dial test. The corresponding advances of the sub-standard meter will give the true values of the average power corresponding. The tests should be conducted at full load and about one-quarter of full load. When the averaging periods are controlled by a self-contained clock, the substandard meter reading must be observed at the commencement of each averaging period and the time durations of these periods simultaneously measured. The true average KW in this case will be obtained from the substandard advances and the observed times.

2.11 Testing KVAR Meter and KVA Demand Indicators

These instruments are of four classes : KWh and KVArh combinations with a seperate KVAh mechanism, phase-compensated KWh meters, current-operated instruments with voltage compensation and KWh meters with fixed phase compensation which are accurate at one power factor only.

The first steps in testing an instrument of the first class are to test the KWh and KVArh components seperately by the methods which have already been described. The KVAR register and KVA demand indicator should then be tested by methods corresponding to a long-period dial test and to an ordinary KW demand indicator test at KVA loads of various power factors. The method of testing will, provided the KVA load be known, follow the standard procedure, but it is

difficult to measure the KVA value of a 3-phase test load
over a range of power factors, one method of doing this is
illustrated by the schematic diagram (Fig. 2.4). The KVA
instrument is tested without its current transformers, as
a 5-Ampere instrument. This meter, together with a sub-
standard 3-phase watthour meter and a substandard polyphase
wattmeter, carries the current of a non-inductive test load.
The substandard watthour meter voltage circuits are in para-
llel with this load, those of the KVAh meter and the poly-
phase wattmeter are energised from the secondary of a phase-
shifting transformer. The magnitude of the voltages applied
to the KVAh meter is adjusted by the voltage regulator to be
exactly equal to those applied to the substandard watthour
meter, this equality being indicated by the voltmeters V_1 and
V_2. In this circuit the phantom volt-amperes in the KVAh
instrument and in the polyphase wattmeter are the same as the
actual volt-amperes in the substandard watthour meter, and,
as the load of the circuit containing this latter meter is
non-inductive, the rate of advance of the substandard meter
will correspond to the KVA in the phantom load for all values
of the power factor of this load. Thus, setting the rotor
of the phase-shifting transformer to give the desired values
of power factor of the phantom load in the KVAh meter, the
advance of the KVAh register or of the KVA indicator should
correspond to the advance of the substandard watthour meter.
The polyphase substandard wattmeter is used to obtain the

position of the phase-shifter rotor corresponding to zero power factor, indicated by zero reading of the wattmeter. Thereafter the movable pointer of the phase-shifting transformer is set to 98 degrees in the usual way. The power factor of the phantom load in the KVAR meter will thereafter he directly indicated on the power factor scale of the transformer KVAh meters should be tested at zero and unity power factors and two or three intermediate power factors which should not, preferably, correspond to phase angles which are an exact submultiple of 90 degrees.

The foregoing method of testing is defective, in that it does not follow the standard and most desirable practice of testing supply meters and associated current transformers as a single measuring unit. But this is overweighed by the convenience of obtaining a direct measure of the KVAh, as compared to the indirect methods, in the phantom test load by means of 3-phase substandard meter. The only adjustment to be made during tests of the KVAh register and KVA indicator is that of maintaining voltages V_1 and V_2 exactly equal.

The above mentioned method of testing is immediately applicable to KVAh meters with automatic phase compensation, the meter first being tested as a standard 3-phase energy meter in the usual way without its auxiliary relay and voltage dividing resistances, and at its normal voltage.

KVA demand indicators, which consist of a watthour meter with fixed phase compensation, can also be tested by the method just described at the nominal p.f. at which they

are correct. This p.f. can be set by the PST, and it can be checked by comparing it with the ratio of the wattmeter reading to the maximum reading which can be obtained by phase adjustment of the voltage. The meter should then be tested with the phase of the voltage shifted 10 degrees on each side of the position corresponding to the average p.f. to verify that, in each of these positions, a slow error of about 5 percent is obtained.

Three phase KVA demand indicators containing three current operated electromagnetic elements should be tested for balance at two or three loads, the voltage-compensating circuits being excited, and current, of a phase corresponding to balanced load conditions, being passed through each element in turn. The speed of the rotor should be the same for the same current in each element, but there is no definite relation between speed and current. Thereafter the meter will be tested as a 3-phase KVA demand indicator at selected points of the scale at constant 3-phase loads corresponding. The test at rated full load may be carried out at three or four values of p.f. and at unity p.f. with values of the applied voltage 10 percent above and below the rated value to check the accuracy of the voltage compensation.

CHAPTER-3

ELECTRONIC AND COMPUTER TESTING

3.1. ELECTRONIC TESTING

In the field of meter testing electronics has been introduced for carrying out objective measurements. There are, for example, crystal clocks, photoelectric scanning equipment, which has come into general use, and electronic counters for counting the revolutions of meter discs or the pulses of calibrating meters.

3.1.1. Stroboscopic and Counter Method

This method has been discussed by M.L. Done[5] and A.J. Bagott[6]. In this method, shown diagramatically in Fig.3.1, a rotating substandard is fitted with a pick-off device, either of photoelectric or inductive pattern arranged to give either 200 or 400 impulses per revolution of the disc. The output is amplified and switched to either a strobe lamp fitted with a flash tube or else, through dividing circuits to a series of counters, one for each meter.

The rotor of the meter under test is impressed with markings which are arithmetically identical to the subdivisions on the disc of the rotary substandard and under the action of the stroboscope an indication of the performance of the test meter is given. On low loads stroboscopic method can not be used and here, and also, for obtaining actual figures on higher

SUB STD. METER

AMP

DECADE C.T.

PRECISION C.T.

CURRENT SUPPLY

STROBE METHOD
COUNT SWITCH

STROBE LAMP

COUNTERS

METERS
UNDER
TEST

MULTI – SEC. V.T.

VOLTAGE SUPPLY

FIG.3·1: STROBOSCOPIC AND COUNTER METHOD

STANDARD PULSES

ELECTRONIC COMPUTER

G

COUNTER

REGISTER

START; STOP

DETECT PULSE

MEMORY OF
SIGNAL
&
COUNT

INTERRUPTION
PROGRAM
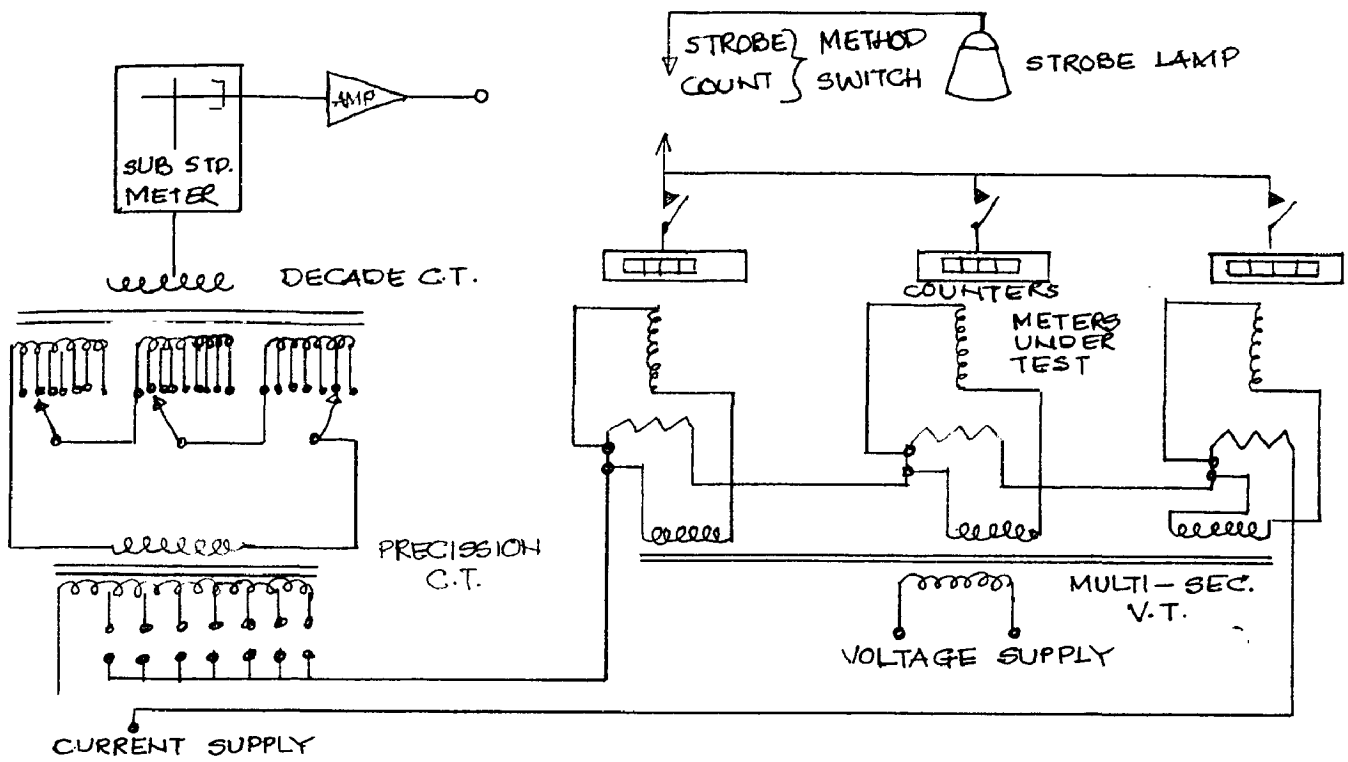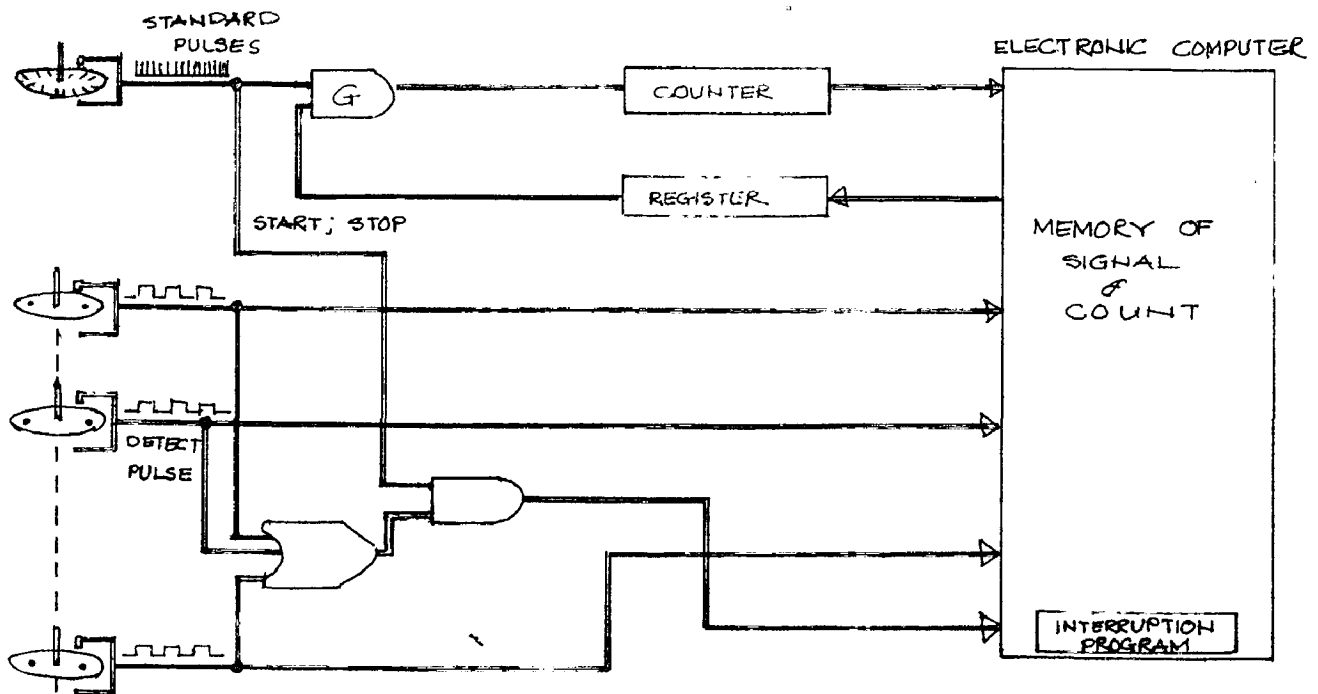
FIG.3·2: COUNTING SYSTEM.

loads, the counters are used as timers. The speed of the PSS
meter and the division factors are so arranged that the counters
record 1000 for an integral number of revolutions of the test
meter, enabling the error to be read directly to the nearest
0.1%. The counters normally started and stopped manually could
be operated automatically.

3.1.2. Calibration and Repair Bench

M.L. Done[5] has discussed a testing, repair and calibra-
tion bench which can accept two batches of meters, fifteen each,
with calibration facilities capable of being transferred from
one batch to the other. In operation, one batch is being repaired
while the other is being calibrated, the calibration facilities
are then transferred to the first batch while the other is
moved on for dial test and a new batch put up and repaired.

3.1.3. Automatic Load Holding Facility

Another device given by M.L. Done[5] is an extension
to a conventional test set whereby the total load on the meters
under test is controlled to a predetermined. level on an inte-
grated energy basis. Stop watches may then be used to time meters
in the normal way.

3.1.4. POWER TIME METHOD FOR PRECISION METERS

A system particularly suitable for the calibration and
testing of precision watt hour meters as well as precision
standard watt meters, single and three phase, has been described

by J. Pawlat[7]. It functions by the power-time method. With
the use of self- balancing comparators for the power measure-
ment and an electronic controller of original design, an accu-
racy and stability of the power control of better than $\pm$ 0.05%
is obtained. The development described in this paper aims
firstly at eliminating the necessity for the potentiometer
and manual regulation of the d.c. control and, secondly, auto-
matically to control the a.c. (power). One of the main advantage
claimed by eliminating the potentiometer with its manual con-
trol is the reduction of the response time from about 4 seconds
to 200 milliseconds.

3.2. AUTOMATIC METER TESTING

The automation of meter testing is a subject which
has aroused considerable interest in recent years and a number
of papers has appeared in literature on installations which
involved automation in various degrees.

3.2.1. Automatic watthour Meter Test Equipment Controlled by Electronic Computer

This test equipment was developed by Japan Electric
Meters Inspection Corporation[8]. It can test 60 meters per hour
with an accuracy within $\pm$ 0.2%. The equipment consists of
meter desks, electronic computer, a controller, power supplies
and a control panel. The errors of the meters are measured by
comparing the speed of their discs with that of a precision
rotating standard, and then calculated and printed automatically

according to the computer program. The comparison of speed is carriedout by counting the standard pulses from the precision rotating standard by means of a counting system shown in Fig.3.2. On receiving the ' start ' signal, gate G is opened and counter starts. Whenever, one or more signals of the meter came to the 'OR' circuit, its output signal is synchronised with the front edge of the standard pulse through the ' AND ' circuit and sent to the computer as the ' Interruption ' signal. The computer calculates the error and registers it. A definite count is preset so that the last bit (14th bit) of the counter means the 'stop ' signal. The count preset is determined keeping certain consideration in view.

(ii) Comments : The measuring accuracy of the equipment is determined by the following :

(a)   Counting accuracy,

(b)   The accuracy due to the fluctuation in one revolution. of the standard,

(c)   Variation in the power supplies and ambient conditions.

Efficiency is determined by the time taken for self heating which is more than 30 minutes.

Advantages : The advantages which make the equipment economical, reliable and easy to maintain are :

(a)   Saving of detectors and their change- over switches by using the horizontal driven detecting device.

(b)   Saving of counters by using computer counting system.

3.2.2. Computer Controlled Automatic Testing

D.F. Ashton[9] proposed that automatic meter testing can be employed which will assist the testing staff. This may be controlled through a testing cycle based on either method B or C (described in section 2.3.) by a digital computer which will also handle stores records and meter documentation, including production of the certification sheet entry. Figure 3.3. shows how the test operators work in conjunction with the computer controlled test bench. This system based on a work study, shows that two operators could handle 86,000 meter per annum and that in testing time of 10 minutes (statutory time for methods B or C) each operator could perform the manual tasks for eight meters. A layout for an automatic test bench which will realise this productivity has also been suggested by the author. Batches of four meters only are loaded alternatively onto two moving belts which carry the meters through the stages of meter warm up, automatic load testing and computer supervised. The control console would have a purpose built keyboard arranged to assist the operator in correctly inputting the computer data in shortest possible time. The programming of the computer would be arranged to indicate to the operators what their next function should be i.e. load meter to indicated position, take dial reading, etc., etc. The operators would remain in overall control by failing to perform the next indicated step. At this point, testing would continue on those meters at present on the test cycle but the bench would not advance to the next operation and
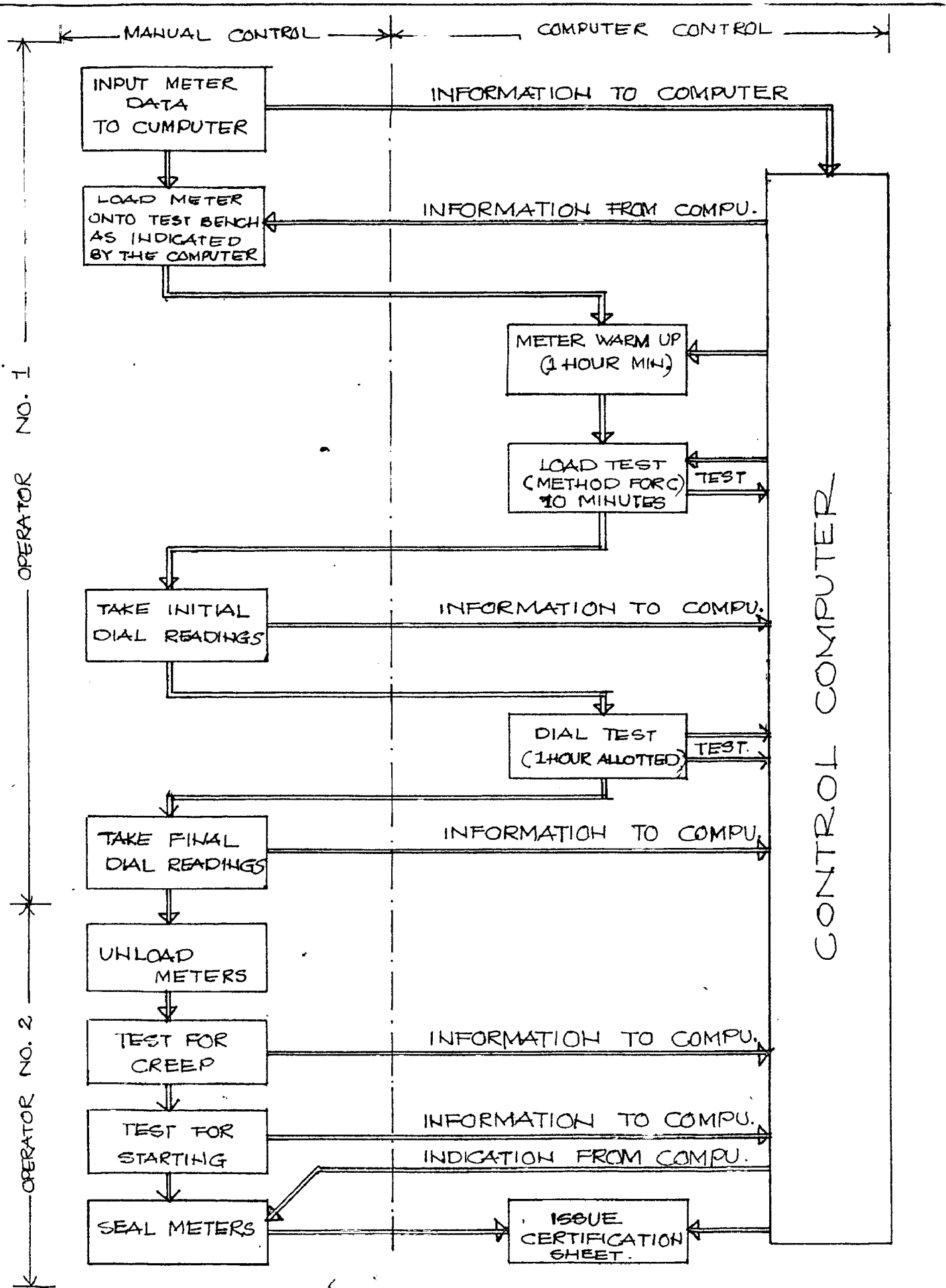
FIG.3.3: BLOCK DIAGRAM OF COMPUTER CONTROLLED AUTOMATIC TESTING

would revert to a standby condition of meter warm-up until the missing operation hadbeen completed.

After all testing has been completed, the computer indicates whether the meter is satisfactory or not. Meters successfully passing all the tests will then be sealed and will be returned to stores. Meters failing test will not be sealed and will be returned to the calibration section alongwith a print out of the full test results.

3.2.3. Automatic Test Equipment

An installation at Bexleyheath[60] comprises two duplicate test equipments, or precalibrators which can be operated independently to feed four dial test benches each carrying 60 meters in single rows (Fig.3.4). The precalibrators contain normal power units, control and monitoring instruments appropriate for testing a single meter. Before the test cycle can commence a quick set adjustable probe is adjusted to the disc of the meter under test to obtain information and control the test programme.

The supplies to both meters are provided conventionally except that four separate outputs, solenoid controlled, permit the pre-set loads to be applied to both meters in series according to the selected programme. The rotating standard meter is fed via variable ratio current and voltage transformers adjusted so that its speed is equal to the theoretical speed of the test meter.

The test cycle is programmed by the meter under test, controlling the load changes and error determination. An output

FIG. 3.4 : AUTOMATIC TEST EQUIPMENT

ULTRA-VOILET SOURCE

METER UNDER TEST

SIGNAL: 1 IMPULSE PER REVOLUTION

AMPLIFIER

PARALLEL INPUT PRINTER

SEQUENCE CONTROL

GATES

GATE

SIGN AND ERROR DETECTOR

ERROR DIFFERENTIAL

DECADE COUNTERS

F.L.

0.5 P.F.

HALF LOAD

LIGHT LOAD

GATES

SUPPLY

STANDARD

SIGNAL : 500 PULSES PER REVOLUTION

AMPLIFIER
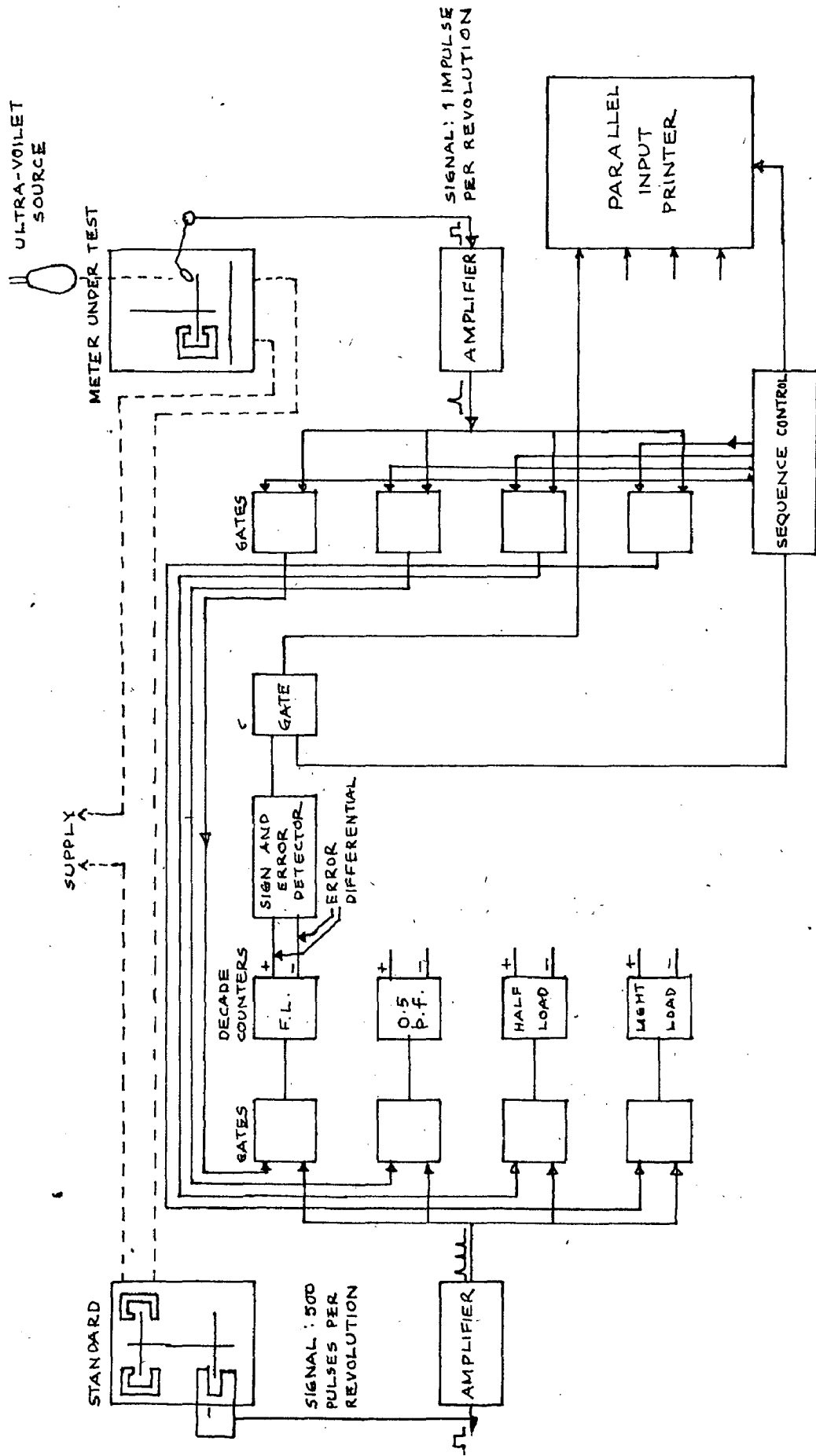
signal for each revolution is taken from the meter disc, each
signal representing a definite stage in the testing programme
either starting or stopping the registering counters or advan-
cing the programmes so allowing comparison at each of the four
loads.

The standard meter, with whose speed the speed of the
testmeter is compared, is fitted with a photo-electric trans-
ducer and provides for a count of 1000 impulses if the meter
under test is error-free. Deviations from this count represent
errors in units of 0.1%. The count is displayed separately for
each load and percentage error for each is printed out.

The signal output from the standard meter, after ampli-
fication, is fed to four separate decade counters giving a
four figure display for each load. A parallel entry printer
is used to record the meter errors and its prints out the diff-
erence between the signal count and 1000.

The printer takes its information from the counter sys-
tems via a sign and error detector. Print out is at the end of
the programme cycle when the four load counts are displayed.

The equipment has built in facilities for reducing
the number of loads taken so that if a detailed investigation
at one load is needed repetitive checking at this load can
take place. For stability and other investigations this is a
useful way to obtain vital information.

3.2.4. Fully Automatic Meter Testing System

E.F. Haerdle[10] has described a fully automatic meter testing system which -

1)   can test upto 40 meters simultaneously and fully automatically,

2)   works with test records in the form of punched cards,

3)   and produces the meter records necessary for administration, so that manual punching is no longer necessary and the meter records are kept automatically.

The test arrangement consists of the meter installation as such, the electronic control equipment, the recording and processing apparatus for the measured data, the punched tape output. The meter test installation is conventional in principle. The electronic control assembly consists mainly of the American Packard Bell 250 computer instructions to be followed and the operands necessary for the computing are stored in a single store. The store consists of a number of magnetostrictive conductors, in which the information is propogated in the form of a pulse train of torsions of the wire. At the two ends of each wire there is a write out coil and a reading coil to transform electric pulses into torsion pulses and to perform reverse transformation respectively.

A special electronic device records the measuring data coming from the test equipment in the form of pulses and processes them in such a way that they can be taken over by the stores in the computer.

The method of measurement used is an energy comparison method. If the meter is correct,the number of pulses counted in an electronic counter are equal to the rated value.

While the first group comprising 20 meters is tested, the 20 meters of the second group are preheated in their suspension frames. This is followed by no-load and half-load tests.Meanwhile the photoelectric scanning heads- one for each meter are adjusted to the sensitivity needed for reading the marks on the meter head. When the maximum sensitivity of these heads has been adjusted the computer starts the precision test to interrogate continuously the calibrating meter aswell as the meters under test.

3.3. COMMENTS ON STROBOSCOPIC TESTING

Stroboscopic methods have the advantage of giving an instanteneous indication of the disc speed and may be used with an unmodified meter since the normal disc markings suffice.

These methods can easily be used for calibration purpose. The use of these methods for the calibration of high loads reduces calibration time while providing the requisite accuracy at these loads. It is, however, unsuitable for low load calibration. To cope with the diverse range of meters encountered in Area Board Test Rooms, precision current and voltage transformers and pulse test division techniques will extend the range of the method.

However, there are complaints that stroboscopic testing causes eye strain and operator fatigue, and to avoid these complaints a cathode ray tube display has been developed. Pulses derived from markings on the disc of the rotating substandard are filtered to produce a sinusoidal wave. This is used to produce a circular trace on a C.^{R}.T. Pulses from the disc of the test meter intensity modulate the trace giving a dashed pattern on the circle. If the test meter disc is rotating at the same speed as the rotating substandard disc then the pattern is stationary. This method is favoured by one particular manufacturer where the test meter pulses are obtained from an optical detector working on the serrated disc edge. In this scheme the C.^{R}.T. has now been replaced with a ring of light emitting diodes for greater reliability.

CHAPTER-4

NEW SCHEMES FOR AUTOMATIC TESTING

In this Chapter author has proposed a few schemes for meter testing incorporating automation in various degrees. The advantages and limitations of each scheme have also been dealt with.

Generation of pulses from the meters is achieved by placing uniformly spaced marks on the meter discs and using photo devices. This aspect has been discussed at length in the next chapter.

4.1. MANUAL START AND STOP (Fig. 4·1)

The pulses obtained from the substandard and test meters are counted by electronic counters over a fixed period of time. Computation of error from the two counts is done manually. The meters which are started manually, are also stopped in the same manner after the predetermined time has elapsed.

This scheme, as also the following schemes, involving electronic counting eliminate the error in reading and recording of number of revolutions by the human operator(s). As the number of revolutions of the meters for a fixed period of time may at many times not be an integral number, human operator is unlikely to read it accurately. Also different operators may read the same amount as different ones.
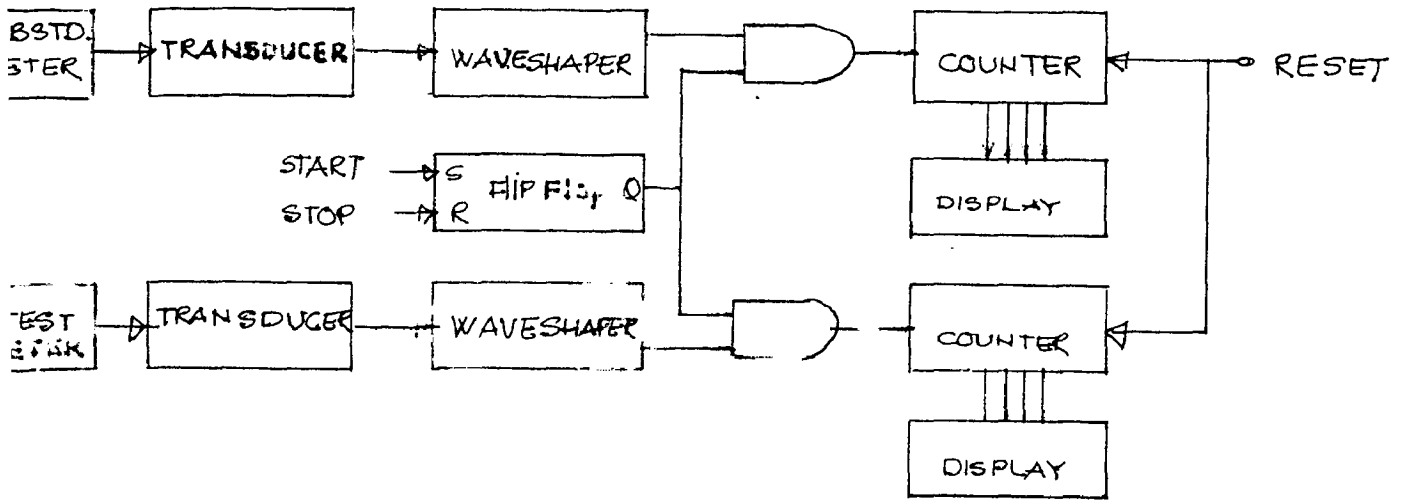
FIG 4.1: MANUAL START AND STOP
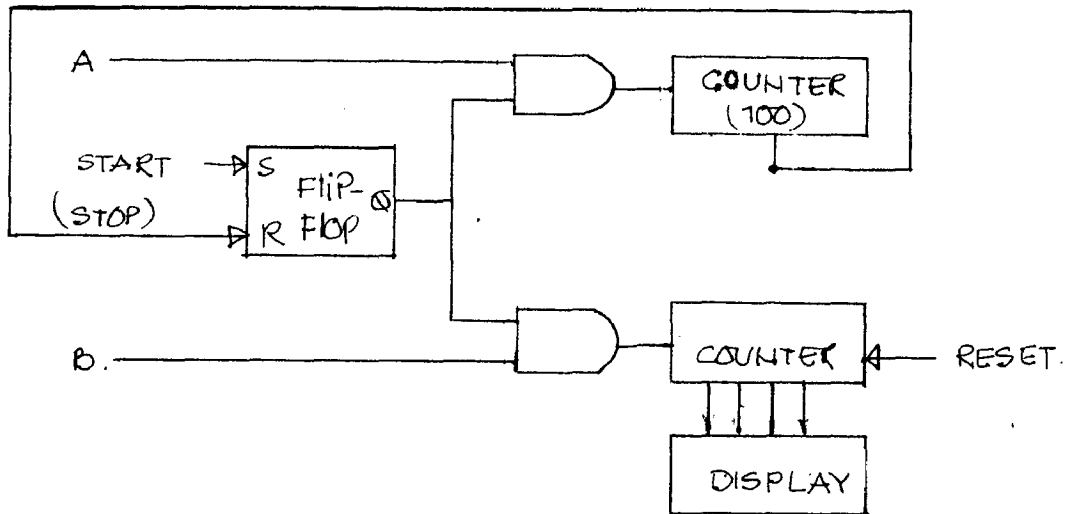
FIG 4.2: MANUAL START AND AUTO STOP
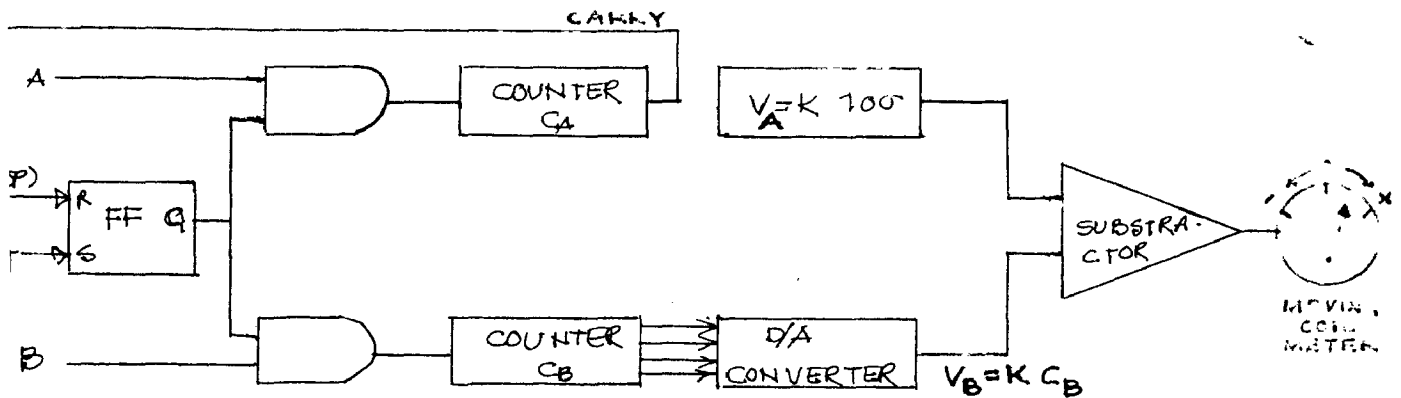
FIG 4.3: ANALOG ERROR COMPUTATION

4.2. MANUAL START AND AUTO STOP

In this scheme pulses from test meter are counted corresponding to a prefixed (say 100) number of pulses from the substandard meter. The two meters are started manually and at the same time flip-flop is ' set ' externally (Fig.4.2). Setting the flip-flop enables two 'AND' gates and the pulses from two meters start accumulating in the counters C_A and C_B. As soon as the counter C_A registers 100 pulses not only the counter C_A but also the flip-flop gets ' reset '. Resetting of flip-flop in turn disables the 'AND' gates to prevent further entry of pulses to the counters. Error in magnitude and sign is then computed manually. Whereas the resetting of counter C_A by the last pulse makes it ready for the next cycle, counter C_B should be manually ' reset ' to zero before commencing the next cycle.

This scheme has the advantage of automatic extinction of counting of pulses.

4.3. ANALOG ERROR COMPUTATION

The basic philosphy of this scheme is similar to that of the last one but it incorporates one more degree of automation. Here the error is computed by analog circuits. The complete costing scheme is shown schematically in Fig.4.3. The digital count C_B is converted to a proportional analog voltage by using D/A converter. A voltage equivalent to 100 pulses of the substandard meter is generated. The two voltages

are fed to an analog substractor and the difference (error)
is displayed on a moving coil meter. As the error may be of
either polarity, the meter required is a centre-zero meter.
Obviously, for the next cycle counter C_B will have to be reset
to zero.

This scheme reduces the involvement of human operator
by one more degree as the error is now computed by analog cir-
cuits. Accuracy of the system depends on the accuracy of the
D/A converter and the accuracy with which the voltage proportion-
al to 100 pulses of the substandard meter is generated.

4.4. DIGITAL ERROR COMPUTATION USING SUBSTRACTOR AND COMPARATOR

The pulses obtained from the substandard meter A and
test meter B are counted. These counts are then compared in
a digital comparator. Three distinct outputs for the three
possible conditions are available from the comparator. These
outputs are used to drive polarity indicators as well as to
give command to a digital substractor to perform substraction
if the two counts are unequal, and to carry no operation in
case the two counts are same (Fig. 4.4)

4.5. DIGITAL ERROR COMPUTATION WITH NEGATIVE AND POSITIVE ERROR DISPLAYS

Unlike the other schemes discussed so far in this
Chapter the markings on the two meters are not identical.
The substandard meter is marked to give pulses (A in Fig.4.5.)
1000 in number or its multiple for a fixed number of revolutions
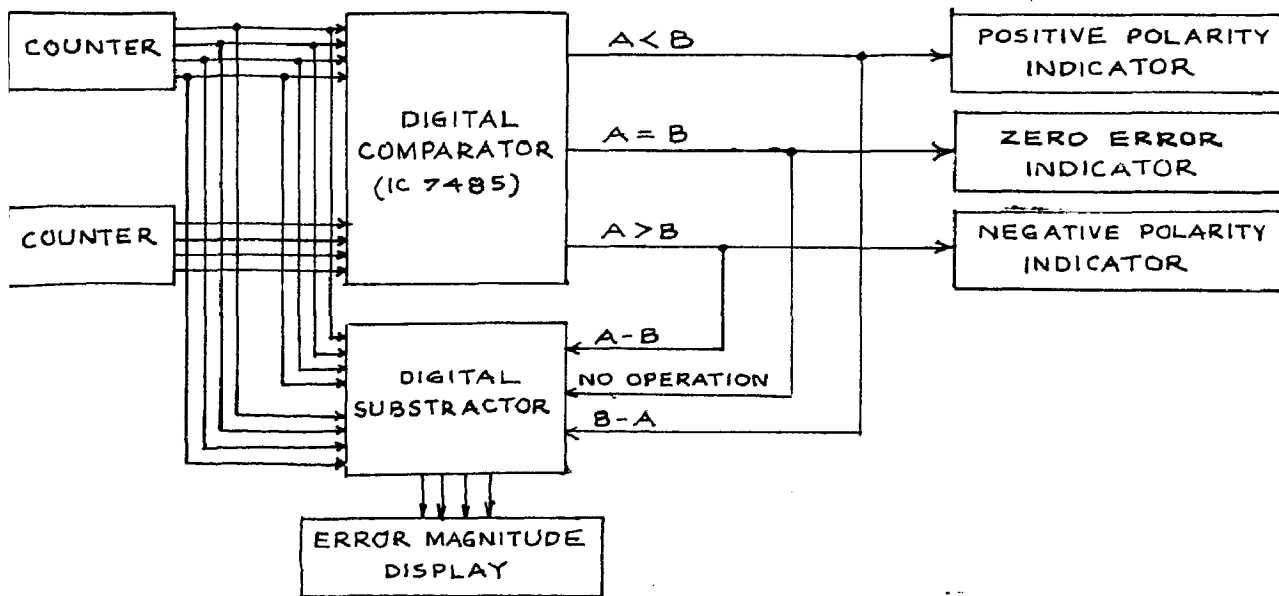
4.4: DIGITAL ERROR COMPUTATION USING SUBSTRACTOR & COMPARATOR
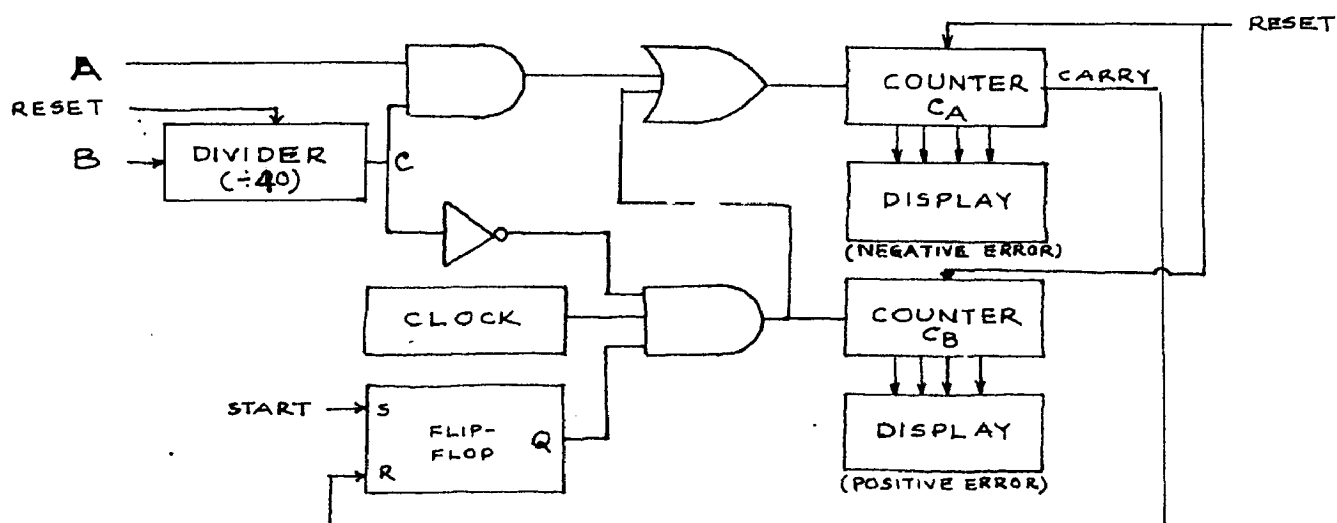
FIG. 4·5: DIGITAL ERROR COMPUTATION WITH NEGATIVE
AND POSITIVE ERROR DISPLAYS
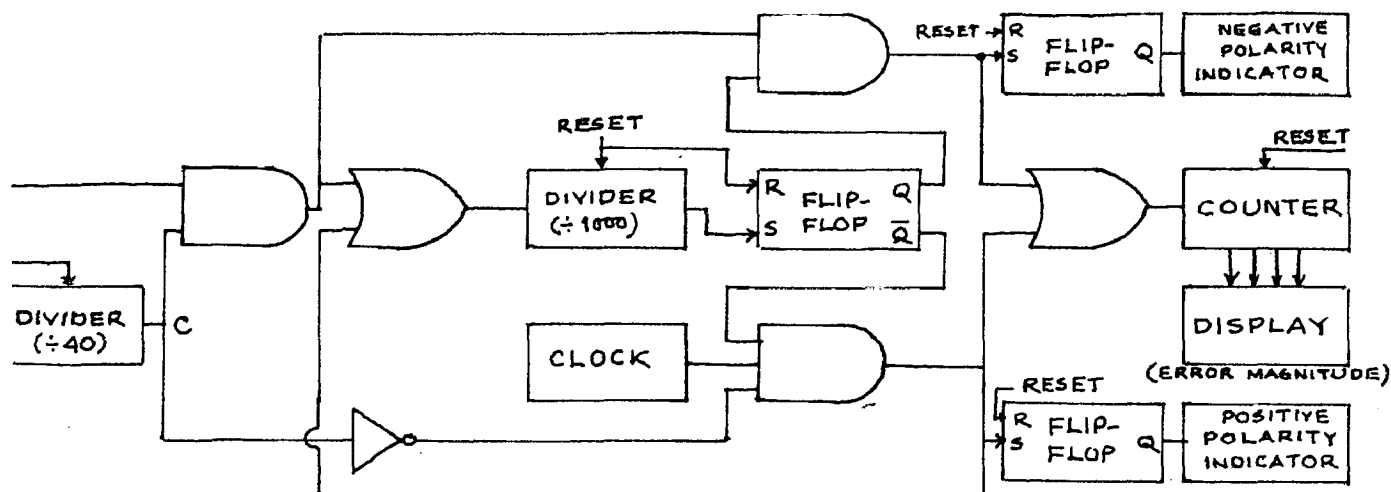
4·6: DIGITAL ERROR COMPUTATION WITH ERROR & POLARITY DISPLAYS.

of its disc. The test meter pulses (B) are divided using dividers to give one pulse, C, for the same number of revolutions. AND-1 gate remains enabled during the high state of pulse C and allows the pulses from the substandard meter to be counted and digitally displayed. If the test meter speed is smaller than that of the substandard, the reading of counter is the error (negative). In case the speed of the test meter is greater than the speed of the substandard meter the count will have to be substracted from 1000 to give error. To perform this function additional pulses from a clock are added to the counter C_A to make the count 1000. These clock pulses, also allowed to be accumulated in counter C_B, are digitally displayed to give the positive error. The addition of pulses is performed during the subsequent low time of the pulse train C. As soon as the count in counter C_A becomes 1000 negative error display gives zero reading and the carry resets a flip-flop to disable AND-2 gate to stop the feeding of any more pulse to the two counters automatically.'Not' gate keeps the AND-2 gate disabled during high times of pulse C. For the next cycle the counters are required to be 'reset ' to zero and the flip-flop need be set.

This scheme eliminates the error in reading analog meter by the human operator.

4.6. DIGITAL ERROR COMPUTATION WITH ERROR AND POLAPITY DISPLAYS

This scheme has been practically realized by the author and is shown in block schematic form in Fig.4.6. Details of the

scheme are discussed in the next chapter.

This scheme has a common display for the magnitude of error (for positive and negative errors) and separate indication for polarity of the error.

4.7. MICROPROCESSOR BASED TESTING

In this scheme author proposes the use of micro-processor for the testing. While a fixed number of pulses from the substandard meter are counted by a hardware counter, the actual corresponding number of pulses from test meter are counted in the microprocessor. The error in magnitude and sign both, is then computed by the software of the microprocessor. This scheme has been discussed at length in Chapter-6.

CHAPTER-5

A DIGITAL SCHEME DEVELOPED FOR AUTOMATIC TESTING

From the various schemes discussed in the preceding chapter, the author has chosen the one described in section 4.5 for practical implementation. The scheme adopted is fully automatic one with inevitable manual start and anautomatic stop. Digital circuits have been chosen for the computation and display of error. Compared to the analog circuits, the digital circuits have greater resolution, better accuracy, lower susceptibility to noise, and avoid parallex and other errors in reading.

5.1. PRINCIPLE OF TESTING

The basic principle of the testing scheme is shown in 'flow-diagram' form in Fig.5.1. Pulses from the substandard meter (A) are counted during 'high' state of the test meter pulses (C). If the substandard meter pulse count is equal to 1000, the test meter does not have any error, relative to the substandard meter. The difference of actual pulse count from 1000 represents the magnitude of the error in the units of 0.1%. In case the pulse count is greater than 1000, pulses after 1000th pulse are counted and displayed and at the same time negative polarity of the error is also indicated. However, if the pulses are less than 1000 in count, extra pulses from an external clock are fed to make the count 1000. These extra pulses which represent the magnitude of the error in this case are counted and displayed.

```
┌──────────────────────┐     ┌──────────────────────┐
│   GENERATE PULSES     │     │   GENERATE PULSES    │
│        FROM           │     │        FROM          │
│  SUBSTADARD METER     │     │     TEST  METER      │
└──────────────────────┘     └──────────────────────┘
            │                            │
            ▼                            ▼
┌──────────────────────────────────────────────────┐
│   COUNT PULSES FROM SUBSTANDARD                    │
│   METER OVER A 'HIGH' STATE OF                     │
│        TEST METER PULSES C                         │
└──────────────────────────────────────────────────┘
                         │
                         ▼
         NO    ◇ IS COUNT ≥ 1000 ◇    YES
         ┌─────┘                  └─────┐
         ▼                              ▼
┌────────────────────────┐   ┌────────────────────────┐
│ INDICATE POSITIVE       │   │ INDICATE NEGATIVE       │
│ POLARITY OF ERROR AND   │   │ POLARITY OF ERROR AND   │
│ FEED EXTRA PULSES TO    │   │ ALLOW PULSES AFTER      │
│ MAKE THE COUNT 1000     │   │ THE COUNT 1000          │
└────────────────────────┘   └────────────────────────┘
            └──────────┐      ┌──────────┘
                       ▼      ▼
               ┌──────────────────┐
               │       MIX        │
               └──────────────────┘
                        │
                        ▼
               ┌──────────────────┐
               │  COUNT THE PULSES │
               └──────────────────┘
                        │
                        ▼
               ┌──────────────────┐
               │     DISPLAY       │
               │  ERROR MAGNITUDE  │
               └──────────────────┘
```
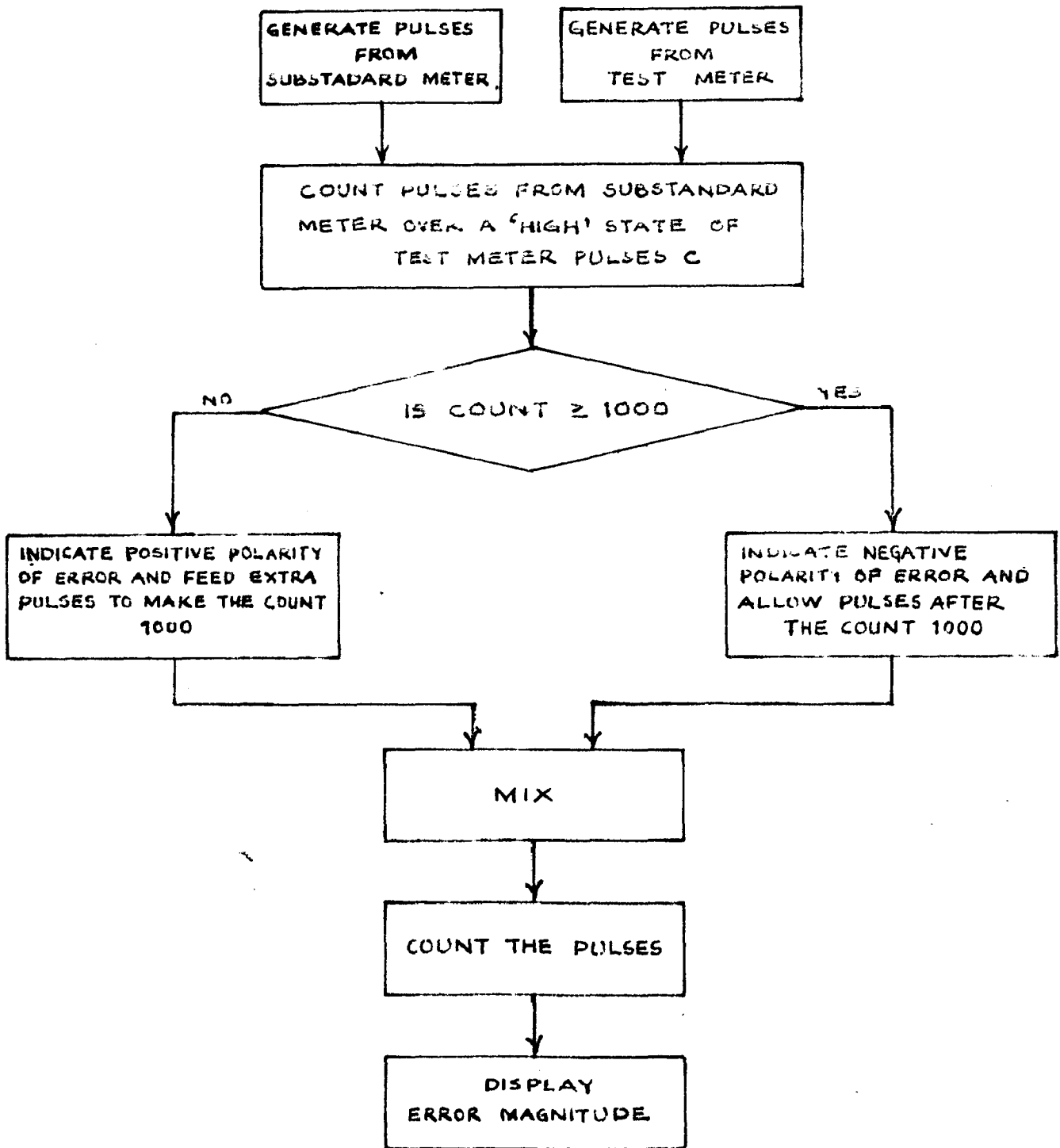
FIG. 5·1: FLOW DIAGRAM

Provision for positive polarity indication of the error has also been incorporated.

5.2. ELEMENTS OF TESTING SCHEME

The design of an accurate measurement circuit requires a systematic appraisal of the complete system consisting of primary stimulus (the physical quantity to be measured), the transducer (used to convert the primary stimulus into an electrical signal) and the signal conditioner (used to make the transducer output appropriate for the following stage)[11].

5.2.1. Primary Stimulus

As the speeds of the two induction discs are to be compared, the primary stimulus here is angular speed.

5.2.2. Transducer Assembly

The transducer consists of light source and phototransistor (ACP 132). Light from two sources is focussed on the edges of the two discs which are marked in a specific manner. The substandard meter circumference is divided into hundred equal parts and of these alternate ones are pointed by black water-based paint. The substandard meter disc edge is painted black except for one part (equal to that of the test meter). The reflected light from the discs is focussed using double convex lenses on two phototransistors. Whenever there is painted portion in line of incident light, there will be no reflection of light from the disc on to the phototransistor and hence it remains 'off '. Unpainted or bare portion of the disc reflects light to cause an increase

in the collector current. Thus mechanical rotation of the discs
is transduced into electrical pulses 50 per revolution of the
substandard meter disc and 1 per revolution of the test meter
disc.

5.2.3. Signal Conditioners

(a) Amplifier:

As the pulses obtained from the phototransistor are of
very low magnitude, they have to be amplified (Fig.5.2). This
has been performed by using an operational amplifier- IC 741. The
connections[12] are shown in Fig.5.4. Because the phototransistor
is located at some distance from the succeeding stage (amplifier),
induced pick-up in long leads and unavoidable ground loops give
rise to signals which are many times greater than the transducer
output signal. In an attempt to minimize the unwanted signals,
shielded wires and proper earthing have been used to correct the
transducer to the amplifier.

(b) Zero-crossing Detector[12]

Because of the switching time the phototransistor gives
a slowly varying output voltage.To convert this slowly varying
voltage into an output having an abrupt waveform, occuring at
a precise voltage (zerohere), a zero crossing detector is used
(Fig.5.2).

5.3. WORKING OF TESTING SCHEME

The testing has been performed for 20 revolutions of the
test meter. As shown in fig.5.2 pulses from the test meter (B)
are divided by 40-using IC 7490 followed by IC 7493 in divide by

FIG. 5.2: BLOCK ...

10 and divide by 4 mode respectively - to give one pulse for 20 revolutions of the test meter. During a ' high ' time of the pulse train C, AND-1 gate remains enabled and allows the pulses from the substandard meter to pass through it. If the substandard meter pulses are more than 1000, 1000th pulse sets flip-flop-1, which in turn enables AND-2 gate and disables AND-3 gate. Output pulses of AND-1 gate one now counted with the help of two cascaded decade counters[13] (as the error is generally in the units of few percents). Pulse count is decoded using IC 7447 and the count (error) is displayed on 7-segment LED_s. To avoid the flickering display, latches (IC 7475) are used as temporary storage between the counters and decoders/drivers. Information present at its input is transferred to its output when the clock is ' high ' and the output follows the data input as long as the clock remains 'high '. When the clock goes ' low ', the information (that was present at the input at the time of transition) is retained at its output until the clock is permitted to go high. The first pulse after 1000th sets flip-flop-2 to drive a LED to give negative polarity indication.

In case the pulses in the specified period - high time of pulse train C - are less than 1000, flip-flop 1 remains reset (all the counters and flip-flops are reset at the instants: of 'low' to ' high ' transition of pulse C and input to AND-3 gate from flip-flop -3 remains in ' high ' state. For the' low' state of the pulses C, AND-3 gate is enabled and clock pulses start accumulating in the counter and divider ($\div$ 1000). As soon as enough pulses from the clock have accumulated in the

divider to make its count 1000, flip-flop-1 gets ' set' and stops further accumulation of pulses in the counter and divider. The clock pulses, representing error, are finally displayed. The display represents the error in the units of 0.1%. First clock pulse out of AND-3 gate is used for positive polarity indication in the similar manner as used for negative polarity indication. Timing diagram shown in fig.5.3 helps in better understanding of the sequence of operations.

5.4. DESIGN CONSIDERATIONS

The only elements requiring elaboration of design are clock, monostable (delay) circuit, and power supplies. Other components being in directly usable digital integrated circuits require/discussions here.

no

5.4.1. Clock

IC 555 connected in free-running mode serves the purpose of a clock[14]. Its connections are shown in Fig.5.5. The external capacitor C charges through R_A & R_B and discharges through R_B only. The charge time (output high) is given by
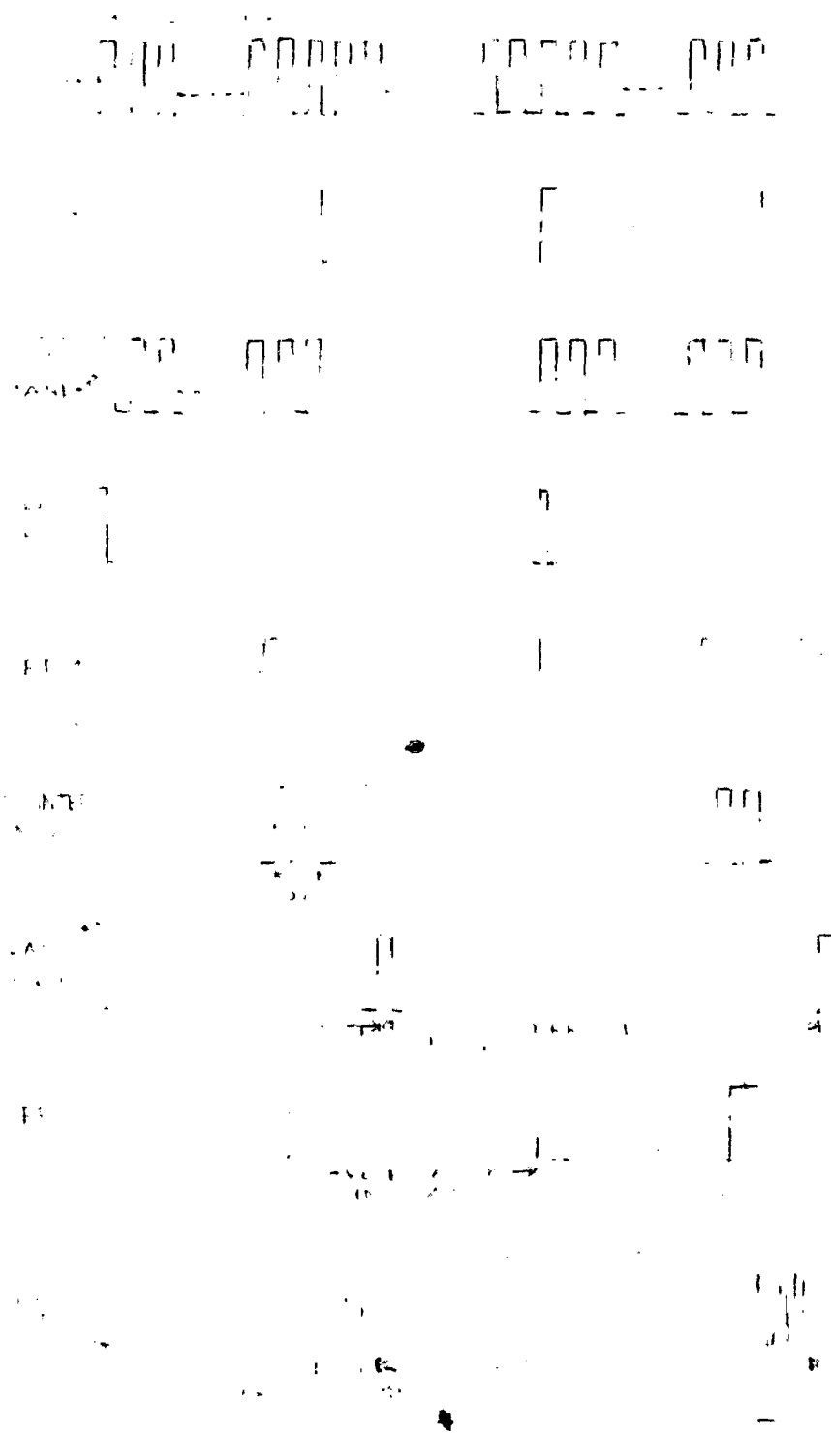
$$t_1 = 0.693 (R_A + R_B) C$$

and the discharge time (output low) by

$$t_2 = 0.693 (R_B) C$$

Thus the total period is given by

$$T = t_1 + t_2 = 0.693 (R_A + 2R_B) C$$

FIG. 5-6 TIMING DATA

The frequency of oscillation is then

$$f = \frac{1}{T} = \frac{1.44}{(R_A + 2\,R_B)\,C}$$

The clock is needed here to feed extra pulses during a time period equivalent to 20 revolutions. As the maximum speed of the integrating meters at full load can be 100 r.p.m. the time for 20 revolutions is 12 seconds. The provision is required to be made for feeding at the most 100 pulses (as the error can never exceed 10%) during 12 seconds. Thus sets the lower limit of clock frequency approximately equal to 8.5 Hz. Taken

$$R_A = 10\ K\Omega,$$

$$R_B = 1\ M\Omega,$$

$$C = 100\ pF.$$

These parameters result in clock frequency of 7 K-Hz. Such as high frequency is chosen to make the error computation and display time after the time of 20 revolutions minimum.

5.4.2. Monostable (Delay) Circuit

Latches are used between counters and decoders/ drivers to permit the transfer of counter output to decoder/driver and display after the addition of requisite number of clock pulses have been added to make the count 1000. This is achieved by enabling the latch after a delay of 100 times the time period of clock pulses after the instant of ' high' to ' low ' transition of pulse train C. Design of the delay circuit[15] (Fig.5.5) is as given below:

Supply voltage, V_{cc} = + 5 volts transistor used are SG 106(NPN)

Taken I_c(sat.) = 2 m A

When transistor T_2 is conducting

$$R_{c_2} + R_E = \frac{V_{cc}}{I_c(\text{sat.})} = \frac{5.0}{2 \times 10^{-3}} = 2.5 \, K\Omega$$

Taken R_E = 1 KΩ , R_{c2} = 2.2 KΩ

Similarly when T_1 is conducting

$$R_{c1} + R_E = \frac{5.0}{2 \times 10^{-3}} = 2.5 \, K\Omega$$

Taken R_{c1} = 2.2 KΩ

Now $I_{B2} = \dfrac{I_{c2}}{h_{fe}} = \dfrac{2 \times 10^{-3}}{20} = 0.1 \, mA$

$$R_1 + R_{c2} = \frac{5.0}{0.1 \times 10^{-3}} = 50 \, K\Omega$$

Taken R_1 = 47 KΩ

R_B = 22 KΩ

Delay required = 100 x T = 0.69RC

Or $0.69 \, RC = \dfrac{100}{7 \times 10^{3}}$

$$RC = \frac{100}{7 \times 0.69 \times 10^{3}} = 0.2 \, sec.$$

Taken R = 2 KΩ

C = 22 μF

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5.4.3. + 5 Volts Regulated Power Supply (Fig.5.4)

A 5-volt, 2 amp. regulated power supply is required for the TTL ckts. Mains voltage (230V a.c.) stepped down to 12-0-12 volts with the help of a 1150 (30 SWG)/120 (20 SWG) transformer with secondary centre tapped. This voltage is then rectified using a full wave rectifier to 9 volts. The unregulated voltage is regulated using IC 723. Design of regulator circuit[14] is given below:

Reference voltage for $\land$ 723 = 7.0 V (specified)

Required output voltage, V_{out} = 5.0 V

$$\therefore V_{out} = V_{ref} \cdot \frac{R_2}{R_1 + R_2}$$

$$5 = 7.0 \times \frac{R_2}{R_1 + R_2}$$

or, $R_2 = 2 R_1$ \hfill (1)

To avoid poor regulation at low V_{IN} and high dissipation at high V_{IN} the current drain from V_{REF} should not exceed 2 mA.

$$\therefore R_1 + R_2 = \frac{7.0 \ V}{2 \ mA} = 3.5 \ K\Omega \hfill (2)$$

Taken R_1 = 1.5 KΩ , R_2 = 3.3 KΩ

To extend the load current range upto 2 amp. two β- cascaded transistors (SL 100 and 2N 3055) are connected at pin 6 of the regulator.
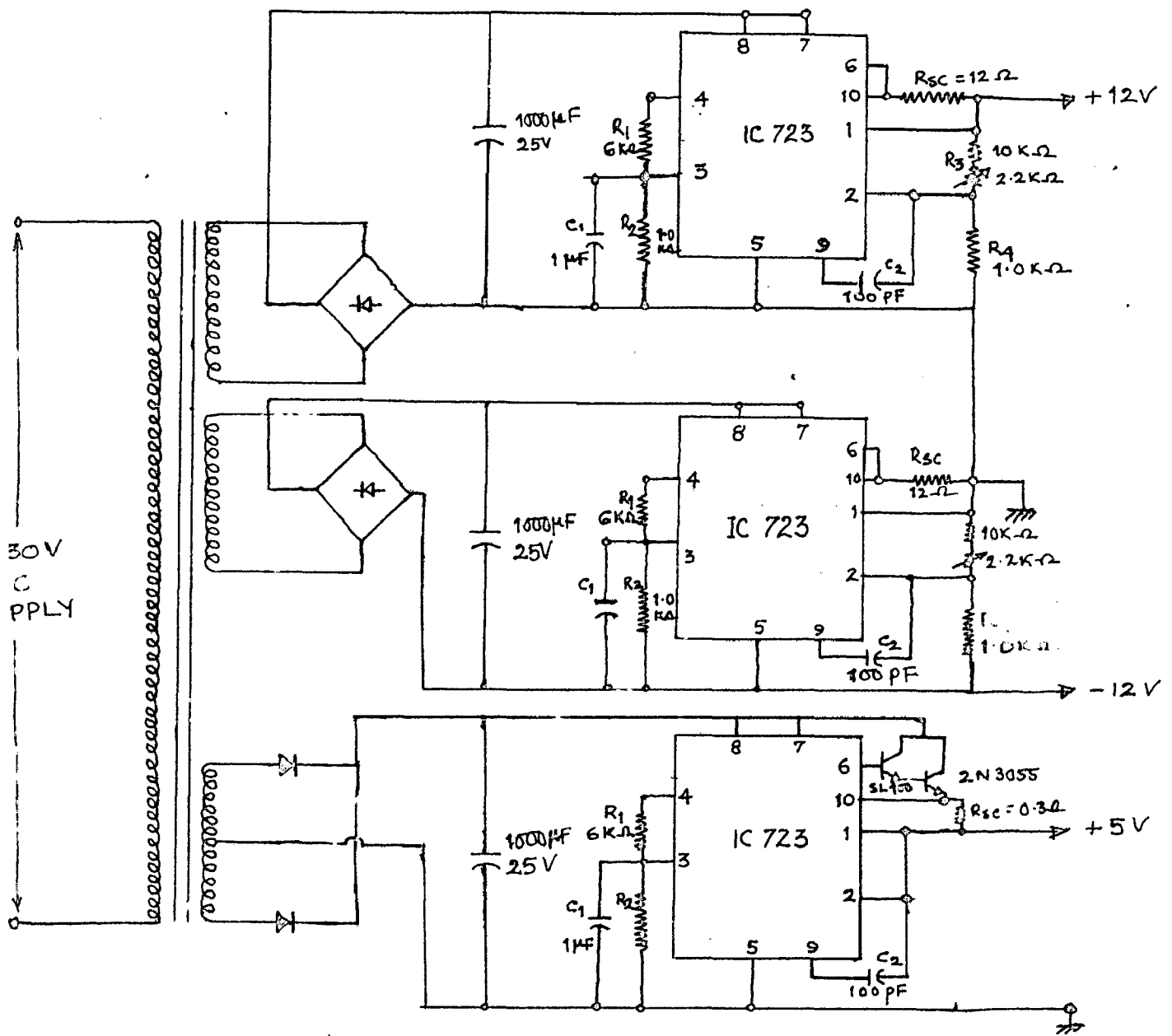
FIG. 5.4 : REGULATED POWER SUPPLY OF ±12V & +5V

Resistance for short circuit protection is given by

$$R_{SC} = \frac{V_{BE(off)}}{I_{load}} = \frac{0.6 \text{ V}}{2 \text{ A}} = 0.3 \, \Omega$$

Taken $C_1 = 0.1 \, \mu F$, $C_2 = 100 \, pF$

5.4.4. $\pm$ 12 volts power supply (Fig.5.4)

A stabilized supply of $\pm$ 12 V required for supplying the operational amplifiers was also designed and fabricated. Two additional windings of 140 turns each are placed on the same transformer as used for the + 5 V supply. Voltages detained from these windings are rectified and filtered then and fed to two identical regulators. Design of each regulator circuit using IC 723 is as given below :

$$V_{ref.} = 7.0 \text{ volts (specified)}$$

$$V_{out} = 12 \text{ volts}$$

short circuit current, $I_{load} = 50 \text{ mA}$

Voltage at pin 3, $V_3 = V_{ref} \cdot \frac{R_2}{R_1 + R_2}$

Taken $V_3 = 1.0 \text{ V}$

$\therefore \quad 1.0 = 7.0 \, \frac{R_2}{R_1 + R_2}$

Taken $R_1 = 6.0 \text{ K}\Omega$ and $R_2 = 1.0 \text{ K}\Omega$

$(R_{SC}$ short circuit resistance) $= \frac{V_{BE(off)}}{I_{load}}$

where, $V_{BE(off)}$ = voltage drop across base to emitter (in off. condition) of output transistor of the regulator.

$$\therefore \quad R_{SC} = \frac{0.6}{50 \times 10^{-3}} = 12 \ \Omega$$

$$V_{out} = V_3 \ \frac{R_3 + R_4}{R_4}$$

Taken $R_4 = 1.0 \ K \ \Omega$

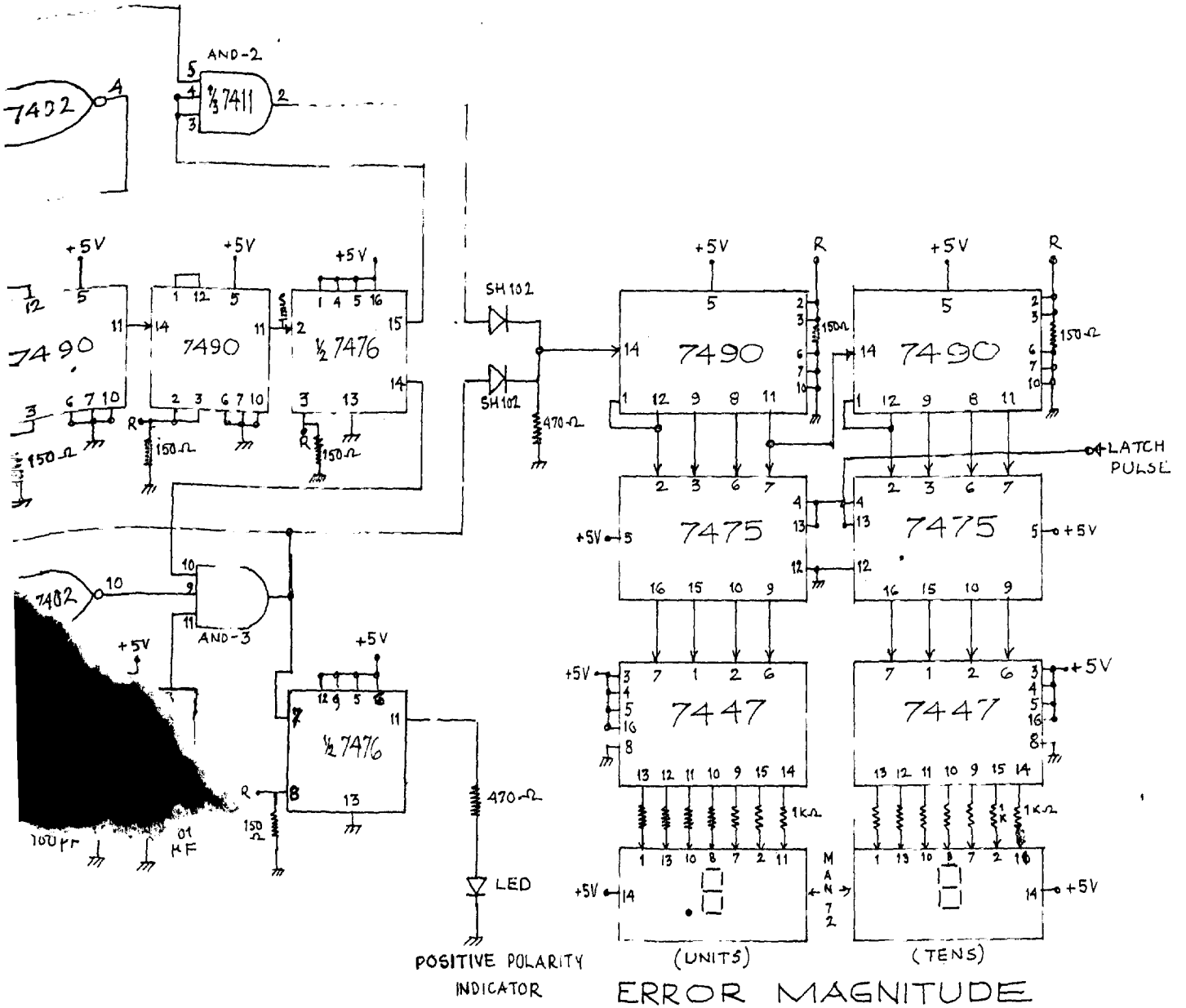$$\therefore \quad 12 = 1.0 \times \frac{R_3 + 1}{1}$$

or, $R_3 = 11 \ K \ \Omega$

Taken R_3 as a fixed resistance of 10 K Ω and a pot. of 2.2 K Ω.

5.5. TEST SET UP

Practical details of the developed test set-up are shown in Fig.5.5.

POSITIVE POLARITY
INDICATOR

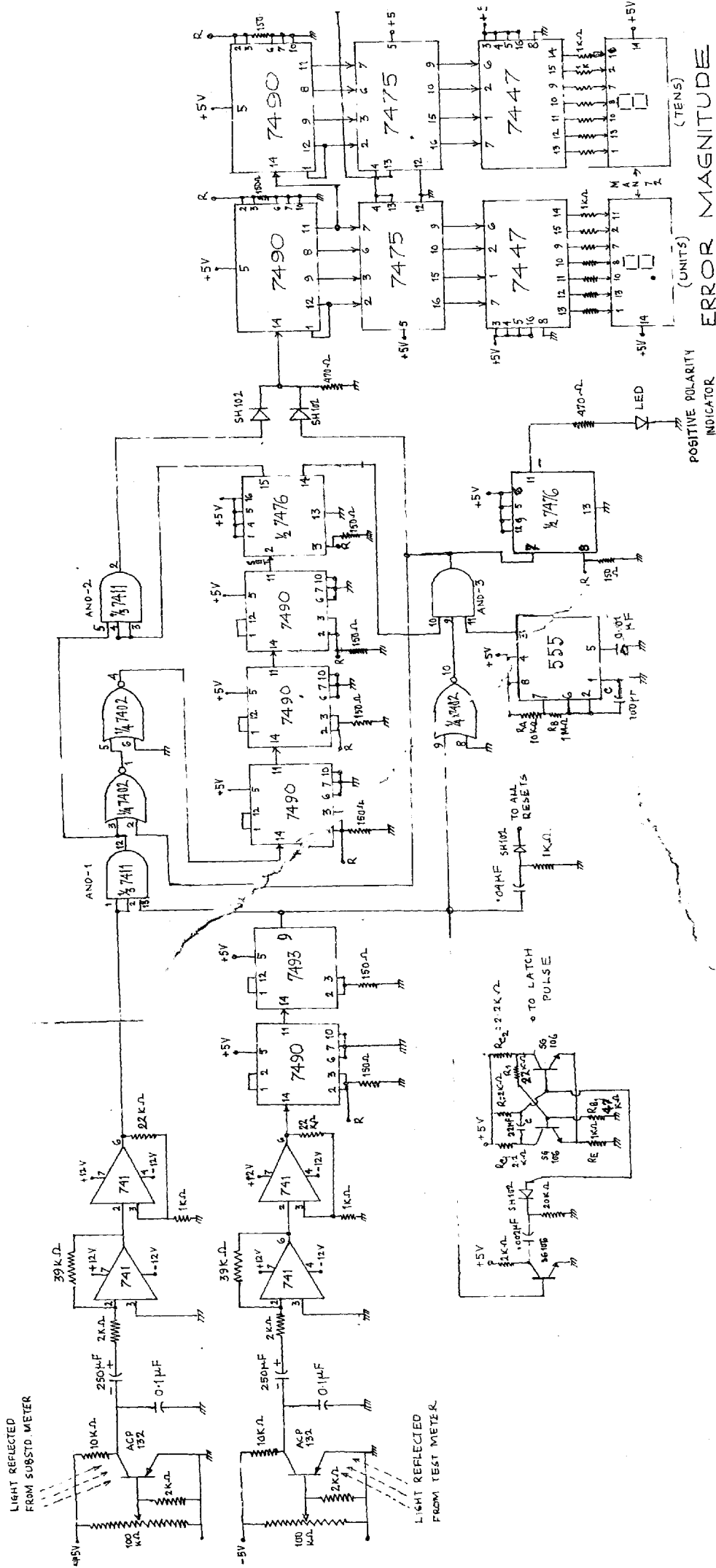(UNITS)   (TENS)

ERROR MAGNITUDE

FIG. 5.5 COMPLETE CIRCUIT DIAGRAM

CHAPTER - 6

A MICROPROCESSOR BASED TESTING SCHEME

Testing of energy meters using electronics, and of late digital computer, has drawn considerable interest and attention of the test engineers as discussed in Chapter 3. Use of digital computer being very expensive has been limited to automatic batch testing and calibration of the meters, and a few pilot projects set up in some technologically advanced countries have been reported (Section 3.2.1 to 3.2.4). In the situations where a single meter is to be tested, an inexpensive and semi-automatic test set-up can only be justified. In this chapter the author has presented such a testing scheme after success-fully testing it in the laboratory. It is based on the use of a SC/MP microprocessor[16] (National Semiconductors, U.S.A.)

6.1 PRINCIPLE OF TESTING

The speeds of the induction discs of the test meter and rotary substandard (with which the test meter is to be compared) are converted into proportional electric pulse frequencies as has already been discussed in the preceding Chapter. A time interval corresponding to a fixed number of pulses from the substandard meter is produced by a hardware counter. The actual number of pulses generated by the test meter over the same time interval are counted in the micro-processor through software. The difference between this number accumulated in the microprocessor and the fixed number

counted in the hardware counter is computed in the micro-processor[17] which then computes the percentage error and makes the same available to the test engineer.

The number of pulses to be counted by the hardware counter is preplanned based on the number of pulses per unit energy and the load for which meter is to be tested. A test schedule for testing the meter at different leads is worked out and correspondingly the numbers to be counted by the hardware counter are fixed up and stored in the microprocessor. The microprocessor later uses these numbers to calculate percentage errors for the respective test loads. The errors for the various leads are finally printed out.

6.2 TEST SET-UP

Fig.6.1 shows the block schematic of the test set-up. Photoelectric transducers are used to generate electric pulses from the rotation of the induction discs of the two meters. The pulses from the test meter are applied directly to S_A terminal of the microprocessor, and these from the substandard meter are applied to SIN terminal through an AND gate and a counter. A starting command is monitered at S_B terminal. A 'done' signal is given out by the microprocessor after completing the job.

6.3 SOFTWARE

Upon detecting a start command which is given after adjusting the applied lead to the meters, the hardware counter is
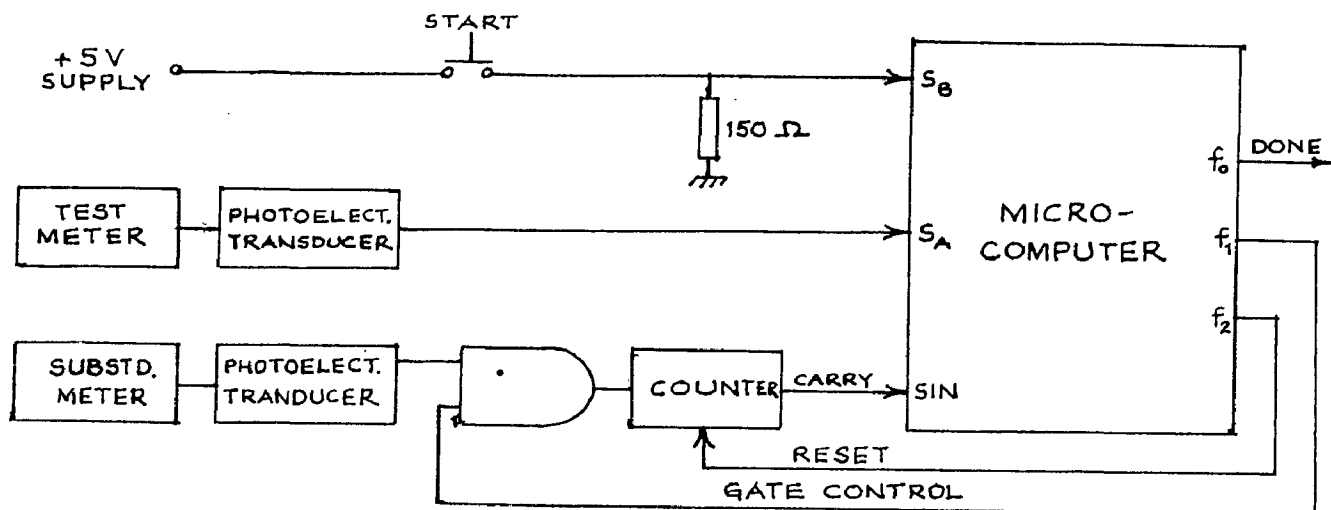
FIG. 6.1: TEST SET-UP
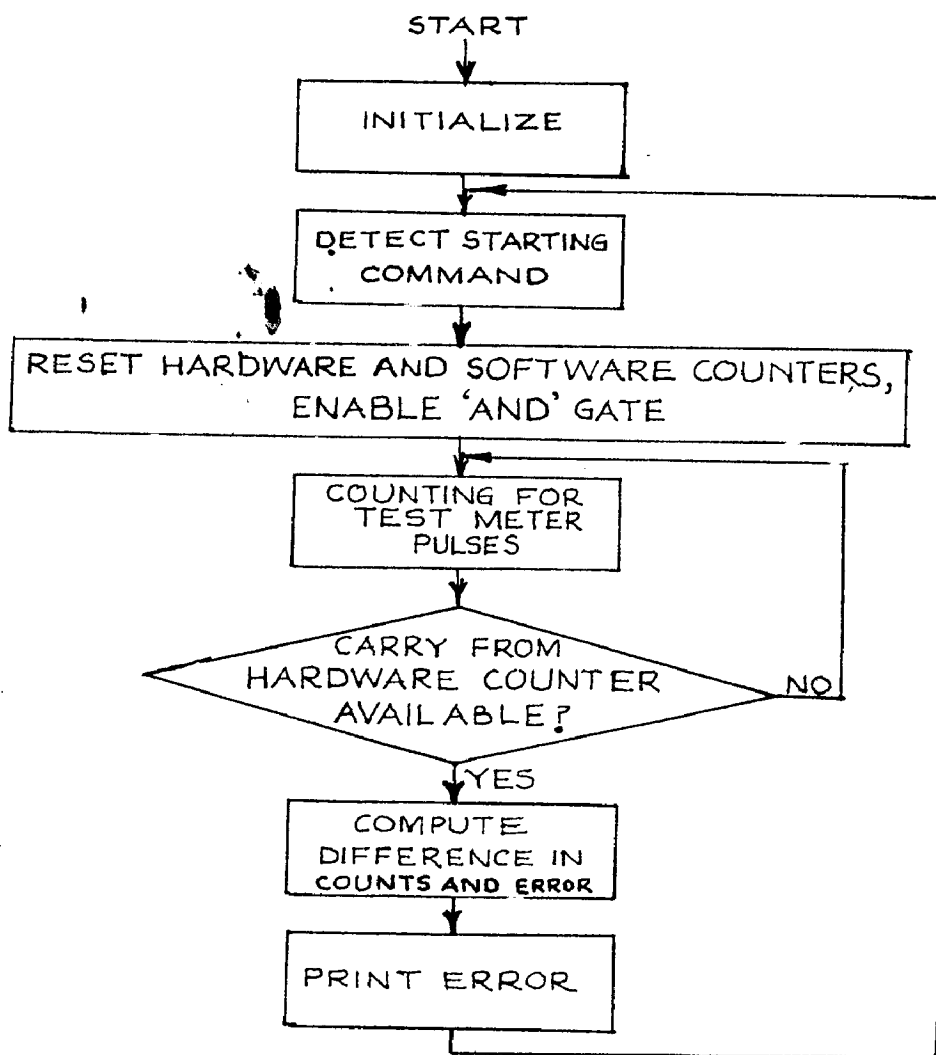
FIG. 6.2: FLOW CHART

reset and the AND gate is enabled to permit the counting of the pulses by the counter. Simultaneously, the pulses from the test meter are counted by the software till the hardware counter completes counting upto a preplanned number of pulses. The error is subsequently computed and stored in the memory for print-out. The counting of pulses by software is done by detecting a -ve to +ve zero-crossing of the input signal and incrementing a counter each time.

A simplified flow chart is shown in Fig.6·2 which is self explanatory and performs all the operations as mentioned above. It occupies only 68 bytes in the RAM.

6.4 PROGRAM

The program used is given in Appendix A.

CHAPTER - 7

CONCLUSIONS AND SUGGESTIONS FOR FURTHER WORK

7.1 CONCLUSIONS

The dissertation combines a report on the state of art of integrating meter testing and presentation of the work done by the author on automatic testing of energy meters. Scope of the dissertation has been put out clearly in the first Chapter.

The conventional methods of testing followed in this country and elsewhere have been reviewed (Chapter 2). An exhaustive account of these methods is given under three categories, viz. comparison of dial readings on the test meter and a precision substandard meter, comparison of speeds of the rotors of the test meter and substandard meters, and time checking of the speed of the rotor of the test meter using precission indicating instruments and a step watch.

Relative advantages and disadvantages of these approaches have been brought out. Testing procedures for 3-phase meters, reactive meters, kilowatt demand indicators, KVA demand indicators and KVAh meters have been discussed.

In the third chapter various electronic and computer controlled testing methods of testing adopted in some advanced countries or being developed have been reviewed briefly. It has been found that batch testing is preferrable in many cases.

Some new schemes of automatic testing involving automation in varied degrees have been proposed (Chapter 4). These schemes offer the alternatives of manual start and manual stop, manual start and auto stop, automatic analog error computation, automatic digital error computation with seperate displays for negative and positive errors, digital error computation with error and polarity displays, digital error computation, digital error computation using substractor and comparator, and microprocessor based testing. Out of these, two schemes have been practically implemented. All these schemes are based on the energy comparison approach, i.e. comparison of the speed of test meter with that of a rotating substandard, because of its basic advantage that the pre-set power need not remain constant during the measuring period as both the meters are subject to the same power variations. It also excludes the involvement of a human operator or automatic regulating devices that would otherwise be required for maintaining the pre-set power constant.

A digital scheme for automatic testing has been successfully developed by the author. Digital circuits have been chosen in this scheme for the measurement of error and its display because as compared to analog circuits they have greater resolution, better accuracy, lower susceptibility to noise, and are free from parallex and other errors in reading. Photoelectric transducers have been used for obtaining pulses from the motion of the meter discs. To put marks on the meter

discs for such purposes a numb r of paints have been tried by
the researchers[18]. The author has used black water-based paint
for this purpose with fairly good success. As such the provi-
sion needed in the meter for electric signal generation is very
simple and includes practically no extra cost. It can be very
easily incorporated by the manufacturers during production of
meters. Since substandard meter has been marked with 50 dots
and the test meter with one dot, only one dot has to be put on
the commercial meters. Shielded wires with proper earthing
have been used to exclude stray signals likely to be generated
in the long leads connecting phototransistors to the following
stage. Indication for only one polarity (positive) has been
given with a view to save the cost of another indicator and a
flip-flop. The presence of error magnitude on the digital
display unit and the absence of negative polarity indication
indicates that the polarity of the error is positive.

This test set-up has been successfully used for testing
of an electromechanical energy meter with single phase, 5A,
230 V, 50 Hz ratings.

A microprocessor based testing scheme has also been
developed successfully. Speeds of the two meters are monitored
automatically with the help of photoelectric transducers, a
hardware counter, software counting in the microprocessor. The
error is computed for every load in the microprocessor and
printed out at the end of the test schedule. As an alternative
to printing out the error, the same can be visually displayed

on LED, LCD or nixie tubes by connecting these devices to the input-output bus of the microprocessor through buffers and latches. Use of a digital computer can enable fully automatic testing of meters in batches with calibration facility. The limited capabilities of microprocessors, however, restrict their application to only semi-automatic testing, such as described here. But the difference between the costs of digital computers and microprocessors is too obvious to be elaborated.

7.2. SUGGESTIONS FOR FURTHER WORK

The two test schemes developed by the author can be made more sophisticated and include more automation.

The error (difference between substandard and test meter speeds) can activate a servomechanism capable of operating the adjusting devices on the test meter. The meter can thus not only be tested but also calibrated automatically.

The schemes can also be extended to the testing of demand meters as it additionally involves the checking of time interval for which the demand is recorded. The time checking must be done against a highly accurate and stable timing device. A crystal controlled clock, followed by digital frequency dividers, is best suited for the purpose because of the very high accuracy and stability of the crystal controlled oscillator.

The new testing methods in Chapter 4, 5 and 6 have been described with regard to the electromechanical energy meter. Nevertheless, they can be used equally well for the testing of solid state meters too, though this class of meters is still in its infancy[19]. Application of the proposed test methods to the solid-state meters would make the set-up still simpler as no transducers would be required for obtaining electric pulses. Such meters are generally based on transducing the measured power into proportional pulse rate.

Furthermore, the proposed schemes assume that the test and substandard meters have same rev./kwh constant. However, they can be easily modified for meters having different constants by including suitable frequency dividing circuits.

Lastly, the proposed schemes are directly applicable to the testing of individual meters only. Nevertheless, they can be extended for batch testing by using moving test benches or moving detectors[9].

APPENDIX - A

AN EXAMPLE OF ERROR LIMITS

According to IS : 722 (Part II) - 1962, Clause 7.5
the limits of error for single phase 2-wire whole current
watthour meters at the rated voltage, standard frequency and
standard temperature shall not exceed the values given below.

Current (percentage of the rated current)	Power Factor	Limits of Error (percent)
2.5	1.0	± 2.5
5 to 100	1.0	± 2.0
5	0.5 lag	± 2.5
10 to 100	0.5 lag	± 2.0

APPENDIX B

LISTING OF THE PROGRAM FOR MICROPROCESSOR BASED TESTING

TOFOO

OFOO	08	OF1E	D4
OF01	C4	OF1F	10
OF02	44	OF20	98
OF03	32	OF21	FB
OF04	C4	OF22	BA
OF05	OF	OF23	00
OF06	36	OF24	06
OF07	C4	OF25	D4
OF08	04	OF26	10
OF09	07	OF27	9C
OFOA	19	OF28	FB
OFOB	40	OF29	90
OFOC	D4	OF2A	EC
OFOD	80	OF2B	19
OFOE	9C	OF2C	40
OFOF	FA	OF2D	D4
OF10	C4	OF2E	80
OF11	00	OF2F	98
OF12	CA	OF30	OE
OF13	00	OF31	06
OF14	C4	OF32	D4
OF15	02	OF33	10
OF16	07	OF34	98
OF17	19	OF35	FB
OF18	40	OF36	BA
OF19	D4	OF37	00
OF1A	80	OF38	06
OF1B	9C	OF39	D4
OF1C	OE	OF3A	10
OF1D	06	OF3B	9C
		OF3C	FB
		OF3D	90
		OF3E	EC
		OF3F	C4
		OF40	01
		OF41	07
		OF42	90
		OF43	FB
		OF44	A4
		OF45	00
		OF46	00

_R_E_F_E_R_E_N_C_E_S_

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