REVERSIBLE BINARY COUNTER AND
SHAFT POSITION INDICATOR

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A binary counter has been developed that responds to subtracting pulses as well as to adding pulses. The two types of pulses are distinguished by different input channels, by polarity, or by size, and the reversible action is accomplished by suitable carry-over provisions between the counter stages. Each stage employs four CA55's. Resolving times of $10^{-5}$ sec and less are readily obtainable. In conjunction with a photoelectric activated pulse generator and a reading circuit, the counter has been used to indicate the angular position of a rotating shaft. The pulse generator produces adding pulses for clockwise rotation of the shaft and subtracting pulses for counterclockwise rotation. The reading circuit "scores" the several counter stages and gives the counter reading in the form of a micro-second pulse binary wave-form number. While the system has been designed to provide one of the input parameters to a digital electronic computer, the methods employed can be used for other situations involving two directional action and differential counting.
The components described in this paper have been
developed to serve as an input device for a digital
computer. The computer would be a component of a large
control mechanism, the mechanism being such that at
least one of the input generators must be furnished by
the angular position of a shaft. The shaft is free to
turn in either direction at irregular intervals and speeds.
Precise information concerning the position of the shaft
must be continuously available and it must be furnished
to the computer in the form of a binary wave-form number.

The system which has been developed to furnish the
necessary mechanical-electrical link is shown in block
diagram form in Figure 1. As the shaft moves, a pulse
generator produces a pulse for each minimum discrete
angular increment. These pulses are counted by a reversible
counter. A reading which then clears the counter stages
and furnishes the necessary wave-form number to the
computer. The pulse generator is designed to distinguish
the direction of the shaft rotation and the counter responds
correctly in both adding and subtracting pulses.

While the system constitutes one solution of a
specialized problem, the reversible aspects of the counter
and pulse generator are new, and the general method employed
can be used for other situations involving two directional
motion and differential counting.
The short cut are collected into pairs outside a light shutter for the phototubes V1 and V2. In order to distinguish the direction of rotation these tubes are placed as shown in Figure 3. Light sensitivity on V1 are instrumental in causing pulses provided that these transitions occur while V2 is illuminated. The condition light to dark causes a clockwise (or adding) pulse. The condition dark to light causes a counterclockwise (or subtracting) pulse. If phototube V2 is not illuminated, the pulse that would otherwise result from V1 transitions are blunted from the generator output. Thus, for example, continuous clockwise rotation results in a series of adding pulses, one being produced at the instant the leading edge of each fast pulses in front of the disk aperture for V1.

The essential features of the pulse generator circuit are shown in Figure 3. V5 and V6 constitute a direct coupled multivibrator that is stable only when one tube is completely cut off. The circuit constants have been chosen so that the high transition (V5 changing suddenly from non-conducting to conducting) occurs as the potential of the V5 grid increases above 80 volts, while the low transition (V5 changing suddenly from conducting to non-conducting) occurs as this potential decreases below 50 volts. The sudden rise of the plate potential of V5 at the low transition (phototube V1 light to dark) causes a positive pulse on the grid of V6, which (if V2 is light) produces a pulse in the clockwise output channel. A similar rise in the potential of the V5 plate at the high transition causes a positive pulse on the grid of V10, which (for V2 light) produces a pulse in the counterclockwise output. Phototube V2 controls a multivibrator


The circuit shown in Fig. 4 (Fig. A-36) is composed of 99 and 92, and the output pulses are of the same polarity. The differences of 50 volts between the high and low carrier pulses ensure that the output pulses remain constant, even if the drive jitter is back and forth across a transition position.

A complex circuit diagram is shown in Figure 4 (Fig. A-36). 97 and 98 are G.M. photo cells for VL and V2. Direct coupling is required to the grids of V5 and V8 in order to take care of any phase rotation. Their "dark" potentials must be below 0 volts and their "light" potentials above 25 volts. The corresponding 0-50 volt in size and of 0.7 wavelength duration are obtained in the 70-cm line output.

During operation of the disc, the potentials applied to the grids of V6 and V4 vary approximately sinusoidally about 65 volts with a 180° phase difference between them. The grids have been biased by applying sinusoidal potentials from a 300-kc to 600-kc to the grids with proper phase differences. Direct line pulses appear when the V5 grid leads the V3 grid and counter-clockwise pulses then the V8 grid lags the V4 grid. The generator operates satisfactorily at frequencies up to 300 kc. This limit can be extended with proper grid biasing.

The photograph of the output has been taken with a slow speed having 10 minutes. It is planned to produce "casts" and film by photographically. The degree of angular distribution possible depends on the distance with which projection is to be made. The associated inaccuracy of the equipment, the understanding to which the operator can conform, and the mathematical limit to which it must respect. For a larger and more accurate photograph (employing modern picture record techniques) corresponding to a direct resolution of about 24 minutes for a 5-inch diameter disc, use an optical arrangement.
A conventional counter circuit of counter consists of a series of similar circuits triggered pairs. Suppose the components of a pair are called A and B tubes, and assume that for any particular signal component of each stage, conduct, or in B (but never input point to any stage) across a stage during to the next stage. For every addition a change to present value occurs on the transition to 0 then 1, and the component changes from ON to OFF. The direction of the counter progression will reverse, corresponding to subtracting. If carry-over takes place instead on the transition to 1, or vice versa changes from ON to OFF.

Figure 6 shows a functional diagram of the reversible counter. Three counter pairs are indicated by the six circles, the prefixes A, B, or C (or D) denoting the number of the associated with each stage. The C and D squares represent on-off contacts. All C tubes are associated with electrical carry-over. The D tubes, with subtractive carry-over. A pulse to be added is received in the upper channel. It triggers a self-restoring multivibrator, the addition gate, and applies a positive square wave to the second C tube. This prepares the C tube for activation. The input pulse also passes through a brief delay to ensure the output of the first counter tube. If OA is conducting, the pulse turns OA off and O6 provides a pulse to the next stage. Similarly,
In this part of the counter, the A and B lines are connected to a magnetostrictive iodine
actuator with a 0 to 5 V input. The iodine is triggered with
degenerative feedback from both gates. This
results in a negative voltage, which is amplified by
both stages. The current passed through the counter
changes from 0 volts
to 200 milliamperes in a single very low
period. During this time, the control acts to adjust the
control, which acts to control current behavior in the rise
of the A plate. The current change is constant, indicated
the quiescent current rising in less than 10 ms. A single
stage has a sensitivity of about 1 microsecond and a
carry-over time of about 1 microsecond.

For a 15-stage counter, the set of
counter gates can have a duration of
approximately 2.4 microseconds
for 15 so that, at a 100 input, the number
rates of the set are measured to 90
nutes.

The minimum/member of the current
counter is determined by this set which increases in time about 1 microsecond.
The reading circuit is designed to be derived reading by
noninverting integrally the current output of the
appropriate combination of a set of tubes.

Figure 9 is a complete schematic of input arrange-
ments that have been used reliably with a 5-stage trial
counter. In this circuit the delay for both add and
subtract channels is provided by the self-resetting multi-

vibrator V3. V1 serves to trigger the add multivibrator
V6 as well as V5, and it acts similarly for the subtract
channel. The two gate voltages are taken from the cathode
followers V3 and V6.

READER

A simple reading circuit is shown in Figure 9. It
consists of a series of CAS6 coincidence tubes, VOB, VIP, 
V2B, ---. The suppressor grids of these tubes are connected
directly to the plates of VOB, VIP, V2B, --- respectively.
The cathodes of the 6 tubes are kept at the normal non-
conducting potential of the 6 tube plates and their grids
are biased to cut-off. The grids are connected to a
common output circuit. If a single positive reading pulse
is applied to the control grid of each 6 tube successively
at microsecond intervals, a pulse wave form number
corresponding to the counter reading will be generated in
the output. The microsecond delay introduced between each
6 grid can be provided by delay lines with amplification
as needed to ensure the progressive attenuation.

The reading pulse can be indicated by the fall of
the add or subtract gates of the counter, so that a new
counter is sent out whenever the counter reading changes.
This feature necessarily lengthens the time that must be
allowed between input pulses to the counter.
In alternate, each F tube generates a scanning pulse for each stage it must fire in sequence. The P tubes are
connected as they are in Figure 7. The 25 tubes are
Keesee-Jordan pairs. Each F tube receives negative "clock"
pulses of 1.5 microseconds each 1.5 microsecond intervals
from the synchronizing system of the computer. These pulses
normally keep all F tubes non-conducting, P tubes conducting.
When the counter in to be read - a single positive pulse is
applied to the grid of V1. This triggers the first pair,
turning VOG off. The next clock pulse turns VOG on again
and the fall of the pulse voltage is transmitted to the
grid of V1G as a negative pulse. This triggers the VIF-VIG
pair. VIG remains off for the microsecond interval between
clock pulses and so it returns to the on state VIF-VIG is
triggered. In this way, the F tubes are successively turned
on for microsecond intervals. As each F tube returns to
its normal off state the rise of its plate gives the required
positive scanning pulse to the corresponding P tube grid.

A 5-stage reader has been constructed and operated
with the constants shown in Figure 6. The circuit is quite
critical to the characteristic of the clock pulse, and
difficulty is experienced with the tendency of later stages
to trigger previous ones. A low impedance clock pulse
source and careful shielding between stages should increase
the reliability, and some modification of the constants
is also probably desirable.
The basic concept of the system in conjunction with a reasonable dc power supply and a final output of the type developed by the author. The closed loop constituted a substitute for a purely oscillating output with the advantages of lower noise levels, lower and higher speed possibilities.

The action in the system is presumed to cause continuous indication of small deviations from either natural or nonnatural states and causes it to serve as the device for control. A special directional sense is obtained by a current difference introduced between the input system that produces current on the two input grids of the power system.

Figure 3
FIGURE 4