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BINARY COUNTERS
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BINARY COUNTERS

A. BINARY COUNTING

The binary system of representing numbers has been outlined in Section 1, Introduction to Binary, and we shall now look at the binary system as used in relation with multivibrators to form binary counters. Binary counters find use in:

1. The direct counting of events
2. Direct measurement
3. Indirect measurements,

Frequency, time, speed, digital computers

As stated previously, multivibrators or binaries, are two tube devices which have two stable states (see sketch below). One state is designated by the binary number "0" and the other state by the binary numeral "1". The section from which the output is obtained is called the output tube and unless otherwise noted, the output is usually taken from the plate of the right hand tube (RHP). Whenever the output is taken from the left hand tube, the binary is designated (LHP).

B. SCALE-OF-4 COUNTER

The binary chain of figure 1 constitutes a "scale-of-4" counter. The circuit has 4 different possible states and at the occasion of each input pulse the circuit will make a transition progressively from state to state. After 4 pulses the circuit will reset itself into its original state.

Figure 1

The sequence of triggering pulses is fed in a symmetrical fashion into the first binary labeled B_0 . Output signal of the first binary (which is the signal that appears at the output plate of B_0) is applied symmetrically to the second binary B_1 . B_0 will have a transition on each pulse. B_1 makes a transition only when the preceding binary goes from a "1" to a "0". Then B_1 will go from "0" to "1".

This is due to the internal circuitry of the binary, which only changes state on a negative pulse. Thus, the only time a change of output plate voltage in B_0 affects the state of B_1 is when the plate voltage of B_0 drops. These features are easily recognized from the counter and waveform chart of figure 2a, 2b, 2c, 2d, and 2e.

2 c) T_2 , Second Input Pulse

2 d) T_3 , Third Input Pulse

2 e) Waveform Chart.

Figure 2

C. SCALE OF 16 COUNTER

As seen in figure 3, the binary chain counter consisting of 4 binaries has 16 possible different states. Consider the initial state of the combination of the binaries in which all four individual binaries are in state "0". Beginning from this reference state, the waveforms which appear at the output plates of the multivibrators as a result of the application of 16 successive input pulses are shown in figure 3.

FIGURE 3

Table A - Decimal and Binary Numbers

Decimal Number (No. of input pulses)	Binaries or Registers	<u>Binary Number</u>			
		B ₃	B ₂	B ₁	B ₀
0		0	0	0	0
1		0	0	0	1
2		0	0	1	0
3		0	0	1	1
4		0	1	0	0
5		0	1	0	1
6		0	1	1	0
7		0	1	1	1
8		1	0	0	0
9		1	0	0	1
10		1	0	1	0
11		1	0	1	1
12		1	1	0	0
13		1	1	0	1
14		1	1	1	0
15		1	1	1	1
16		0	0	0	0

Examine table A for a moment. Consider the first few decimal number 0, 1, 2, and 3. To use the decimal system of numbering in a computing device you would need to have 4 registers in order to record the information presented. Now, from the table, you can see that the binary system needs only two registers to represent the first four numbers. In this case, four conditions of information can be represented by the use of two registers. You now should be able to see where an on-off electronic system fits into the binary pattern very well. Say that you wish to indicate the decimal number in a computing function. This can be accomplished

in the binary digital computer by representing it (from table A) as 0 0 1 1. The binary digits 0 0 1 1 would be represented in a relay system by the two "1" relays being in the closed (go) condition.

Once again referring to the table A, you see that three registers of the binary system will enable you to represent eight pieces of information, four registers represent 16 pieces of information. By the time you have seven registers, you can represent 128 pieces of information.

D. BINARY COUNTERS TO A BASE OTHER THAN 2

From the previous discussion we have learned that to have a counter of 4, we need 2 binaries, and for a counter of 8, we need 3 binaries, and for a counter of 16 we need 4 binaries. Therefore, for a counter with N number of binaries we may have a counter equal to 2^N .

To make a counter other than that equal to a base of 2, we take the output from the last binary and feed it back to the appropriate binary or binaries. Thus, to convert a counter of 16 into a counter of 10, we feedback our 8th pulse to B_1 and B_2 , changing the states of both binaries from a "0" state to a "1" state. The 7th pulse will then fill all registers to a "1" state and the 10th pulse will reset it. A binary counter of 10 and its waveforms are represented in figure 4.

Figure 4

To determine the feedback loops, we use the following three steps:

1. Find the total count possible
2. Subtract from the total count the scale by which you prefer to count
3. Feedback unsymmetrically to the binaries that total the difference between the two scales.

Example:

1. We wish to have a counter of 10.
 $2^3 = 8$ and since 8 will not cover the count of 10 we try
 $2^4 = 16$. We need 4 binaries. We wish to count by 10 so
 we have $2^4 = 16$

$$\begin{array}{r} - 10 \\ \hline 6 \end{array}$$

Binary representation $2^1 \times 1 + 2^2 \times 1 = 6$. Therefore we feedback to binaries B_1 and B_2 to make a counter of 16.

2. To make a counter of 41:
 $2^5 = 32$ and will not cover 41
 $2^6 = 64$ and we therefore need 6 binaries
 $- 41$
 $\hline 23$

Binary representation $2^0 \times 1 + 2^1 \times 1 + 2^2 \times 1 + 2^4 \times 1 = 23$.

Therefore we feed the 32nd pulse back to B_0 , B_1 , B_2 , and B_4 changing the state of the counter from 32 to 55 and 9 pulses later the counter completes one cycle. ($32 + 9 = 41$)

32nd pulse 1 0 0 0 0 0 = 32

After feedback 1 1 0 1 1 1 = 55

E. APPLICATION OF COUNTERS

I. Direct Counting

An early application of counters arose in connection with research into the properties of the nucleus of an atom. In order to determine the radioactivity

of a source, it is necessary to count individually the emitted particles for a given time interval.

2. Measurement of Frequency

The basic principle by which counters are used for the precise determination of frequency, is illustrated in figure 5.

Figure 5

The input signal whose frequency is to be measured is converted into pulses and applied through a gate to an electronic counter.

3. Measurement of Time

The time interval between two pulses may also be measured with the circuit in figure 5. The first pulse could open the gate and the second pulse close the gate.

4. Measurement of Speed

A speed determination may be converted into a time measurement, if two photo cell-light-source combinations are set a fixed distance apart, the average speed of an object passing between these points is proportional to the time interval between the generated pulses.

5. Digital Computer

Counters constitute a basic building block in digital computers and are used to perform many functions such as storage.

6. Waveform Generation

The waveforms which occur at the plates or grids of binary counters may be combined with other circuits to generate complex pulse type waveforms.

The next section will deal with basic digital computer circuits, binary dividers and some basic digital systems.

REFERENCE:

1. Millman - Taub "Pulse and Digital Circuits", McGraw-Hill, 1956

Here are a list of corrections that should be made to Section 1.

1. Page 3 - top paragraph
Figure 5 6 9 5 should be 1 6 9 5.
2. Page 4 - Section B
Decimal 182 should be binary 1 0 1 1 0 1 1 0.
3. Page 6 - Section 3
 $0 \times 1 = 0$.