A. H. BRUINSMA

MULTIVIBRATOR CIRCUITS

Introduction to Robot Technique

MULTIVIBRATOR CIRCUITS

INTRODUCTION TO ROBOT TECHNIQUE

BY

A. H. BRUINSMA

1959

POPULAR SERIES

PHILIPS TECHNICAL LIBRARY

PUBLISHER'S NOTE:

Translated from the German by E. Harker, London

This book is published in German, Dutch, French and English

The book contains 74 pages; 15.3 x 21 cm, 6" x $8^1/_2$". 41 figures

UDC NR. 621.373.431.1

Copyright N.V. Philips' Gloeilampenfabrieken - Eindhoven (Holland), 1959

First published in 1959
Printed in the Netherlands

The information given in this book does not imply freedom from patent rights

PREFACE

In these days of mechanization, automation, and cybernetics, a knowledge of the possibilities offered by certain relevant electronic circuits is of much value.

The subtitle of this booklet "Introduction to robot technique" indicates that we should try to treat multivibrator circuits with a view to their use in robot circuits.

Perhaps this would seem at first sight to be a limitation of the term "robot", which according to the generally held view is a machine with an external resemblance to man or beast and which is able to perform (usually limited) actions associated with living things. Obviously this differs from the definition of a robot as a circuit or a machine capable of reacting independently and continuously to certain stimuli applied from without.

Needless to say that with such a wide definition of a robot there are many kinds of circuits that are used, or have to be considered for application. In practice it does appear, however, that in certain parts of an apparatus problems arise which can be solved, or solved better, by making use of different kinds of multivibrator circuits and auxiliary gate circuits. The rather new field of square wave voltages and of pulse voltages derived therefrom offers so many possibilities that a more detailed discussion would definitely not appear to be superfluous.

Not only for the construction of robots within the restricted meaning of the word, but also for many other switching problems, which up to a short while ago seemed insoluble, the multivibrator circuit appears as the indicated method.

Now there are already books giving in great detail the theoretical aspect of such circuits (among other's Neeteson: ANALYSIS OF BI-STABLE MULTIVIBRATOR OPERATION, Neeteson: VACUUM VALVES IN PULSE TECHNIQUE, published in the Philips' Technical Library). For many users, however, it is sufficient to master a limited number of practical facts. From experience it appears that, with such limited data, circuits for many purposes can be constructed successfully.

Furthermore there appears to be a need for a more detailed treatment of multivibrator circuits, especially for those not yet familiar with a theory and who are unable to bring themselves to study a detailed theoretical book.

For those who are already familiar with the principles and have also a knowledge of the theory there still remains the need for a short discussion of the more practical applications.

May the reader appreciate that the editors were willing, for these reasons, to publish a separate work on this subject.

Eindhoven, July 1958. The Author.

CONTENTS

Chapter 1. Multivibrator circuits 1

1.1 Operating principles of free-running multivibrator circuits 1

1.2 Determination of pulse amplitude 5

1.3 Determination of pulse-width 7

1.4 Pulse shape 12

1.5 Pulse differentiation 14

1.6 Synchronization 18

1.7 Monostable circuits 24

1.8 Monostable circuits in cascade 32

1.9 Bistable circuits 36

1.10 Bistable circuits in cascade 41

1.11 Pentodes in multivibrator circuits 46

a. Larger pulse-amplitude at the anode 46

b. The "knee" in pentode characteristics 46

c. Triggering relays 48

d. Bistable circuits as D.C. voltage amplifiers 51

1.12 The blocking of monostable circuits 53

Chapter 2. Gating valves 57

2.1 Fast electronic switch 59

2.2 The timing of given periods 59

2.3 Fast scanning of different voltages 61

CHAPTER 1

MULTIVIBRATOR CIRCUITS

Because all the different forms of multivibrator can be derived from, and mostly are actual developments of the original free-running multivibrator, this will be described first.

1.1 Operating principles of free-running multivibrator circuits

There is some evidence that the discovery of the free-running multivibrator by Abraham and Bloch was due to a error in the assembly of a two-stage A.F. amplifier, whereby the output was accidentally connected to the input. So also in fig. 1, showing the circuit in its elementary form, output (b) is connected to input (a) to make a free-running multivibrator.

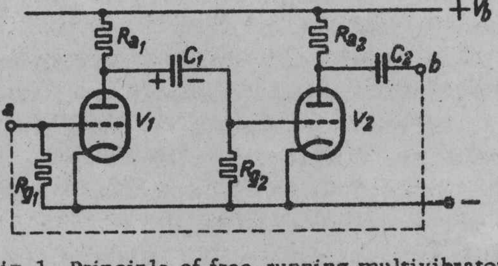

Fig. 1. Principle of free-running multivibrator circuit as embodied in 2-stage resistance-coupled amplifier with input connected to output.

The simplest way of explaining this is to postulate a small negative transient occurring at a, that is, on the control grid of valve V_1. It is well known that valves invariably produce something of this nature, namely "noise", often heard in sensitive receivers, during intervals between signals, and also in sensitive microphone amplifiers. Such noise is merely an irregular migration of electrons in the valve itself and in the grid leak (R_{g1}). To simplify matters, then, let us suppose that a negative voltage, say 1 mV, is set up across R_{g1} at a given time. Amplification (say 10 x) in valve V_1 produces a positive 10 mV signal at R_{a1}.

Isolating capacitor C_1 then passes this signal to the control grid of valve V_2. Assuming that there is no grid current, a negative transient, 100 mV this time, is obtained at R_{a2}. As assumed at the outset, however, point b is connected direct to point a; the result, as we have seen, is that the original transient of 1 mV builds up in what may be described as an "avalanche" to 100 mV. What is more, the electrons in the valve travel so fast as to produce a further avalanche to 100 x 100 mV = 10 V almost immediately, and with nothing to limit the avalanche this would continue to 1000 V and so on. As it is, however, the anode voltage of V_2 obviously cannot go on decreasing indefinitely. The lowest value this voltage can fall to depends upon the characteristics of the particular valve, and may be defined as the anode voltage which with zero grid potential, will allow anode current to flow in valve V_2, to such an extent that it provides the corresponding voltage drop in the anode resistance. Let us assume this anode voltage to be 30 V. It is reasonable to suppose that this is low enough compared with the original condition of the circuit (before a and b were connected) to drive valve V_1 temporarily below cut-off, or in other words to suppress anode current in this valve. The result is that capacitor C_1 has time to charge to the equivalent of V_b, since the anode voltage of valve V_1 which is now cut off, is approximately + V_b. In this way the anode voltages of the two valves become temporarily stable, V_1 being without anode current and V_2, on the other hand, fully conducting. This stability does not last very long, however, because the charge of C_2, constant throughout the avalanche, has time to leak away through R_{g1}, thereby causing the grid potential of valve V_1 to increase exponentially.

Once V_1 produces enough anode current to take the overall amplification of the two valves beyond 1 x (which does not take long, since valve V_2 is already at full gain) another avalanche takes place in the opposite direction. Valve V_2 now gets a negative voltage peak of $V_b - V_{a1}$ on its grid, (since C_1 had been charged to a voltage equal to V_b) i.e. roughly 70 V with $V_b = 100$ V, driving this valve far below cut-off. Next, grid current in V_1 charges C_2 to voltage V_b, thus producing another interval of stability. During this, the charge of C_1 leaks away through R_{g2} and R_{a1} and also, of course, through the internal resistance of the voltage source (V_b). Because R_{g2} is usually very much higher than the other two resistances, however, the duration of the stable interval is mainly governed by it.

When C_1 has discharged enough to enable anode current to flow in V_2, the circuit triggers again, thereby returning to the original condition. It will be evident that the circuit operating in this way continuously is in effect a form of oscillation. The whole process can be divided into four distinct stages invariably occurring in the same order, i.e.:

1. a quick change whereby V_a of V_1 becomes more positive and V_a of V_2 more negative;
2. an interval of stability with $V_{a1} = V_b$ and V_{a2} at the minimum positive value;
3. another quick change whereby V_{a1} becomes more negative and V_{a2} more positive;
4. another interval of stability with V_{a1} at the minimum positive value and $V_{a2} = V_b$.

The effect is that the anode voltages of V_1 and V_2 are both square waves, as shown in fig. 2. The diagram also shows that, as implied, though not stated, the two voltages are in anti-phase.

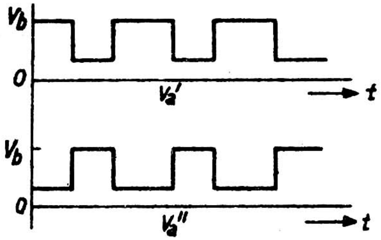

Fig. 2. Anode-voltage variation of the two valves in a free-running multivibrator circuit.

Fig. 3 is a more conventional circuit diagram of the free-running multivibrator containing the same components as the circuit of fig. 1; the same explanation covers both.

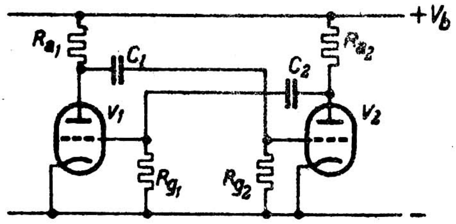

Fig. 3. Conventional free-running multivibrator circuit.

Note that the conventional circuit is symmetrical throughout and that the two valves perform similar tasks.

With this in view, double triodes are usually employed in free-running multivibrator circuits, although not necessarily so. It is probably clear from the description of the action of such circuits that two valves of different types will do as well, and it may happen that this is even better in some respects, as will be explained later.

To lead up to this explanation, let us consider the specific properties of square-wave voltages as generated by multivibrators. Since the one anode-voltage wave-form, is usually the other in reverse, it is enough to examine only one of them.

Fig. 4 shows the general wave-form of such voltages, with T as the time for one cycle of the oscillation, or, in other words, the reciprocal of the frequency; A as the pulse-amplitude, that is, the peak-to-peak value of the oscillation, in volts, t_1 as the width of the positive pulse, in seconds or microseconds, and t_2 as the width of the negative pulse.

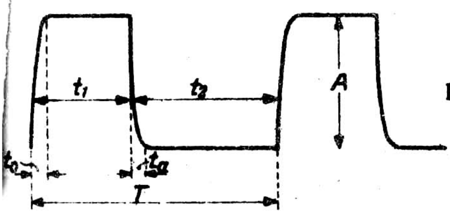

Fig. 4. Characteristics of square-wave voltage: t_1 and t_2 are pulse-widths; A is pulse-amplitude; t_0 and t_a are the rise and decay time of the pulse; T is the periodic time = 1/frequency.

Note also t_0 and t_a, the times in which the oscillation varies from the negative peak to the positive and back again; together with the amplitude, they govern the steepness, or slope, of the edges of the pulse, and therefore determine how far the oscillation deviates from a true square-wave form.

The properties will now be examined individually.

1.2 Determination of pulse amplitude

As explained with regard to the action of multivibrator circuits, the valves used are most of the time in the two semi-stable states, i.e. cut off, or in the maximum current state with grid potential at zero. Unless the anode has a load connected to it, the anode voltage at cut-off equals the supply voltage. With the grid potential at zero, the anode voltage depends on the data for the particular valve and is best determined by means of the I_a/V_a characteristic as shown, for a triode, in fig. 5. The anode-load resistance can be plotted on these characteristics as a load-line joining the point on the V_a co-ordinate indicating the available supply voltage, to the point on the I_a co-ordinate corresponding to the particular anode current $(\frac{V_a}{R_a})$; fig. 5 shows three load-lines corresponding to anode loads of 2000, 6000 and 10 000 Ω with supply voltages of 40 V, 120 V and 100 V, respectively. The point of intersection of the load-line and

此为试读,需要完整PDF请访问: www.ertongbook.com

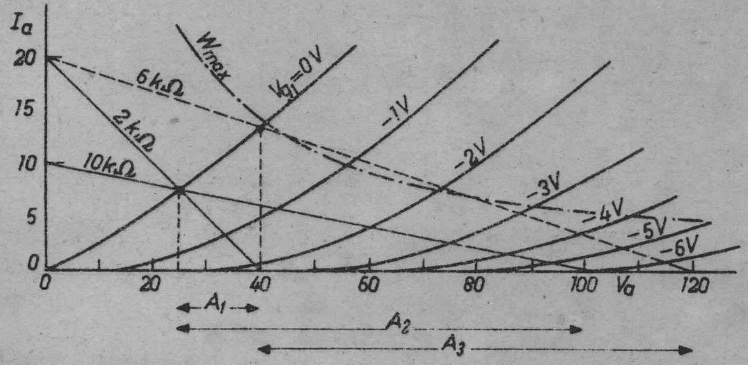

Fig. 5. Pulse-amplitude as deduced from the Ia/Va characteristics of a triode.

the characteristic for $V_{g1} = 0$ indicate the anode voltage (and anode current) for this particular value of grid potential. The difference between this anode voltage and the supply voltage (see dotted line in diagram) is the maximum pulse amplitude obtainable with this particular valve, anode load and supply voltage. It will be evident from the examples that pulse amplitude increases with anode load and supply voltage.

A point to remember is that the anode voltage must not be too high or the maximum anode dissipation will be exceeded. This happens when, referring to the diagram, the point of intersection of the load-line and the $V_{g1} = 0$ line lies outside the area contained by the curved dotted line W_a max. With multivibrator circuits, however, it does not matter very much if the load-line happens to pass outside this area (6 kΩ-line, for example), because the valve does not operate in this region for very long.

As we shall see later, a high anode load affects the shape of the pulses, although in many applications this effect is not so serious as to prevent a certain variation in resistance.

On the other hand, with a low anode load the anode dissipation soon becomes excessive, unless a low supply voltage is employed, which in turn limits the amplitude.

1.3 Determination of pulse-width

Since pulse-width depends on the variation of grid potential, this must be determined first. As explained with regard to the action of multivibrators, the anode potential of valve V_1 falls rapidly as the pulse is formed, and since the V_1 anode is connected by a capacitor to the grid of V_2, the grid potential of this valve suddenly becomes negative.

Whereas the anode potential of V_1 remains low, the grid potential of V_2 begins to build up again almost immediately, owing to the current discharged by the isolating capacitor. The latter, which was charged to the value V_b before the triggering of the multivibrator, must now reduce its charge to suit the changed conditions, that is, to a potential equalling the supply voltage minus the pulse amplitude (on the anode load of V_1).

The discharge current flows from the positive end of the capacitor through the anode load of V_1 (against the flow of anode current) and through the internal resistance of the supply unit (from + to -), and returns through the grid leak to the negative end of the capacitor (connected to the control grid).

As the anode load and the internal resistance of the supply unit are invariably very much lower than the grid leak, it is safe to neglect them and assume that the discharge current does not affect the anode voltage of V_1 appreciably.

Now, capacitors not charged by or discharging into circuits containing inductive components invariably charge and discharge in accordance with an exponential function, or exponentially, as it is usually called. Fig. 6 shows such a function, with voltage plotted on the vertical axis and time on the horizontal co-ordinate, or, in other words, with capacitor voltage V_C varying as a function of time from $V_C = 0$ at the time $t = 0$.
We are concerned with the time for V_C to reach 0.632 of the applied voltage, that is, the time constant of the circuit (CR). This increases with the capacitance (heavier charge takes longer to pass through a given resistance)

and with the resistance (current density, or charge per unit time, is inversely proportional to resistance at a given voltage).

Accordingly, the time constant in seconds is dependent upon the resistance in megohms and the capacitance in microfarads, and is equivalent to the product of the two; again, the time constant in microseconds equals resistance in megohms times capacitance in picofarads.

For example, given $R = 1{\cdot}2$ MΩ, and $C = 820$ pF, the time constant will be $1{\cdot}2 \times 820$ μsec = 984 μsec. As the voltage goes on increasing (see fig. 6) after the initial time constant, there is in effect another time constant: the time to charge from 63.2 V to $(100-63.2) \times 0.632$ V, i.e. 86.4 V. Therefore, voltage V_C, after a time equal to $2 \times CR$, is 86.4 V. Similarly, with 3 times the time constant, the overall voltage reaches 95 V, and so on.

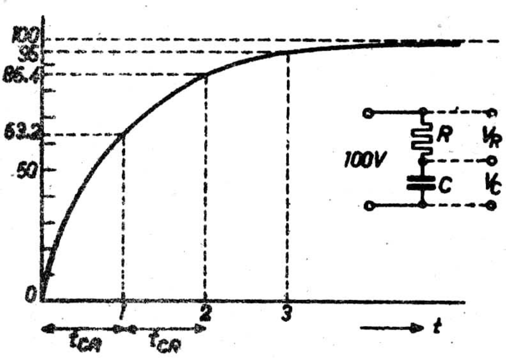

Fig. 6. Variation of voltage across a capacitor with 100 V supply, plotted exponentially against time.

The voltage V_R, across the resistor, falls as the capacitor voltage V_C rises. The variation of V_R with time is, of course, the same exponential curve in reverse, as shown in fig. 7.

The diagram also shows that, when capacitors discharge into resistors, the voltage falls exponentially, dropping to 0.368 of the original value after one time constant, then to 0.136 after twice the time constant, to 0.05 after three times the time constant, and so on. This refers, of course, to the same voltages V_C and V_R.

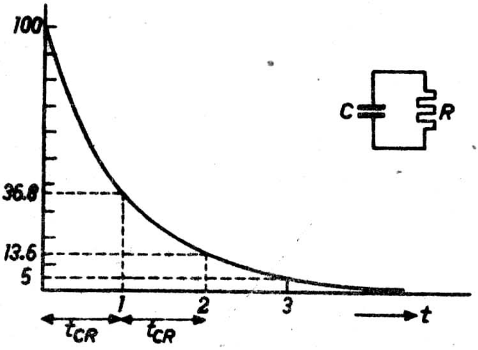

Fig. 7. Discharge from a capacitor charged to 100 V, plotted against time, and variation of voltage V_R (fig. 7). General exponential function for calculation of pulse-width.

The grid potential in multivibrator circuits varies as shown in fig. 8. As we have seen, at time t_1 the zero potential grid falls by an amount equal to the pulse amplitude

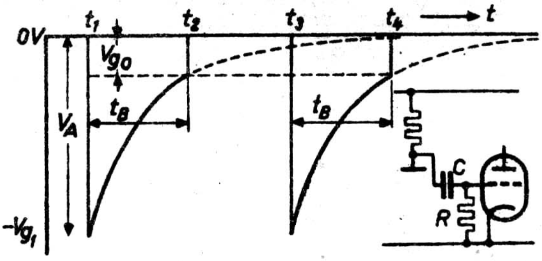

Fig. 8. Variation of grid-voltage in multivibrator circuit with grid leak connected to 0 V-line (cathode voltage). Dotted line indicates variation as this would be without anode current.

(V_a) of the other valve. At least, that is what happens when the triggering of the circuit is infinitely fast, or, in other words, when the edges of the pulse are infinitely steep, as may be assumed, in calculations. The result is that the grid voltage rises again at once in accordance with the exponential curve governed, as we have seen, by the resistance R of the grid leak and the capacity C of the isolating capacitor. At cut-off potential the multivibrator triggers and the grid voltage quickly returns to zero. The cut-off potential V_{go}, depending on the type of valve employed and the anode voltage, is readily deduced from the I_a/V_g characteristic.

Referring to fig. 8, we see that cut-off is at time t_2 and that the pulse-width of the particular valve is $t_2 - t_1 = t_B$. The time between t_2 and t_3 is the pulse-width of the other valve, t_3 being the moment when grid voltage falls, thereby starting the charging cycle again. Accordingly, pulse width depends on the ratio of V_{go} to V_a, since this determines what portion of the exponential curve will remain unused. In the case illustrated by fig. 8, the ratio is 20%, corresponding to 1.7 t_{CR}, as will be seen from fig. 7 (general exponential curve).

Given the values of R and C, the pulse-width can be computed as 1.7 times the CR value. Conversely, a given pulse-width can be obtained by dividing the desired time by 1.7 in order to determine the required CR product.

In this way it can be shown that pulse-width depends on the following:

1. the type of tube employed, with a certain cut-off potential V_{go} also depending on
2. the supply voltage, which, as we have seen, affects
3. the pulse amplitude, governing ratio V_{go}/V_a;
4. the time constant as a variable quantity affording direct, that is, linear control of the pulse-width;
5. the potential of the grid leak with respect to the cathode of the particular valve.

Under given operating conditions, points 1, 2, 3 and 5 provide a specific factor for use with the time constant.

Point 5 has been left out of account hitherto because the potential referred to was zero in the particular example and therefore did not affect the result. However, the grid leak may be connected to a positive supply instead of the cathode. Nevertheless, this does not affect the principle, because for all practical purposes it is usually safe to assume that in the steady state the grid leak is high enough, and the grid current heavy enough, to keep the grid voltage at zero. How far this assumption is true depends upon the grid-cathode conduction resistance of the valve employed and the resistance of the grid leak, as we shall see later.

With a positive voltage applied to the grid leak, the grid potential varies in very much the same way, i.e. falls with the pulse amplitude, rises exponentially to cut-off and then returns suddenly to zero. The only difference is that the portion of the exponential curve covered is smaller, as will now be explained. Referring again to fig. 8, it will be seen that without anode current the grid voltage would go on rising after time t_2, as indicated by the dotted line, returning to zero, in theory, at infinity; the capacitor is then down to the new charge level (= V_a of the valve connected) and the voltage across the grid leak is zero. This may be defined as the ultimate steady state.

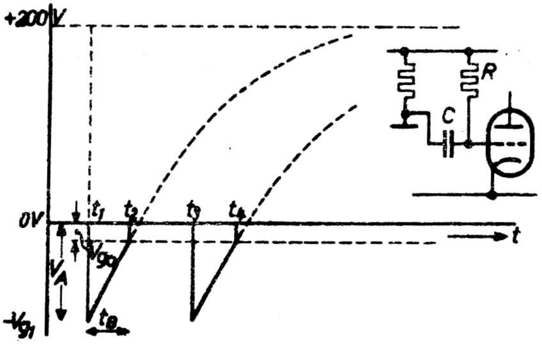

Fig. 9. Variation of grid-voltage in multivibrator circuit with grid leak connected to 200 V supply.

With other than 0 V, say, 200 V on the grid leak, current will flow in this resistor until the "grid voltage" reaches + 200 V, still on the assumption, of course, that anode and grid current are both absent. Fig. 9 illustrates the situation from the practical point of view. Because the valves invariably carry a certain amount of anode current, the circuit triggers as soon as the grid voltage reaches V_{go}. At the same time, it will be seen that the portion of the exponential curve not covered is very much larger than

此为试读，需要完整PDF请访问：www.ertongbook.com