# PULSE FUNDAMENTALS

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*Under the editorship of Dr. Irving L. Kosow*



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# PREFACE

This book presents a comprehensive course in pulse circuit techniques at the technical institute level. A working knowledge of d-c and a-c circuit theory is presupposed. A working knowledge of basic algebra is the only mathematical requirement.

The introductory chapter describes the essential differences between pulse and communication-type networks and shows typical applications of the former. Various nonsinusoidal waveshapes and the parameters by which they are described are also included.

Chapter 2 discusses linear networks (resistors, inductors, and capacitors), and their response to the nonlinear waveshapes studied in Chapter 1.

In Chapter 3, the operation of resistance-capacitance coupled vacuum-tube amplifiers is reviewed. Equivalent circuits are derived and their importance as an analytical tool is demonstrated.

Chapters 4 and 5 are devoted to the transistor. No attempt is made to discuss the physics of these devices, but problems of such practical importance as stability of the operating point, load line analysis, and equivalent circuit parameters and their application are covered thoroughly. From this point forward, vacuum-tube and semiconductor devices are treated in a unified, integrated manner.

Methods of amplifier compensation for wideband application are investigated next. High frequency shunt, series, shunt-series, four-terminal compensating networks, and low-frequency compensation networks are described. Important factors in selecting vacuum tubes and transistors for pulse work are also studied.

Cathode and emitter followers are discussed in Chapter 8. Equivalent circuits are derived for both type "followers" and gain, and impedance calculations are again demonstrated.

Chapter 9 discusses characteristics of vacuum tube and transistors as switching circuit components. The principles discussed in this chapter are most important for a thorough understanding of the remainder of the book.

Following this are chapters on nonlinear waveshaping circuits (those using active elements — tubes and transistors), clamping circuits, the various types of multivibrators, blocking oscillators, time base generators, counting circuits, transmission gates, pulse modulation systems, and delay lines. Typical applications for each type of circuit are described. Free use is made of circuit diagrams and waveform illustrations to clarify the explanations.

In the final chapter, all circuits previously described are shown working together in a laboratory type oscilloscope.

Numerous references are given throughout the book. Wherever possible, the selected references are also at the technical institute level. Of necessity, however, some are of a more difficult nature, but the reader should still find them useful.

Questions are given at the end of each chapter. They are intended primarily as a stimulant to group discussion, but may also be used as objective "homework" assignments to classroom instructors. Full answers may be obtained by qualified instructors upon written request to the publisher.

It is my pleasure to acknowledge assistance from the following persons and organizations in the preparation of this book: Dr. Irving L. Kosow, Professor and Head, Electronic Technology, Staten Island Community College, Staten Island, N. Y., whose contributions to the organization and scope of the text were invaluable; Dr. Charles M. Thompson, Wentworth Institute, Boston, Mass., for reading the complete manuscript and making suggestions for improvement; Darrell L. Geiger and G. O. Allen, Chief Instructor and President, respectively, Cleveland Institute of Electronics, Cleveland, Ohio, for initial prompting to write the book, constant encouragement, and permission to use portions of texts originally written for the C.I.E.; Jake Davis Jr., Educational Director, National Radio Television School, Cleveland, Ohio, for permission to use portions of this text in resident study courses and to my students for their many worthwhile comments; my editorial associates at the National Radio Institute, Washington, D. C., particularly, John F. Zung, for manuscript reading and comment; Lindbergh H. Trent, independent service technician, for his most observant comments on the practical aspects of circuit operation; Nolan G. Thorsteinson, free lance technical writer, and his good wife Patty,

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# 1

## INTRODUCTION

*Pulse circuits are defined as those circuits required for the* generation and control of precisely timed waveforms. They differ widely from those used in radio communications equipment, in which the waveform of the operating voltage is usually sinusoidal or a simple combination of sinusoidal waves. Some pulse circuits are used to develop square, sawtooth, trapezoidal, or peaked waves of voltage that are required in indicating, timing, and modulating circuits of television, radar equipment, and so forth. The circuit operating conditions in most cases range from *full on* to *full off* and do not fall into the simple classifications of Class A, B, and C operation. The circuits, therefore, are named for the function they perform rather than their type of operation.

### 1.1 Historical developments

Pulses, in the form of dots and dashes, were used to convey intelligence by wire in the earliest days of electrical communication. Marconi used short and long pulses in his "wireless" to form the modulation envelope for radio-frequency energy.

The advent of the triode vacuum tube made possible modern radio communication and the transmission of intelligence by means of an amplitude-modulated carrier. In this scheme, the prime-signal source is a sinusoidal-signal generator. Recently, many electronic systems have been developed that require the use of pulses as the prime-signal source.

## 1.2 Typical pulse applications

Pulses are used in radar, which is an electronic system employed to detect the presence, range, and direction of objects. The block diagram of a typical radar system is shown in Fig. 1-1. It consists

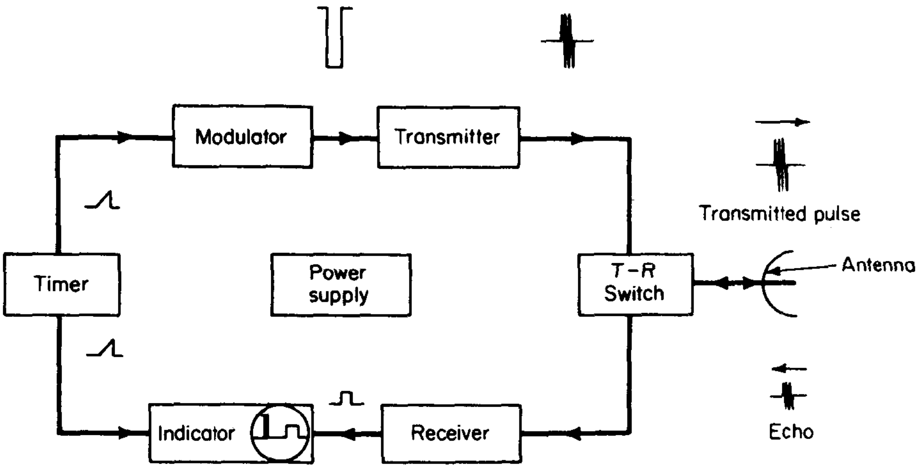


*Figure 1-1 Block diagram of a radar set.*

of a timer, modulator, transmitter, transmit-receive (T-R) switch, antenna, receiver, indicator, and power supply.

The timer synchronizes the indicator and transmitter circuits. At regular intervals it produces a pulse, that causes the sweep (horizontal movement of the scanning spot) to start in the indicator. At the same instant, or after a precise predetermined time, the timer produces a signal, which is also applied to the modulator.

When the modulator receives the synchronizing timing pulse it develops a high-voltage, high-power pulse, which turns the transmitter on for a short time interval.

The transmitter is a very high frequency (vhf) high-power generator of radio-frequency (r-f) energy. It produces a radio wave of constant frequency and amplitude for the short time during which it is turned on by the modulator.

The T-R switch is an electrically operated switch that effectively disconnects the antenna from the receiver during the production of the transmitter pulse and connects it to the transmitter. During the remainder of the operating period, the T-R switch connects the antenna to the receiver.

The antenna acts as a radiator of the transmitter-produced energy when the transmitter is pulsed. A small portion of the radio wave transmitted from the radar set travels to the object (target) and is reflected as shown in Fig. 1-1. The reflected waves, called *echoes,* are picked up by the antenna and conveyed to the receiver. The antenna is designed to be directive for both transmission and reception so that the *bearing* (direction) as well as the *range* (distance) of the target may be determined.

The receiver amplifies the echoes and provides *video* pulses, called *pips,* of sufficient amplitude to produce visual indications on the indicator.

The indicator can be thought of as an electrical stop watch that measures precisely the small time interval required for the transmitter pulses to travel to the target and for the echoes to return. Because the speed of propagation of radio waves is known with great accuracy, the range can be determined as accurately as the time interval can be measured.

Pulses are also used in *radio telemetering.* In this application, certain variables, such as changes in temperature of the outer casing of a rocket, are sensed and measured in flight. This information is then transmitted to a ground station where permanent records are made for analysis by engineers.

A simplified explanation of telemetering can be given with the help of Fig. 1-2. The output signal of a pickup device, termed a *trans-*

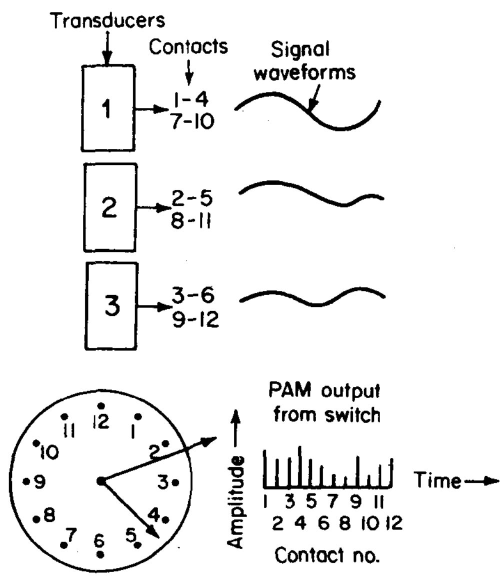


***Figure 1-2** Simplified illustration of how the output of a transducer is "sampled."*

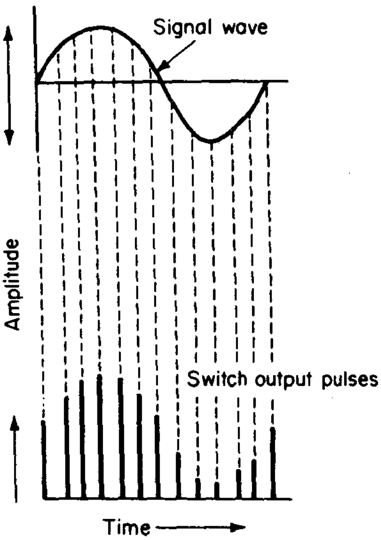


*Figure 1-3 Illustration of how switch output is a series of pulses having uniform width and amplitudes proportional to the corresponding amplitude of the signal wave.*

*ducer*, is shown as a sinusoidal waveform. This signal is applied to several contacts on the stationary plate of a mechanical switch. A revolving brush then passes over each contact and samples the transducer output. Assuming that each contact is of uniform area and that the brush is revolving at a constant speed, the switch output is a series of pulses having uniform width, and the amplitude of each successive pulse is proportional to the corresponding amplitude of the signal wave, as shown in Fig. 1–3. The output signal of the switch is now *pulse-amplitude modulated*, abbreviated PAM. It is apparent that the successive pulses reproduce the signal wave rather faithfully. If the number of samplers per second exceeds twice the highest frequency contained in the signal wave, the original signal can be reconstructed from the succession of pulses.

The PAM signal is next used to modulate an FM transmitter whose output is radiated by means of a suitable antenna.

At the ground station the signal is picked up by an antenna of a special type and applied to the input terminals of a highly sensitive receiver. The receiver amplifies the weak signal and separates the FM carrier signal from the PAM signal. The PAM output signal of the receiver is then applied to a detector, whose instantaneous output voltage is proportional to the instantaneous amplitude of the input voltage. This voltage is then used to operate a mechanical reproducer that reconstructs an essentially faithful reproduction of the signal originally produced by the pick-up transducer.

A re-examination of Fig. 1–3 shows considerable unallocated time between successive pulses. For example, the time required for each pulse may be 10 μsec and the elapsed time between pulses may be 100 μsec.

Use of this unallocated time introduces the possibility of *time-division multiplexing*, in which successive intervals of time are assigned to different signals or information channels. In practice, this is exactly what is done in radio telemetering. One transducer may be used to record, say, temperature variations; separate transducers may measure other variables, such as atmospheric pressure and cosmic radiation. The output signal of each transducer is applied to successive contacts on the mechanical switch. This operation is illustrated in Fig. 1-4. The amplitudes of the successive output pulses

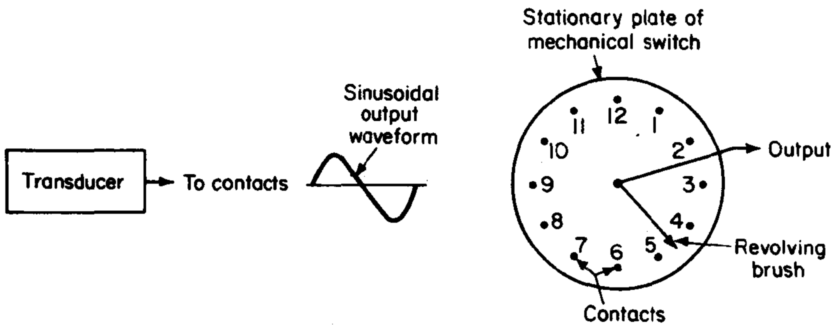


***Figure 1-4 Simple multiplex system.***

from the switch are now proportional to the corresponding amplitudes of each signal wave.

At the output of the ground-station receiver, suitable filters are required to separate the various transducer signals from the composite PAM signal, but this filtering represents no great technical difficulty. Once separated, the individual signals are handled in the manner previously described.

A television system also serves to illustrate another practical application of pulses. At the television studio, a camera is trained on the scene to be televised. A *horizontal line pulse*, occurring at a frequency of 15,750 cps, causes the electron scanning beam to begin in the upper left-hand corner of the camera tube and move at a uniform rate from left to right along lines that lie at a constant distance from each other. This is illustrated by the solid lines in Fig. 1-5. At the end of each horizontal line, the scanning beam returns to the left and starts a new line. During the return interval, a *horizontal blanking pulse* is applied to the camera tube, and the spot does not appear in the reproduced picture. When the scanning