1974

Steady-State Response of Differentiating Circuits

Tom Greenslade

Kenyon College, greenslade@kenyon.edu

Follow this and additional works at: https://digital.kenyon.edu/physics_publications

Part of the Physics Commons

Recommended Citation

"The Steady-State Response of Differentiating Circuits", *American Journal of Physics*, 42, 604-605 (1974)

This Article is brought to you for free and open access by the Physics at Digital Kenyon: Research, Scholarship, and Creative Exchange. It has been accepted for inclusion in Faculty Publications by an authorized administrator of Digital Kenyon: Research, Scholarship, and Creative Exchange. For more information, please contact noltj@kenyon.edu.

Steady-State Response of Differentiating Circuits

Thomas B. Greenslade Jr.

Citation: *American Journal of Physics* **42**, 604 (1974); doi: 10.1119/1.1987786

View online: <http://dx.doi.org/10.1119/1.1987786>

View Table of Contents: <http://scitation.aip.org/content/aapt/journal/ajp/42/7?ver=pdfcov>

Published by the American Association of Physics Teachers

Articles you may be interested in

[Reliability and frequency specificity of auditory steady-state response](#)

J. Acoust. Soc. Am. **120**, 3245 (2006); 10.1121/1.4788282

[Neuromagnetic steady-state responses to auditory stimuli](#)

J. Acoust. Soc. Am. **86**, 1033 (1989); 10.1121/1.398093

[Auditory middle latency and steady-state responses in infants](#)

J. Acoust. Soc. Am. **80**, S48 (1986); 10.1121/1.2023822

[Studies of the auditory steady-state response II. Masking](#)

J. Acoust. Soc. Am. **77**, S65 (1985); 10.1121/1.2022456

[Steady-state response of the electron distribution function to an applied electric field](#)

Phys. Fluids **23**, 921 (1980); 10.1063/1.863082

American Association of **Physics Teachers**

Explore the **AAPT Career Center** –
access **hundreds of physics education and other STEM teaching jobs** at two-year and four-year colleges and universities.

<http://jobs.aapt.org>

can also be heard as one of the components in the rectified signal.

This illustrates the effects of introducing a non-linear amplifier (the diode) into the circuit. Without rectification (the diode removed), the signal is composed of the two harmonic oscillations with frequencies f_1 and f_2 . With the diode in

the circuit, the rectified signal contains harmonic components with frequencies f_{av} and f_{mod} .²

¹ D. Halliday and R. Resnick, *Physics for Students of Science and Engineering* (Wiley, New York, 1966), p. 512.

² F. Crawford, *Waves*, Berkeley Physics Course, Vol. 3, (McGraw-Hill, New York, 1968), pp. 322 and 323, Probs. 6.27 and 6.28.

Steady-State Response of Differentiating Circuits

THOMAS B. GREENSLADE, JR.

Department of Physics

Kenyon College

Gambier, Ohio 43022

(Received 4 October 1973)

An R - C differentiating circuit similar to the one shown in Fig. 1(a) is often discussed in electronics texts.¹ The input is a square wave, and the nature of the output depends on both the time constant of the circuit, RC , and the time which has elapsed since the input was first applied to the circuit.

The output which is commonly illustrated is the steady-state waveform which is observed in actual practice on an oscilloscope. A step by step analysis of the operation of the circuit will usually start with the initial application of the square wave to the differentiating circuit and will therefore deal with a transient situation. It is the purpose of this note to show how the steady-state waveform develops from the initial transients.

If the period T of the square wave is much greater than the time constant, the steady state output will be the series of sharp negative- and positive-going pulses shown in Fig. 1(b).

If $T \cong RC$, the square wave will emerge with exponential curves which do not go to zero bounding its upper and lower sides [Fig. 1(c)]. Notice that the discontinuities in potential at the leading and trailing edges of the waveform are equal to the amplitude V_0 of the input square wave and that the waveform is now symmetrical about the zero potential line.

To see how this develops, consider a square wave with its lower edge clamped at zero potential [Fig. 1(d)], applied to the input of the circuit. The condenser, which is originally uncharged, starts to charge through resistor R and the output potential drops exponentially to a fraction f of its original value, where $f = \exp[-T/(2RC)]$. The output potential is now fV_0 . When the input potential drops from V_0 to 0, the output also drops by V_0 , giving a potential of $fV_0 - V_0$. This potential decays to $f(fV_0 - V_0)$ by the end of the first complete cycle. The input potential now

FIG. 1. Input and output waveforms for differentiating circuit.

jumps to V_0 , and the second cycle starts with an initial output potential of $f^2V_0 - fV_0 + V_0$.

The potentials at various points on the output waveform are given below, where the numbers refer to the points shown in Fig. 1(e):

$$\begin{aligned} V_1 &= V_0 \\ V_2 &= fV_0 \\ V_3 &= fV_0 - V_0 \\ V_4 &= f^2V_0 - fV_0 \\ V_5 &= f^2V_0 - fV_0 + V_0 \\ V_6 &= f^3V_0 - f^2V_0 + fV_0 \end{aligned}$$

After a sufficiently long time has elapsed, the maximum output potential at the beginning of each cycle is given by $V_0(1 - f + f^2 - f^3 + \dots)$ or $V_0/(1 + f)$. Since the discontinuity in the output is V_0 , the minimum potential, which is reached halfway through each cycle, is $fV_0/(1 + f) - V_0$ or

$-V_0/(1 + f)$. The steady-state waveform is thus symmetrical about the zero potential line.

In the limit as f approaches 0 (corresponding to $T \gg RC$), these maximum and minimum potentials become V_0 and $-V_0$, as shown at (b). The limit as f approaches 1 ($T \ll RC$) produces maximum and minimum potentials of $V_0/2$ and $-V_0/2$. The input waveform is shifted downward, but is otherwise unchanged [Fig. 1(f)]. This serves to illustrate the fact that any signal which is passed through a series capacitor emerges with a zero average potential.

If the symmetrical square wave shown in Fig. 1(f) is now used as the input waveform, the maximum output potential is again $V_0/(1 + f)$, and the output waveform is that shown in Fig. 1(e).

¹For example: J. J. Brophy, *Basic Electronics for Scientists*, (McGraw-Hill, New York, 1966), p. 112.

Use of Video Tapes in Advanced Laboratory

H. BRODY
P. D. S. PARKINSON
W. SELOVE

Department of Physics
University of Pennsylvania
Philadelphia, Pennsylvania 19174
(Received 15 November 1973)

The advanced modern physics laboratory at the University of Pennsylvania is taken by all majors in conjunction with a course in modern physics at the junior or senior level. The students are required to choose a number of experiments from those that are set up in the lab areas. The experiments include such standard items as the Stern-Gerlach Experiment, Rutherford scattering, Compton scattering, omegatron, Mossbauer effect, mass spectrometer, and relativistic e/m for electrons. The students sign up for an experiment and

for a period of a week or two the equipment is theirs and they work at their own pace. One difficulty occurs because the instructor must explain each piece of apparatus at the beginning of the year to everyone or explain each piece of equipment to each group as they use it. The former overwhelms the students and they forget by the third or fifth week. The latter method works fine, except the instructor ends up giving the same series of lectures every other week for the entire year.

This year, a complete description of every experiment was videotaped. A student, desiring to learn how to use the apparatus, goes to the library, checks out a tape cassette for that experiment, and then plugs it into the video playback unit and has a private lecture.

These videotape lectures last 30–55 min and show the student, in some detail, the theory behind each experiment, how to do the experiment (what button to push), and how to analyze the data.