Sound Synthesis

Analog and Digital Techniques

Terence Thomas

Sound Synthesis

Analog and Digital Techniques

Terence Thomas

TAB TAB BOOKS Inc.
Blue Ridge Summit, PA

FIRST EDITION / FIRST PRINTING

Library of Congress Cataloging-in-Publication Data

Thomas, Terence, 1942 –
Synthesis : analog and digital techniques / by Terence Thomas.
p. cm.
ISBN 0-8306-9276-2 : ISBN 0-8306-3276-X (pbk.)
1. Digital circuits—Design and construction. 2. Synthesizer (Musical instrument) 3. MIDI (Standard) I. Title.
TK7868.D5T49 1990
786.7'4—dc20 89-20464
CIP

TAB BOOKS Inc. offers software for sale. For information and a catalog, please contact TAB Software Department, Blue Ridge Summit, PA 17294-0850.

Questions regarding the content of this book should be addressed to:

Reader Inquiry Branch
TAB BOOKS Inc.
Blue Ridge Summit, PA 17294-0850

Acquisitions Editor: Roland S. Phelps
Book Editor and Designer: Lisa A. Doyle
Production: Katherine Brown

Sound Synthesis

Analog and Digital Techniques

Introduction

Synthesizers have had and will continue to have a most profound effect on the music world. Modern technology has revolutionized the recording industry and has changed the way we make music. These advances, spurred on by the industries' active research and development programs, are nothing short of phenomenal. A veritable avalanche of digital synthesizers and sound-processing equipment has inundated the music market and presented the prospective buyer with a plethora of systems and techniques.

It is the purpose of this book to clear up some of the confusion and provide the reader with an anatomy of analog and digital synthesizer systems. Starting with power requirements, Chapter 1 is on synthesizer power supplies. The next chapter is on waveshape generation, with both audio frequency as well as low-frequency control voltage sources. Although many oscillator designs (both analog and digital) have been proposed, none are superior to the sawtooth design in Chapter 2.

Chapter 3 is on filters and other versatile tone modification circuits. Chapter 4 discusses the subject of exponential control-voltage generation extensively because it is the single most important element in sound synthesis, and high-speed control-voltage generation provides the key to the most advanced and sophisticated level of tonal experimentation. Add to this a multistage voltage-variable envelope generator (Chapter 5) and you leave little to be desired when it comes to the production of electronic sound.

Keyboards and other manual control devices are then covered in Chapter 7 including a home-brew ribbon controller, which is made of common household materials. Any conceivable control-voltage parameter can be attained by the use of devices in Chapter 8, Attenuators and Processors. (The chapter on amplifiers also covers preamplifiers, voltage-controlled amplifiers, and even a device that is designed to recover and reproduce concert-hall ambience that is normally lost in the recording process.) Feedback principles such as dual-loop interlock and link coordination are discussed as well as many other advanced control techniques.

Some unique designs are included in Chapter 9, Miscellaneous Circuits, such as a voltage-controlled reverb, an octavizer, and a simple flanger. Other circuits of interest in that chapter are a control-voltage inverter, a programmable panning circuit, and an envelope detector. Voltage-control techniques are applied to as many circuit elements as possible to accommodate new methods of synchronization and to maximize module efficiency.

No book about synthesizers would be complete without a discussion of the Musical Instrument Digital Interface (MIDI) system (Chapter 11), which includes one important addition—a digital-to-analog MIDI interface. The MIDI system was devised as a communication system for digital equipment, but the MIDI interface presented provides analog equipment with the opportunity to participate in this electronic conversation. The interface can also be used to expand the tonal and envelope control potential of any digital synthesizer.

If you intend to take advantage of the designs in this book, a certain amount of circuit construction will be necessary. Chapter 1 contains information on what you will need for projects as well as some helpful suggestions to get you started. The component mapping and parts identification chapter (13) can also be of special interest to anyone contemplating project construction. If this is your first experience with circuit building, it might be a good idea to pick up a book on basic circuits and wiring techniques. For the more experienced and ambitious, the chapter on systems planning (Chapter 10) contains design details for two complete synthesizer systems, including the cabinets and front panel layouts. The foil patterns provided throughout the book help to assure efficient component layout and proper circuit operation and can be used as a guide for your own designs. Or, you can choose pre-etched circuit boards, available at local electronic suppliers.

For those who show no propensity to build their own equipment, Chapter 12 explains modulation techniques used in digital synthesizers. The "patch" diagrams can open up new possibilities for digital and analog interfacing and at the same time stimulate the imagination. Understanding circuit designs, whether or not you intend to build them, can expand your concepts and enable you to achieve your most ambitious goals.

Another major development from digital research is the sampler (sampling synthesizer), and they come in a wide variety of sizes and prices. The larger and more expensive machines can produce superior quality and a greater number of effects, but with the use of external modules and unusual patching arrangements for both input and output element modification, you can produce, with even the most inexpensive sampler, results that are amazingly comparable to more elaborate sampling synthesizers.

Those considering purchasing a unit should find that the information in the following pages can better prepare them to make intelligent decisions when selecting a commercial synthesizer. Choosing the best equipment for your needs

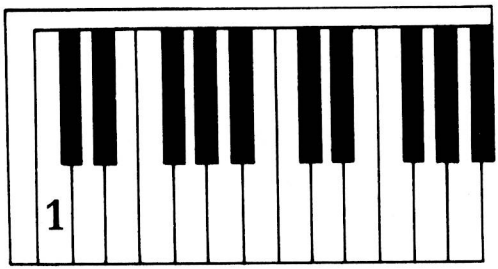
and budget can be an overwhelming experience because of the enormous inventory of equipment available.

The circuits described herein are of the highest quality and were designed to operate alongside and interface with the finest digital synthesizers on the market. Input and output impedances are compatible with a wide variety of equipment. Modules that require trigger pulses can be activated by as little as a few millivolts or by as much as a 15-volt spike.

The book also contains foil patterns for etching circuit boards. Simple circuits can be wired on pre-etched boards that are available commercially, but more complex circuits work better and are easier to build with custom-etched boards. There are beginner etching kits at local electronic suppliers for those who have never had experience with etching.

I hope this book is a valuable addition to your electronic music library. The primary concern is to provide a useful reference for your journey through the ever-expanding world of electronic music synthesis.

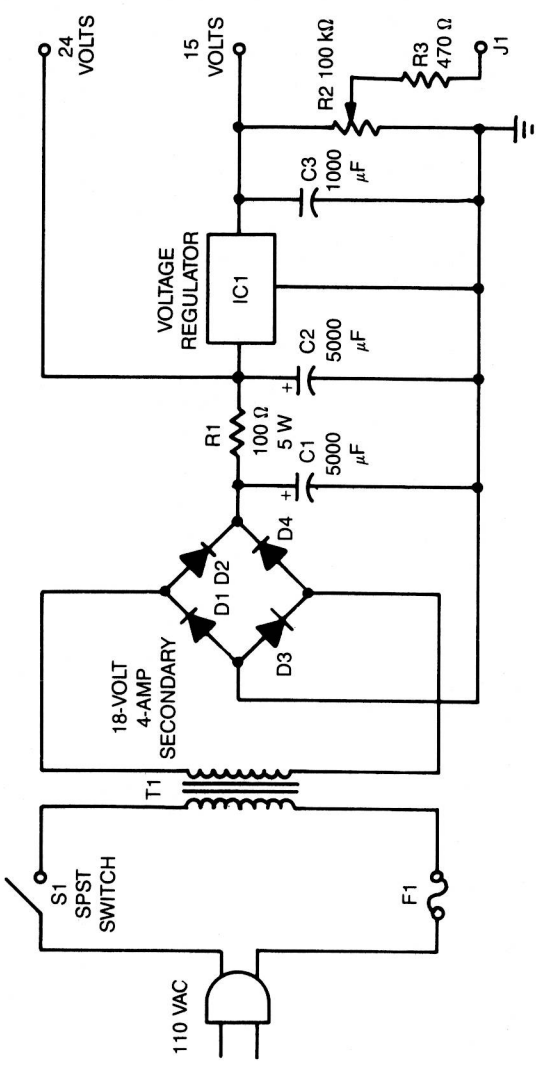
Contents



Power Supplies and Test Equipment

THIS BOOK CONTAINS MANY INTERESTING and valuable synthesizer circuits, but you need first a power supply. Because almost all designs require power, you must build a unit that can deliver enough power to as many circuits as you care to build. Figure 1-1 is a schematic of a 15-volt regulated single-ended power supply. All circuits in this book that use linear ICs have been designed to operate with a single-ended supply to avoid the necessity for the more expensive bipolar design. Transformer T1 converts 110 volts AC to 18 volts AC, while the bridge rectifier changes the AC to pulsating DC. The capacitors C1 and C2 smooth out the DC pulses and increase the voltage to 24 volts. Resistor R1 limits current and voltage regulator IC1 maintains a steady 15-volt output. Capacitor C3 serves as a final filter stage and potentiometer R2 provides an adjustable voltage output. The 24-volt output, the 15-volt output, and the ground should all be connected to barrier strips to give easy access to circuits. All parts for this, as well as the other circuits in this book, are available at local electronic supply stores.

Current and voltage respond to resistance in quite a different manner. A 200-ohm resistor can significantly reduce



S1—SPST SWITCH
T1—18-VOLT, 4-AMP POWER TRANSFORMER
R1—100 Ω, 5-WATT RESISTOR
R2—100 kΩ LINEAR TAPER POT
R3—470 Ω RESISTOR
C1—5000 μF ELECTROLYTIC CAPACITOR
C2—5000 μF ELECTROLYTIC CAPACITOR
C3—1000 μF ELECTROLYTIC CAPACITOR
D1 - D4—BRIDGE RECTIFIER UNIT
F1—3-AMPERE FUSE
J1—BANANA JACK
IC1—15-VOLT, 1-AMP VOLTAGE REGULATOR

Fig. 1-1. A synthesizer power supply.

current flow, while a 68-kilohm resistor would reduce voltage by very little. Therefore to manually control voltage, one side of the potentiometer must be connected to ground. As in the schematic of Fig. 1-1, potentiometer R2 is connected to the 15-volt output on one side and to ground on the other, therefore enabling a sweep of the entire range of voltage from 0 to 15 volts.

Resistor R3 prevents the supply from shorting out in the event that R2 is adjusted to its highest setting and a wire from J1 inadvertently comes in contact with ground.

VOLTAGE DIVIDER

The control voltage range for all of the projects in this book is 0 to 15 volts. Some synthesizer systems use a 0- to 10-volt or 0- to 5-volt control range. Figure 1-2 shows a voltage divider that converts the 15-volt output to control 5- or 10-volt machines. Resistors R1, R2, and R3 are of equal value and thus divide the voltage into thirds. More elaborate voltage dividers are used in keyboards, and transistor biasing is also accomplished with dividers.

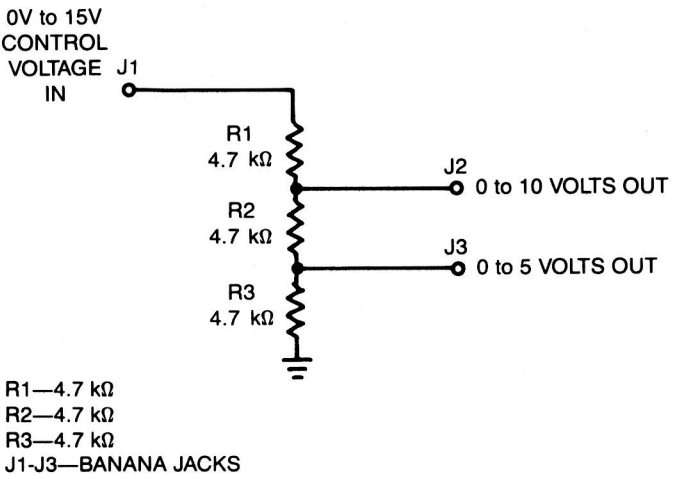


Fig. 1-2. A voltage divider.

VOLTAGE REGULATION

One of a synthesizer's main functions is to generate accurate pitches, a task that can only be accomplished with a rock-steady supply voltage. This requires the use of a voltage regulator, a device that produces a steady output even though its input might fluctuate. Most regulators are rated at only 1 ampere, so a full complement of circuits could put quite a strain on the device. One solution to this problem is to connect voltage-controlled amplifiers, preamps, mixers, ring modulators, reverbs, and other non-pitch-related circuits to the 24-volt output of the power supply. Make sure that all parts can handle the extra voltage before connecting them to the 24-volt supply. Circuits that must be connected to the 15-volt regulated supply are indicated in the schematic.

ABOUT CABLES AND CONNECTORS

Some synthesizer manufacturers use only audio cables to interconnect their circuits or *modules* as they are sometimes called. The designs in this book use two types of cables: the *audio* signals pass through shielded cable and mini-jacks, but *control voltages* and *pulses* pass through banana jacks, plugs, and unshielded cables. There are a number of reasons for this arrangement, not the least of which is economy. All audio signals must be routed via shielded cables and their corresponding plugs and jacks, which are more expensive.

Control voltages and pulses do not require shielding, so they can be routed through less expensive banana jacks and plugs. One other benefit from this system is that you then have a more easily traceable patching network due to color coding (black for control voltages, red for pulses, and grey shielded cable for audio). You'll need a wide variety of cable lengths to accommodate different distances between modules.

EQUIPMENT

Here are some of the things you must acquire if you intend to build any of the circuits in this book. You need a

spool of solder and a soldering iron. If you intend to make your own circuit boards, you need direct-etching dry transfers, a bottle of etchant, and a board. Pre-etched boards are available, but make sure that the board will accommodate all parts and that the circuit is wired correctly. A multimeter comes in handy as does a transistor tester, and equip yourself with long-nose pliers, diagonal cutters, and wire strippers.

Part Substitutions

Most of the parts for projects were chosen on the basis of availability, but there are times when even common parts are hard to find. Bipolar transistors, both npn and pnp can be replaced by general purpose transistors of like polarity. Field-effect transistors present no problem, because almost any number can be substituted for any other of the same type. Capacitors can be substituted, but care must be taken to match the microfarad rating as close as possible or circuit performance will suffer. Power supply capacitors can vary to a great extent, but their voltage rating should exceed the supply voltage by at least 10 volts.

All resistors are rated at 1/4 watt unless otherwise noted. The rule for resistor substitution is that if other parts have been replaced, a different resistor value might be necessary. Experimentation is the key to success in electronic music synthesis, whether with different patches or different circuits components.

Circuit Designer

This section explains how to construct a circuit designer, which provides a method of trying designs before actually soldering together the final circuit on the board. The designer provides the opportunity for you to try different parts, make design changes, and experiment with new designs. See Fig. 1-3.

First, a socket breadboard can be obtained from your local electronic supply house. The socket boards I use are two QT-35S sockets and a QT-35B bus strip. All sockets are formed from a prestressed, spring-loaded, noncorrosive

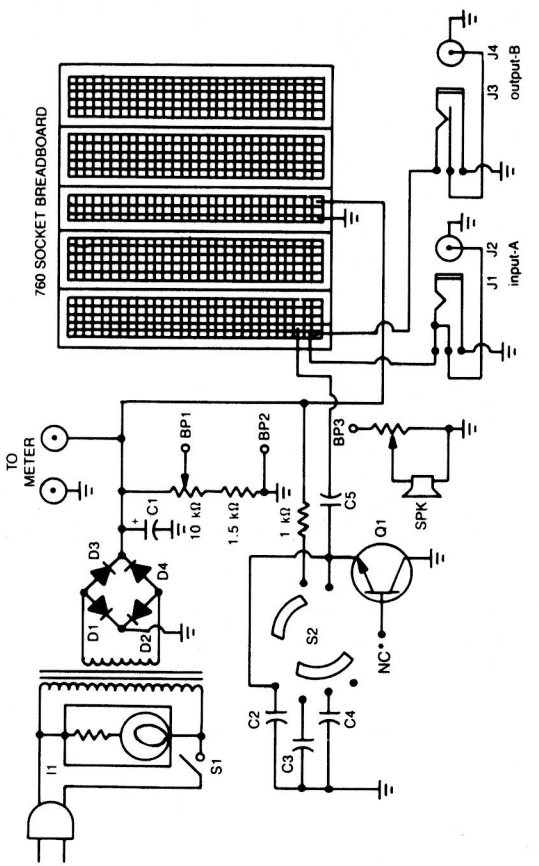


Fig. 1-3. A schematic of the circuit designer.

nickel-silver alloy. Each socket has five tie points per terminal, and each bus strip has two separate rows of interconnecting terminals. Boards conform to 1/10-inch grid, are DIP compatible, and will accommodate 10 flat-pack 14-lead ICs.

The cabinet of the designer is a 7-inch by 5-inch by 2-inch metal chassis that houses all of the circuitry (Fig. 1-4). The power supply is an unregulated 15-volt source that feeds the bus terminals directly. An adjustable voltage divider ranging from 3 to 15 volts is accessible through binding post BP1. Test lead jacks facilitate meter monitoring during all circuit tests or operations.

A negistor oscillator is provided and generates pulse and two audio frequencies for testing amplifiers, filters, or other circuits (see Chapter 2). A small 8-ohm speaker is contained within the unit for oscillator and low-power amplifier testing. A 500-ohm linear taper potentiometer serves not only as a volume control for the speaker, but it can serve as a 500-ohm line impedance output when the speaker is turned completely off.

A set of shielded jacks are incorporated to reduce hum and noise when the unit used with external equipment. Jack J1 is a miniature phone jack, J3 is a subminiature phone jack, and J2 and J4 are RCA jacks.

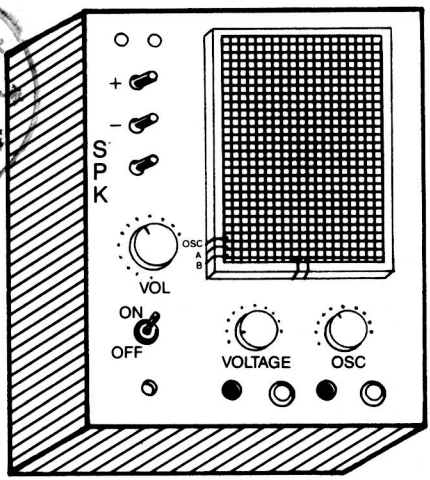


Fig. 1-4. Pictorial diagram of circuit designer.