A pair of electronic devices for detecting restricted-band audio and ultrasonic frequencies

DAVID L. HOATS

Edward R. Johnstone Training and Research Center, Bordentown, New Jersey 08505

Two devices, the bandpass active filter and the phase-locked loop, are briefly discussed, with applications of each. The reader is directed to further sources of information on theory and practical circuitry as well as to sources of components and finished units.

Electronic filters have found use in the behavioral sciences for detecting restricted-band audio-frequency and ultrasonic animal vocalizations (Barfield & Geyer, 1972; Morgret, 1972; Thor, Ghiselli, & Wilson, 1973), for processing human speech patterns (Rogers, Scherer, & Rosenthal, 1971), and in the processing of bioelectric potentials (Helmer, 1975; Paskewitz, 1971; Rouse, 1974). The successful use of the electronic filter as a speech processor suggests its application to overcome some of the difficulties encountered in the use of voice keys (Kapuzinski & Rosenquist, 1973).

The behavioral scientist without extensive training in electronics may find difficulty in understanding the instrumentation used in the studies cited, since information on theory and practice in filter design is scattered throughout the technical literature and is frequently written in unintelligible technical jargon. Should he/she become interested in performing such experiments, the scientist must have sufficient information either to build filters or to specify their purchase from commercial sources. Comprehensible sources of such information are found in Tables 1 and 2.

The type of filter most widely used in behavioral research has been the operational amplifier bandpass filter, an analog device that isolates, and delivers intact at the output, a narrow-band sample from all the frequencies appearing at the input. In applications where simple detection of the output sample is desired (e.g., in animal vocalization studies), the signal from the filter must be further processed to provide a digital output (a voltage level or a relay closure) to operate a counter. For such detection applications, a serious rival to the analog filter should be the Signetics 567 phase-locked loop integrated circuit. The phase-locked loop operates by comparing the frequency of a signal appearing at its input to an internally-generated signal. When the frequencies of the two signals correspond, the phase-locked loop changes the voltage level of its output. This voltage level change may be used as a direct digital output or to drive other output devices (up to

100 mA). Further advantages of the phase-locked loop are low price, wide voltage range (4-10 V), acceptance of very low-level input signals (2mV minimum), and easy incorporation into working circuitry.

At present, the phase-locked loop is used to decode multiple command signals transmitted over a single pair of conductors and, as such, is available from Psyonics as

Table 1
Sources of Information on Theory and Practice
in Circuits Discussed

Article	Information
Cohen, 1975	Theory of phase-locked loop operation.
Goodman, 1964	General discussion of filter characteristics. Formulae and schematic diagrams for low-, high-, and bandpass passive filters.
Graeme, Tobey, and Huelsman, 1971	General theory of active filter design using operational amplifiers. High-level technical discussion with full mathematical treatment (Chapter 8). High-level discussion of operational amplifier theory and practice (Appendices A and B).
Gray, 1974	Practical circuit for midaudio range active bandpass filter. Formulae given for calculating values of feedback circuit components.
Jorgensen, 1974	Low-level technical discussion of operational amplifier theory and practice.
Lancaster, 1973	Technician-level discussion of theory and practice in general active filter design.
Lancaster, 1974	Technician-level discussion of theory and practice in design of active bandpass filters. Table of component values for designing bandpass filters.
Lancaster, 1975a, b	Technician-level discussion of operational amplifier theory and practice.
Portune, 1975	Simple exposition of operation of feedback network in active filters.
Prensky, 1975	Low-level technical discussion of operational amplifier theory and practice.
Waite, 1975	Technician-level construction article on EMG feedback circuit. Circuit theory and practical construction methods well presented. Simple exposition of EMG theory.
Wiklund, 1973;	Practical circuit for building single- or double-ended regulated power supplies.

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Table 2
Commercial Sources of Components, Power Supplies, and Finished Circuits

Source	Address	Items	Literature
Circuit Specialists Co.	P.O. Box 3047 Scottsdale, AZ 85257	Operational amplifier integrated circuits. Integrated circuit voltage regulators.	Free catalog containing reprints of manufacturers' data sheets and application notes.
Delta Electronics Co.	P.O. Box 1 Lynn, MA 01903	Precision fixed resistors. Precision multiturn potentiometers.	Free catalog.
Electroscience Mart, Inc.	119 Foster Street Peabody, MA 01960	Regulated power supplies (single- and double-ended).	Free catalog.
Leasametric/Metric Resources Corp.	822 Airport Boulevard Burlingame, CA 94010	Sales and lease of new and used high-quality filter systems from various manufacturers.	Free catalog.
Poly Paks, Inc.	P.O. Box 942 South Lynnfield, MA 01940	Operational amplifier integrated circuits. Regulated power supplies. Precision multiturn potentiometers.	Free catalog.
Psysonics	73-C Phelps Avenue New Brunswick, NJ 08901	TED-1 through TED-7 phase-locked loop single or multiple channel tone decoder (one to seven channels).	Information brochure available on request.
Radio Shack, Inc.	Various local stores and franchises.	Operational amplifier integrated circuits. Phase-locked loop integrated circuits. Integrated circuit voltage regulators.	Free catalog. Pin callout and specifications for each item listed on its package. 567 phase-locked loop package includes detailed application sheet.
Rockland Systems Signetics	West Nyack, NY 10994 811 East Arques Avenue Sunnyvale, CA 94086	High-quality filter systems. Manufacturers of operational amplifier and phase-locked loop integrated circuits, sold through franchised dealers.	Free catalog. Specification sheets and application notes available for specific integrated circuits free upon request.
Solid State Systems, Inc.	800 North Providence Road Columbia, MO 65201	Operational amplifier integrated circuits. Phase-locked loop integrated circuits. Ancillary circuit hardware.	Free catalog. Manufacturers' specification sheets and application notes provided free upon request, with purchase of cataloged solid state items.
Sprague Products Co.	81 Marshall Street North Adams, MA 01247	Type PP polypropylene film and Type PM polycarbonate film close-tolerance ($\pm 5\%$) capacitors, sold through local franchised dealers.	Cross-reference guide C-873 on capacitors listed available free upon request.

a commercial device designed for use with a tape recorder (Table 2).

REFERENCES

The decision whether to buy or to build detection devices will be mainly economic. Commercially available filters are quite expensive (\$395 to \$1875) and are designed for much more stringent applications than are usually found in behavioral research. A perfectly satisfactory bandpass filter (Thor, Ghiselli, & Wilson, 1973) was built at the Johnstone laboratory for less than \$50 parts cost, including power supply. On the other hand, filter construction should not be attempted unless the builder has considerable technical skill and a good fundamental knowledge of theory, as well as access to an oscilloscope, a good multimeter, and an accurately calibrated signal generator. Closely matched resistors (or potentiometers) and capacitors are required in filter construction, as is a precision double-ended power supply. Sources of these components are shown in Table 2. Phase-locked loop circuits are much lower in price (ca. \$35 per unit parts cost, including power supply) and are much easier to assemble and to calibrate. As with the bandpass filter, access to an oscilloscope, a multimeter, and a well calibrated signal generator is essential for success in calibrating the phase-locked loop circuit.

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