• *Beginner's Bench*

A Utility IC—The CA3046

Five bipolar VHF transistors on a chip! Countless projects can be built around this 14-pin IC. It's an experimenter's delight!

By Doug DeMaw, W1FB
ARRL Contributing Editor, P.O. Box 250, Luther, MI 49656

Have you worked with transistor arrays? If not, here is your chance to find out how compact you can make a "Dick Tracy wrist radio." Imagine having five VHF bipolar NPN transistors in one package! The circuit possibilities are practically without limit. Should you have a transistor failure, servicing is a simple task when you simply plug in another IC and commence using your circuit again.

There are many diode- and transistor-array ICs available, but my favorites are the RCA CA3046 and the Motorola MC3346P. Both have the same pinout, and roughly the same electrical characteristics. For Amateur Radio HF projects they are interchangeable. I have used the CA3046 through 2 meters for VHF work, and the performance was entirely acceptable. The manufacturer leans toward 120 MHz as the upper frequency limit, consistent with the commercial performance specifications of the chip.

The Inner Sanctum

If we could walk through the interior of the CA3046, we would find a common platform (substrate) on which five NPN transistors are formed. We would note that two of the transistors have their emitters connected internally (Q1 and Q2 of Fig. 1). We would observe also that the emitter of Q5 is connected to the substrate of the IC. These two features present the only restrictions we need consider for most of our experiments. First, we must use Q1 and Q2 for circuits that permit the emitters to be in parallel. Second, pin 13 (Q5 emitter) must always be grounded directly to the negative voltage bus. If we allow pin 13 to be above ground, the IC can be damaged. If Q5 is used, be sure the related circuit calls for a grounded emitter.

For lack of a better description, we may think of the five transistors as being similar in characteristics to 2N2222 or 2N3904 discrete transistors. The rating of each internal device is about 300 mW at a case temperature of 20 °C. The maximum safe collector voltage (base open) is +15.

Circuit Possibilities

I have used the CA3046 countless times in recent years to build compact receivers, audio amplifiers, VFOs and QRP transmitters. Numerous other applications will come to mind. The IC is suitable for nearly any circuit, from audio through 144 MHz, that requires two or more NPN transistors. It would be interesting to see how many circuits you could develop around the CA3046. Certainly, the editors of *QST* would be interested in considering your practical circuits for publication.

The purpose of this article is to acquaint you with the transistor-array IC, and to encourage you to experiment. Trying new circuits and innovating has, after all, been the technical backbone of Amateur Radio since the beginning.

Differential-Amplifier Hookup

Differential amplifiers are balanced circuits. For the sake of simplicity, we may consider them balanced push-pull amplifiers. They are useful as odd-order frequency multipliers (third or fifth harmonic, for example), balanced mixers, balanced product detectors and push-pull audio or RF amplifiers. The RCA CA3028A is internally configured as a differential amplifier with an NPN transistor connected as a *current source*. Some of the biasing resistors are included on the IC substrate. The inner workings of the CA3028A are shown in Fig. 2. If you compare this circuit to that of the CA3046 in Fig. 1, you will see how easy it can be to arrange Q1, Q2 and Q3 of Fig. 1 to provide the same circuit. The main difference is that we need to use external biasing resistors for the CA3046. The CA3028A works well as a mixer, IF amplifier or product detector. It has been used by a number of hams as the front end for direct-conversion (D-C) HF receivers. Proper hookup of the CA3046 will permit the same applications listed for the CA3028A.

QRP Transmitter Idea

As an illustration of how we might use the CA3046 as a low-power CW transmitter

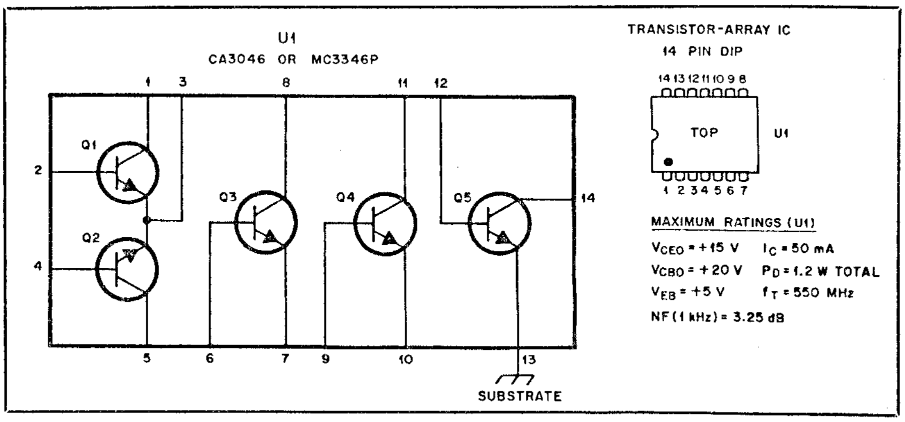

Fig. 1—Internal components of a CA3046 transistor-array IC. The inset drawing shows the pinout of the 14-pin IC.

CA 3046 — 2

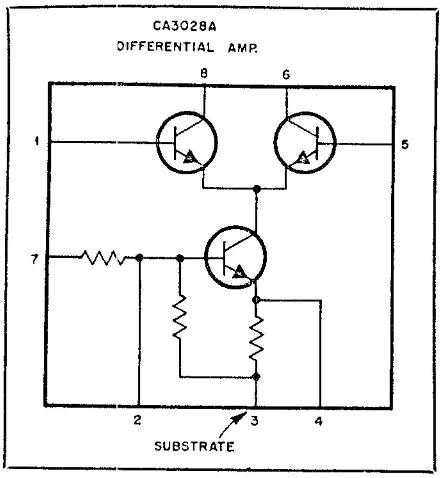

Fig. 2—Circuit elements of a CA3028A differential amplifier IC (see text).

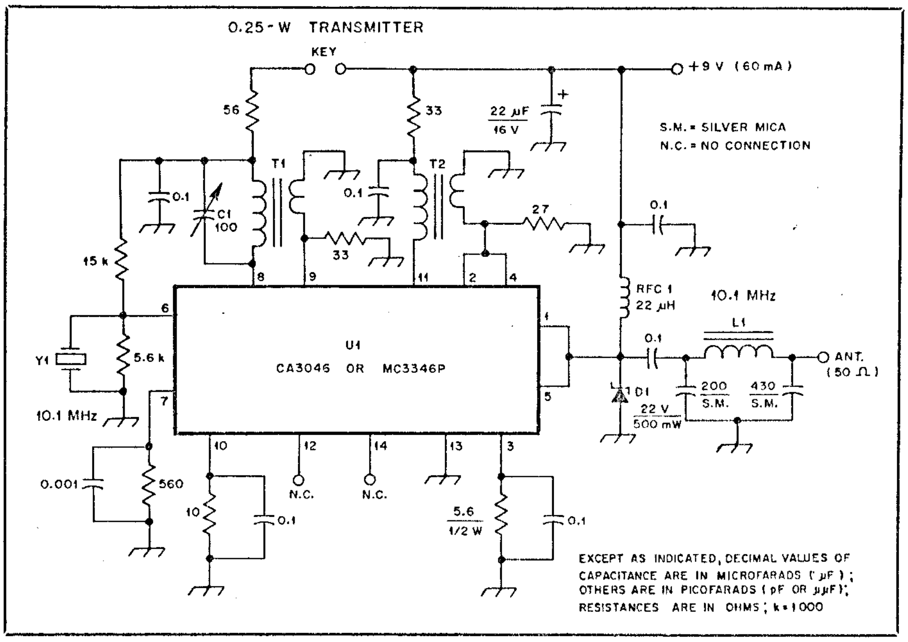

Fig. 3—Suggested QRP CW transmitter built around a CA3046 IC. Fixed-value capacitors are disc ceramic unless otherwise noted. Capacitors with polarity marked are electrolytic or tantalum. Resistors are ¼- or ½-W carbon composition. If the oscillator does not start, add a small-value capacitor (10 to 100 pF) between pins 6 and 7 of the IC.

C1—Ceramic or mica trimmer, 100 pF.

D1—Zener diode, 22 V, 500 mW (1N5251 or equiv.).

L1—1.5-µH toroidal inductor. Use 19 turns of no. 26 enam. wire on an Amidon, RadioKit or Palomar Engineers T50-6 toroid core.

T1—3-µH primary winding. 24 turns of no. 26 enam. wire on a T50-2 toroid core. Secondary has 4 turns of no. 26 enam. wire over primary winding.

T2—15 turns no. 26 enam. wire on Amidon FT50-43 ferrite toroid. Secondary has two turns of no. 26 enam. wire.

Y1—Fundamental-mode crystal for chosen portion of 30-meter band. International Crystal Co. type GP or equiv., 30-pF load capacitance.

(pocket size!), please check the circuit in Fig. 3. This is offered as a starting point for those who want to try the "wrist-radio" concept. I have not built the exact circuit of Fig. 3, but I have constructed similar ones using the CA3046 chip. The major difference between this and previous transmitter circuits for the CA3046 is that the design in Fig. 3 is an improved one.

Compare the block representation of Fig. 3 against the schematic diagram of Fig. 1 to learn how the five transistors are used. In brief, Q3 operates as a crystal oscillator (tuned collector), Q4 is a broadband buffer/amplifier, and Q1/Q2 are connected in parallel as a final amplifier. Q5 is unused, but it could be employed for some special job, such as a dc switch or sidetone oscillator, provided pin 13 is grounded. If you decide to try this circuit (Fig. 3), it may be worth converting Q3 to a VFO or VXO.

To keep the transistors of U1 within their safe voltage ratings, we will use a 9-V power supply. Since the recommended maximum V_{CEO} is +15, we need to allow for the swing of the collector voltage during the RF sine-wave cycle. This means that the peak ac voltage can rise to +18 which, with the circuit shown, will be safe for the IC. If we used a +12-V supply, the ac swing to +24 V would probably destroy the internal transistors (Q1 and Q2, in particular). The emitter resistors of Q1/Q2 and Q4 will provide safe operating conditions (collector-emitter voltage) for the transistors.

I have obtained up to 250 mW of output with the general arrangement shown in Fig. 3. The CW note is chirp free when C1 is adjusted for the best-sounding note, consistent with maximum output power. Zener diode D1 acts as a clamp to limit the peak swing of the PA collector voltage—a safety device.

Layout for this or any other circuit that contains a CA3046 is somewhat critical, but no more so than when working with separate transistors. All RF leads need to be as short as possible, and related components must be located as close to the IC pins as can be managed. T1 and T2 should be spaced apart from one another, and they should not be close to L1, lest unwanted feedback occur; this could lead to self-oscillation.

Practical Direct-Conversion Front End

I have found the CA3046 and CA3028A ICs to be excellent performers in the front ends of simple D-C receivers. Most of the unwanted AM detection that comes with the use of a single-ended product detector, such as a 40673 MOSFET, is eliminated through the use of a singly balanced product detector. The conversion gain of the differential-pair detector is on the order of 10 dB, which is useful in D-C receivers, since they require between 80 and 100 dB of overall gain (audio amplifier included) to provide ample weak-signal output.

An RF amplifier is not needed ahead of the detector for the bands below 20 meters. A low-noise preamplifier will improve the receiver noise figure if it is added between the antenna and the CA3046 detector at 20 meters and higher.

The problem with AM detection is the "blanketing" of the ham band being listened to. The condition is caused by strong out-of-band commercial AM stations that can be heard along with the desired signals. In-band AM broadcast stations can also cause the same problem. A doubly balanced product detector offers the best rejection of AM signals, and the diode-ring doubly balanced mixer (DBM) detector is probably the ultimate choice. But you should experience no significant difficulty with AM detection while using the circuit of Fig. 4. An abbreviated schematic diagram of the innards for the CA3046, as related to the circuit in Fig. 4, is provided in Fig. 5. This shows how the five transistors are used.

Q3 is connected as a current source for Q1 and Q2, thus making the trio similar to those of the CA3028A of Fig. 2. Q3 provides a convenient way to inject the local-oscillator (LO) voltage on the emitters of Q1 and Q2.

Q4 is used as an audio amplifier. It should be followed by a high-gain audio chain. In my testing of the receiver, I used a two-pole RC active CW filter (700-Hz peak) immediately after Q4,[1] then routed the audio signal to a 2N3904 AF amplifier and finally to a 741 op amp set for 40 dB of gain. This provided ample weak-signal output into a pair of headphones.

---

[1] Notes appear on page 24.

CA 3046-3

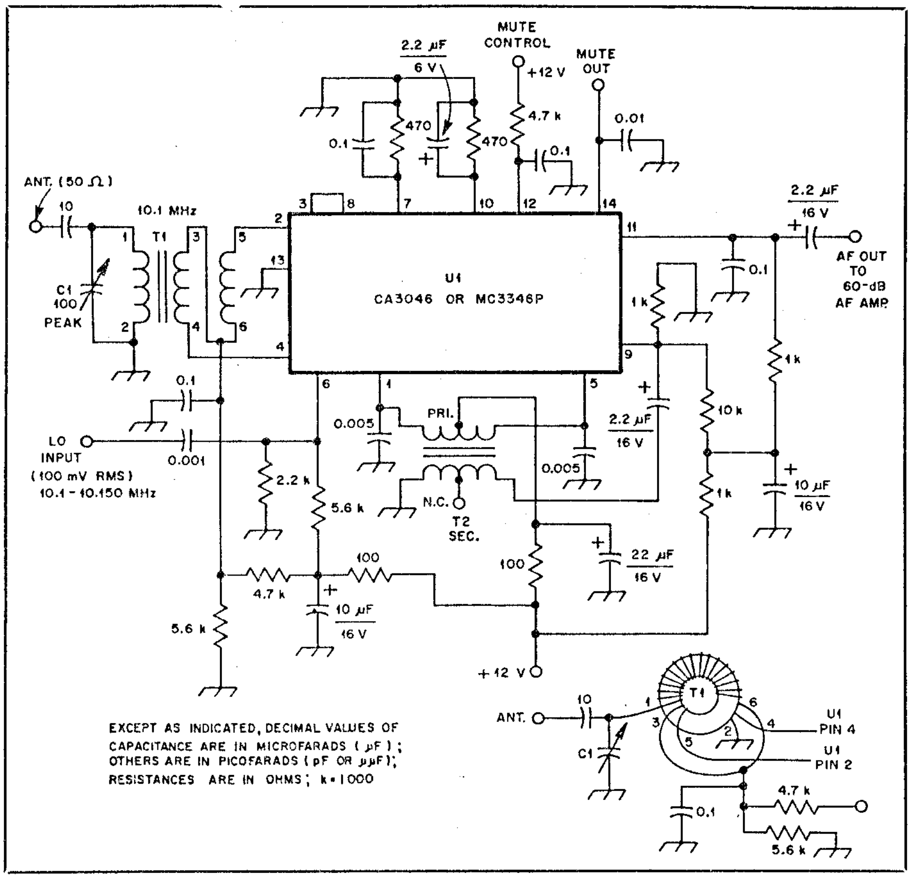

Fig. 4—Hybrid diagram of the direct-conversion receiver front end. Fixed-value capacitors are disc ceramic, except those with polarity marked, which are electrolytic or tantalum. Resistors are ¼-W or ½-W carbon composition.

C1—Ceramic or mica trimmer, 100 pF.

T1—Primary is 3 µH, 24 turns of no. 26 enam. wire on a T50-2 toroid core. Secondary is a bifilar (twisted or parallel pair) winding of 10 turns of no. 26 enam. wire, spread over the primary winding.

T2—Miniature audio interstage transformer, 10-k ohm primary and 2-k ohm secondary. Secondary center tap not used. Mouser Electronics 42TM002 or equiv.

U1—RCA CA3046 or Motorola MC3346P transistor-array IC (see note 3).

I used Q5 as a muting switch. With + 12 V applied to the base of Q5, it provides a short-circuit condition between the collector and emitter. The collector (pin 14 of the IC) can be connected to the base of an outboard audio-amplifier transistor. When the transmitter keying line is activated, thereby placing + 12 V on the mute-control line to Q5, the muting switch will short out the audio signal at the base of the external AF amplifier, quieting the receiver. You may not want to bother with this feature. If the muting feature is omitted, simply leave pins 12 and 14 open, but ground pin 13.

Construction Notes

It should be an easy task to lay out your own PC-board pattern for this receiver front end. If you'd rather not "do your own thing," you may obtain a circuit board from a supplier.[2] Should you have difficulty locating a CA3046 or MC3346P IC, you may order one by mail.[3]

Receiver Performance

I tested the circuit of Fig. 4 on 30 and 40 meters. The sensitivity is good, as is the rejection of AM signals. I used an old VFO I had on hand as a VBFO (variable beat-frequency oscillator). It was necessary to restrict the LO injection to between 100- and 200-mV RMS for best performance. Too high an injection level will shut down the balanced detector, which results in no audio output from Q1 and Q2. You may use a VTVM or FETVOM with an RF probe to measure the LO voltage at pin 6 of the IC (Fig. 4). An accurate scope will serve nicely for this measurement also, but don't forget that the scope measures *peak-to-peak* voltage rather than RMS voltage. If you use a scope, you can obtain the RMS value by multiplying the peak-to-peak reading by 0.3535.

The only adjustment for the receiver front end is the setting of trimmer C1. This is done by tuning in a weak signal and adjusting the trimmer for maximum response in the headphones. Try to find a signal in the middle of the 30-meter band when making this adjustment. The trimmer should not require readjustment unless a different antenna is attached to the receiver.

In Summary

The object of this article is to acquaint you with just one of the many transistor-array ICs. The suggested transmitter circuit and the proven receiver front end were included so those of you who aren't designers would have a basis for experimentation. There is no reason you can't modify the cir-

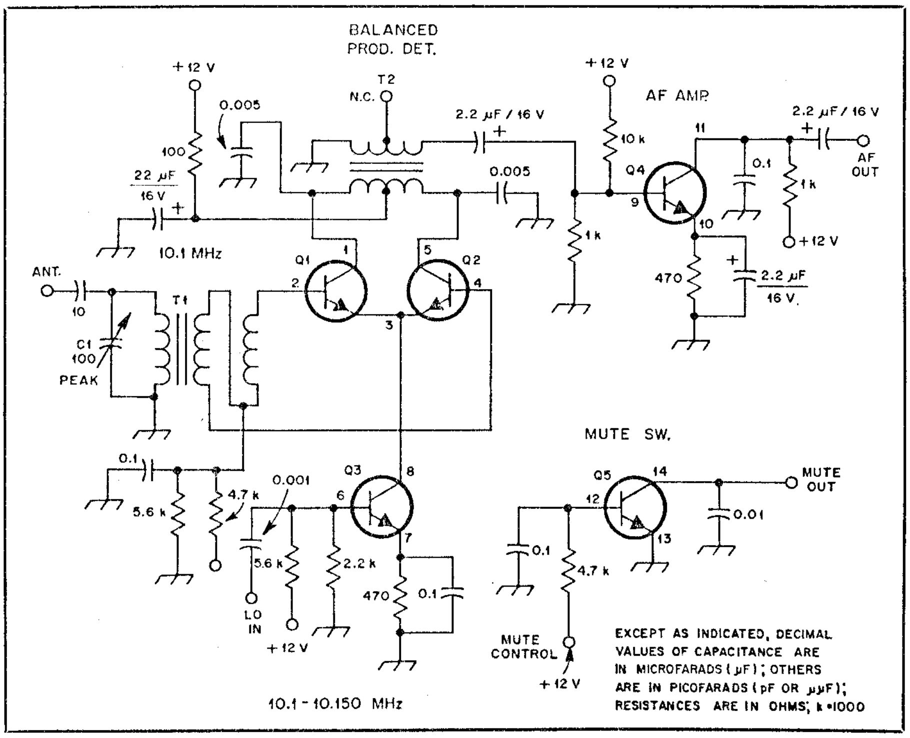

Fig. 5—Partial schematic diagram of the circuit shown in Fig. 4. This is included to illustrate how the five internal transistors are used in the direct-conversion receiver front end.

CA 3046-4

cuit of Fig. 4 for use on 160, 80, 75 or 40 meters. The only changes necessary are winding T1 for the proper inductance when changing bands. The transformer turns ratio will remain the same, regardless of the band of operation. Also, the LO frequency will need to be changed for the band of your choice.

Various VFO circuits can be found in *The ARRL Handbook* and the League's book, *Solid State Design for the Radio Amateur.* Information concerning RC active CW filters is available in the same publications. Whether you have read this presentation purely for "book larnin" purposes, or because you plan to experiment with the CA3046, good luck to you!

Notes

[1] See page 138, Fig. 40 (lower drawing), of *Solid State Design for the Radio Amateur* (Newington: ARRL, 1977). Practical circuit given.

[2] A & A Engineering, 7970 Orchid Dr., Buena Park, CA 90620, tel. 714-521-4160. A PC pattern and parts overlay are available from the ARRL for $1 and an s.a.s.e.

[3] IC available from State Street Sales, P.O. Box 249, Luther, MI 49656, $1.50 each, includes shipping.

Strays

I would like to get in touch with . . .

☐ anyone with information on a Navy 'scope, OS-34/USM-32, a Mite teleprinter (TT299B/UG) and a Collins SSB book. M. Crestohl, VE2FW, Box 642, Montreal, PQ H3Z 2Y7, Canada.

☐ anyone with a *Marine Radio Telegraph Operators License Manual* by Edward M. Noll. Jack Vollrath, KH6ANF, 59-654 Kawoa Pl., Haleiwa, HI 96712.

☐ anyone with tube data for the B&K Dyna Quik Model 650 with Model 610 test panel and the Hickok Model 600 "Micromho." Peter L. Waasdorp, KF6MM, 324 Calle Adela, San Marcos, CA 92069.

☐ anyone with a service and operating manual for a Model LA-239C oscilloscope, manufactured by Lavoie Laboratories. Peter Atenczuk, N3DRM, 8243 Algon Ave., Philadelphia, PA 19152.

Next Month in *QST*

Interested in remotely controlling your station? An article in September tells you how to control your digital-mode communications from the workplace. Also in September is the first installment of "Under Construction," an intermediate-level series for the amateur builder. This installment explains the basic building blocks of a 75-meter transmitter. Been on the contest sidelines too long because of the stiff competition? Learn how contests can be just for fun, too. Also, if your emergency-communications skills need brushing up, check out the Simulated Emergency Test announcement.

New Books

SWITCHED CAPACITOR CIRCUITS

by Phillip E. Allen and Edgar Sanchez-Sinencio. Published by Van Nostrand Reinhold Co., New York, NY. First edition, 1984. Hard-bound, 6 × 9 inches, 759 pages including appendixes and index. $56.50.

Here is a book that contains a wealth of information about switched-capacitor integrated circuits. It covers the latest design, analysis and fabrication techniques of these ICs, made possible by MOS technology.

The book is well-written, and contains an almost inexhaustible supply of technical information. It is not for the average radio amateur, however, nor even for an undergraduate-level electrical engineering student. It is intended to be used as a graduate-level text or as a reference for the practicing design engineer. Both authors are university professors, and they have combined their knowledge with the latest MOS fabrication techniques from the semiconductor industry to produce a textbook for the advanced technical audience.

Each chapter concludes with a sampling of relevant problems to review the material just presented. Although there are no answers provided for these questions, you may gain further useful knowledge by working out the solutions. The text is fully illustrated with many tables, graphs and diagrams to aid your understanding of the material.

A review of the prerequisite background and an introduction to sampled-signal-processing theory is provided in the first two chapters. A thorough presentation of the relationships between continuous and discrete time domains and the transformation differences between the s and z domains when the sampling rate is much greater than the frequencies of interest is also included. The equivalence of switched capacitors and resistors in active networks is well illustrated. This is a subject area that has not been treated well in other books.

Chapter 3 introduces the performance characteristics of switched-capacitor filters (SCFs) using the bilinear Z transform for component simulations. A different approach to switched-capacitor-filter design is offered in Chapter 4. The analog-filter transfer-function parameters, H(s), are transformed into discrete-time-filter transfer-function parameters, H(z). The authors show how to combine individual switched-capacitor building blocks into realizable filter systems. Low-order SCFs are synthesized with examples of low-pass, high-pass, band-pass and band-elimination-type classifications.

Other switched-capacitor applications are introduced in Chapter 6. Some of the examples presented are voltage comparators, phase shifters, modulators, multipliers and oscillators. This offers to a designer the latitude to consider an analog or a digital approach to these devices. I found this chapter especially interesting because the examples cited are usually considered to be classical analog/linear-type circuits instead of digital ones. Through the use of switched-capacitor techniques, they may be implemented digitally. Chapter 7 covers the subject of analog-to-digital and digital-to-analog conversions, using switched-capacitor and MOS technology.

Chapter 8 presents the physical aspects and practical fabrication techniques of CMOS and NMOS technology used by the semiconductor industry. This chapter describes how ICs are built by various fabrication processes. Analog-circuit design techniques are also covered. This information should prove useful to IC designers responsible for the topography and architecture of MOS devices.

The book includes three appendixes. Appendix A contains diagrams and data tables providing information about various passive-filter designs. The second appendix covers the method of bilinear transformation of an analog-filter transfer function into a sampled-data transfer function. This involves replacing the H(s) terms in the analog-filter transfer function using a bilinear transformation operation to obtain the H(z) transfer function:

$$s = K \frac{1 - z^{-1}}{1 + z^{-1}} \qquad \text{(Eq. 1)}$$

where

K = a constant involving frequency prewarping, and $z = e^{j\omega T}$

where

$j\omega$ = the frequency and T = the switching period.

Appendix C offers a number of program routines for the TI-59 and HP-41 programmable calculators to analyze MOS devices.

I recommend this up-to-date textbook for those who wish to advance their knowledge and skill in applying switched-capacitor circuits to the fields of instrumentation and telecommunications.—*R. R. Schellenbach, W1JF (SK)*