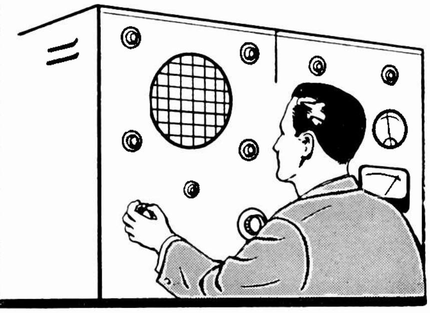
AEROVOX RESEARCH WORKER



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Additional Counting Methods

By the Engineering Department, Aerovox Corporation

Digital computer students and technicians responded with unexpected appreciation to our article "Elementary Binary Arithmetic," reprinted in the July-September 1960 issue. And many of these readers stressed the need of a tutorial piece on number systems other than the binary. The present article is offered in response to that demand.

We repeat preliminarily that our time-honored base-10 (decimal) number system, with its digits 0 to 9, is far from sacred. It is handy, perhaps, only because we have ten fingers with which to count. If nature had given man only one hand, however, we probably would have popularized a base-5 system. Such a **pentanary** counting method would use five digits: 0, 1, 2, 3, and 4. And just as we move one place to the left and resume counting each time we run through the nine digits in the decimal system, so would we shift and resume counting each time we passed through 4 in the base-5 system: Thus, we would count from zero to 10 in this way — 000, 001, 002, 003, 004, 010, 011, 012, 013, 014, 020. It might seem disturbing, because in this system "020 capacitors" means "ten capacitors," but there would be no confusion if the decimal system were not habitual with us.

The truth is that any number can be used as the radix (base) of a counting system and the procedure will remain the same: run through the digits, shift, run through the digits, shift, etc., etc. But various limitations discourage the use of cer-

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tain systems unless some special need arises. Among these are (1) the lower the radix, the more often the place shift must be made, and (2) the higher the radix, the more components and circuitry must be used in a digital computer and the greater the complexity of that machine and the chance of unreliability. Obviously, the binary system is ideal for the digital computer as we now know the machine; but we must translate our common, decimal information into binary form before feeding it into the computer, and the computed result must be changed back into decimal form before we accept it. In some instances, a two-step procedure is employed, the decimal data being first converted into an intermediate system and then into binary going in, and back over this path in the reverse order coming out.

COMMON SYSTEMS

Since all possible number systems obviously cannot be treated in this limited space, we have chosen for comparison the common ones: **decimal, binary, trinary,** and **octal.** The bases are 10, 2, 3, and 8, respectively. With respect to the earlier article, trinary and octal are new to us. For inspection of gross character, consider the following illustration — (decimal 10) = (binary 1010) = (trinary 101) = (octal 12). Or with a larger number, (decimal 128) = (binary 10000000) = (trinary 11202) = (octal 200).

In any number system that follows present standards, positional order is important. Each digit in the number not only has value but is multiplied by that power of the radix corresponding to the position occupied by the digit. Thus, the placement of digits in the decimal number 38261.5 signifies that the total number is $(1 \times 10^0) + (6 \times 10^1) + (2 \times 10^2) + (8 \times 10^3) + (3 \times 10^4) + (5 \times 10^{-1}) = 1 + 60 + 200 + 8000 + 30{,}000 + 0.5 = 38{,}261.5$. Similarly, the octal number 572.1 means $(2 \times 8^0) + (7 \times 8^1) + (5 \times 8^2) + (1 \times 8^{-1}) = 2 + 56 + 320 + 1/8 = 378.125$; the binary number 0011.01 means $(1 \times 2^0) + (1 \times 2^1) + (0 \times 2^2) + (0 \times 2^3) + (0 \times 2^{-1}) + (1 \times 2^{-2}) = 1 + 2 + 0 + 0 + 0 + 1/4 = 3.25$; and the trinary number 2121.11 means $(1 \times 3^0) + (2 \times 3^1) + (1 \times 3^2) + (2 \times 3^3) + (1 \times 3^{-1}) + (1 \times 3^{-2}) = 1 + 6 + 9 + 54 + 1/3 + 1/9 = 70\ 4/9$.

A point separates the positive and negative powers of the radix and thus the digits in these positions. This point is named for the radix; thus **decimal point, octal point,** etc., but its function remains the same in each number system.

Table 1 shows the radix and digits used in each of the four systems and gives the positional values from the zero to the nth power on each side of the point. The powers are also evaluated for each of the systems. This table will be useful for quickly identifying and evaluating numbers.

Table 2 is illustrative, and contains completely worked out examples for long numbers in each system.

SYSTEM	RADIX	DIGITS USED	POSITION OF DIGIT IN NUMBER										
			nth	5th	4th	3rd	2nd	1st	Point	1st	2nd	3rd	nth
DECIMAL	10	0, 1, 2, 3, 4. 5, 6, 7, 8, 9	10^n	10^4 (10,000)	10^3 (1000)	10^2 (100)	10^1 (10)	10^0 (1)	●	10^{-1} (0.1)	10^{-2} (0.01)	10^{-3} (0.001)	10^{-n}
BINARY	2	0, 1	2^n	2^4 (16)	2^3 (8)	2^2 (4)	2^1 (2)	2^0 (1)	●	2^{-1} (1/2)	2^{-2} (1/4)	2^{-3} (1/8)	2^{n-}
TRINARY	3	0, 1, 2	3^n	3^4 (81)	3^3 (27)	3^2 (9)	3^1 (3)	3^0 (1)	●	3^{-1} (1/3)	3^{-2} (1/9)	3^{-3} (1/27)	3^{-n}
OCTAL	8	0, 1, 2 3, 4, 5, 6, 7	8^n	8^4 (4096)	8^3 (512)	8^2 (64)	8^1 (8)	8^0 (1)	●	8^{-1} (1/8)	8^{-2} (1/64)	8^{-3} (1/512)	8^{-n}

TABLE 1.

DECIMAL	57,432.025 =	$5 \times 10^{4} = 5\ (10{,}000)$ =	50,000
		$7 \times 10^{3} = 7\ (1000)$ =	7000
		$4 \times 10^{2} = 4\ (100)$ =	400
		$3 \times 10^{1} = 3\ (10)$ =	30
		$2 \times 10^{0} = 2\ (1)$ =	2
		$0 \times 10^{-1} = 0\ (0.1)$ =	0
		$2 \times 10^{-2} = 2\ (0.01)$ =	0.02
		$5 \times 10^{-3} = 5\ (0.001)$ =	0.005
		Total:	57,432.025
BINARY	11011.011 =	$1 \times 2^{4} = 1\ (16)$ =	16
		$1 \times 2^{3} = 1\ (8)$ =	8
		$0 \times 2^{2} = 0\ (4)$ =	0
		$1 \times 2^{1} = 1\ (2)$ =	2
		$1 \times 2^{0} = 1\ (1)$ =	1
		$0 \times 2^{-1} = 0\ (1/2)$ =	0
		$1 \times 2^{-2} = 1\ (1/4)$ =	1/4
		$1 \times 2^{-3} = 1\ (1/8)$ =	1/8
		Total:	27 3/8
TRINARY	12110.111 =	$1 \times 3^{4} = 1\ (81)$ =	81
		$2 \times 3^{3} = 2\ (27)$ =	54
		$1 \times 3^{2} = 1\ (9)$ =	9
		$1 \times 3^{1} = 1\ (3)$ =	3
		$0 \times 3^{0} = 0\ (1)$ =	0
		$1 \times 3^{-1} = 1\ (1/3)$ =	1/3
		$1 \times 3^{-2} = 1\ (1/9)$ =	1/9
		$1 \times 3^{-3} = 1\ (1/27)$ =	1/27
		Total:	147 13/27
OCTAL	53207.41 =	$5 \times 8^{4} = 5\ (4096)$ =	20,480
		$3 \times 8^{3} = 3\ (512)$ =	1536
		$2 \times 8^{2} = 2\ (64)$ =	128
		$0 \times 8^{1} = 0\ (8)$ =	0
		$7 \times 8^{0} = 7\ (1)$ =	7
		$4 \times 8^{-1} = 4\ (1/8)$ =	1/2
		$1 \times 8^{-2} = 1\ (1/64)$ =	1/64
		Total:	22,151 33/64

TABLE 2.

NUMBER CODING

Earlier, this article mentioned the necessity for translating numerical data into the language of the computer (e. g., decimal to binary). This is sometimes done, in programming, by means of some coding scheme. Thus, a **binary coded decimal number,** often used for this purpose, is obtained in the following manner: Decimal 37 is written, punched, or magnetically recorded as the separate numbers representing the two digits; that is, 37 = 0011 0111. This is quite different from binary 37, which is 100101. In some instances, conversions into and out of the machine are made electronically (striking a 9 key, for example, might automatically punch 1001.)

A number of codes are used advantageously with various types of digital computers. Two such are shown in Table 3. The **reflected binary code** has the advantage that only 1 digit changes at a time when progressing from one number to another, whereas in straight binary notation several digits may change simultaneously. One of the advantages of the **excess-3** code is its use of digits in the number zero, which is an aid when checking results or operation (zero in the straight binary system does not distinguish between actual zero and machine failure).

CONCLUSION

An infinite variety of number systems is possible, and other counting systems than the ones in common use doubtless will find application as electronic devices become available for their reliable use. The binary system, for example, is directly correspondent with on-off (2-state) electrical devices such as switches and flip-flops. A 3-state device (and there already are some) could use the trinary system. However, in the present state of the art, economy and compactness are sacrificed and unreliability is invited unless a switching device has a number of stable states equal to the radix of the number system used.

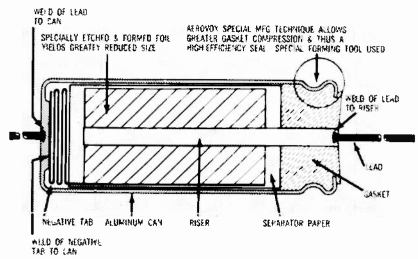
Decimal Number	Reflected Binary	Excess—3
0	0000	0011
1	0001	0100
2	0011	0101
3	0010	0110
4	0110	0111
5	0111	1000
6	0101	1001
7	0100	1010
8	1100	1011
9	1101	1100

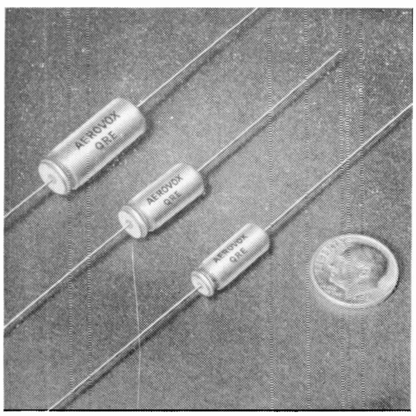
Table 3. Comparison of Two Codes Used in Translation of Data.

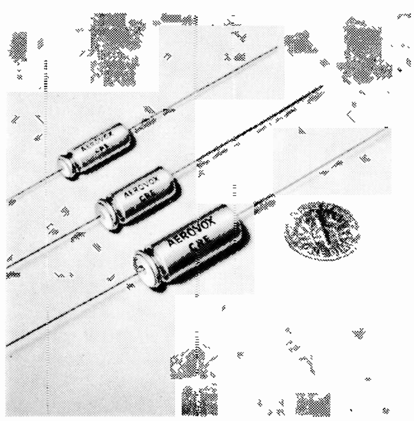
New Long-Life 85°C Electrolytic Capacitors in Ultra-Miniature Sizes a Product of New Design and Manufacturing Techniques

Aluminum-cased units permit circuit applications previously impossible

A new series of ultra-miniature tubular electrolytic capacitors is now available from Aerovox. A product of the continuing Aerovox program of advanced research and development, the greatly reduced sizes of these high-quality units have been made possible by the use of a revolutionary etching and formation process. All critical terminations are welded, thus eliminating the danger of open circuits with the passage of time in service. A unique, high-efficiency seal has been produced by specially designed forming tools which were developed by Aerovox after months of intensive engineering effort to improve on conventional sealing methods.







High-Reliability Type QRE

Due to a totally new design concept, Aerovox has achieved a new industry high for capacitors of this type. Type QRE capacitors offer a useful life expectancy of more than 10 years when operated within ratings.

The combination of long life, ultra-miniature size, and outstanding temperature characteristics now makes available an aluminum electrolytic capacitor which can be used in many circuit applications heretofore not considered possible with capacitors of this type. Design engineers in the computer and communications fields in particular can benefit from the extraordinary advantages offered by Type QRE. These units are manufactured in specially constructed super-clean "White Room" production areas where only the most experienced operators are employed. An exhaustive 100% testing program assures you high-reliability performance.

Commercial Type CRE

Type CRE ultra-miniature units are ideally suited for use in bypass, filter, and coupling applications in low voltage, compact, miniaturized equipments. This is especially true where assembly space is at a premium, such as personal radios, hearing aids, microphones, and wire receivers.

Availability

Aerovox Type QRE and CRE Ultra-Miniature 85°C Aluminum Cased Electrolytic Tubular Capacitors are available in prototype quantities for immediate delivery from the factory. See your Aerovox Representative for delivery information on production quantities.

TYPE QRE SPECIFICATIONS

Operating Temperature: −40°C to +85°C
Capacitance Tolerance: standard capacitance is −10% to +100% of rated capacitance.

DC Leakage Current:

Volts DC	Current – Microamperes
3 to 6	1.0
10 to 15	2.5
25 to 50	5.0
100 to 150	15.0

Surge Voltage:

Rated DC Working Voltage	Surge Voltage (Max.)
3	5
5	8
6	10
10	14
12	15
15	20
25	45
50	70
100	125
150	175

TYPE CRE SPECIFICATIONS

Operating Temperature: −30°C to +85°C
Capacitance Tolerance: standard capacitance is −10% to +100% of rated capacitance.

DC Leakage Current:

Volts DC	Current—Microamperes
3 to 6	1.0
10 to 15	2.5
25 to 50	5.0
100 to 150	15.0

Surge Voltage:

Rated DC Working Voltage	Surge Voltage (Max.)
3	4
6	8
12	15
15	18
25	40
50	65
100	125
150	175

Complete Technical Data

Call your nearest Aerovox Field Representative or write today for a free copy of Bulletin 201B7 (Type QRE) and 201B6 (Type CRE).

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