ANALOG VERSUS DIGITAL

What is analog proportional? Is there a true digital system? Which is best? The author, a top proportional flier and former Nat's champion, presents a penetrating analysis of this current controversy.

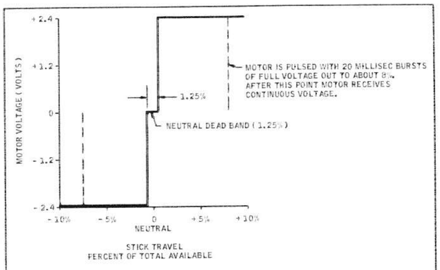
The purpose of this article is to present to the prospective buyer the relative merits of the two major types of feedback proportional systems — digital and analog. I will attempt to catalogue the various characteristics of the two types of systems, both good and bad, so that the buyer may make his choice based on fact rather than opinion. This article will deal strictly with feedback systems only — not systems based on T.T.P.W. concept where servo neutral return is effected by a spring or rubber band. Since the major differences are in the encoding, decoding, and servo amplifiers, I will not go into the RF link other than to point out the methods of transmitter modulation.

First of all, here is a short description of the two systems. Since analog came first, we will start with it.

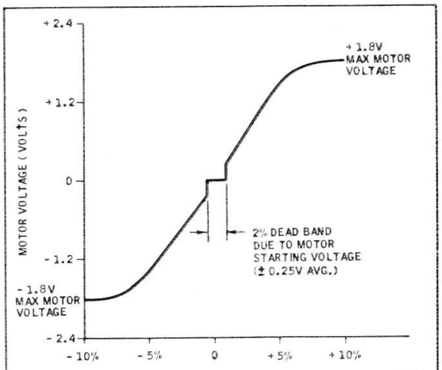
Analog Proportional Systems

There are two major types of analog systems. One type uses four different tones which are multiplexed sequentially at the transmitter. The surface position information is derived from a pot mounted to a stick assembly. This produces a D.C. voltage, or a resistance, which varies with stick position. This voltage, or resistance, is used to vary the frequency of the tones. In the receiver, the tones are fed to four discriminators which develop an output voltage which is proportional to the frequency deviation of the tones. The derived voltage is then fed to a feedback servo consisting of a direct current amplifier, a motor, a feedback pot, a summing junction (which compares the input voltage to the feedback pot voltage), plus suitable gearing. If there is a difference in magnitude between the input voltage and the feedback voltage, the resultant error signal is fed to the D.C. amplifier which drives the motor in such a way as to make the feedback voltage equal to the input voltage.

The other major system uses the same type of servo but the information



GRAPH OF MOTOR VOLTAGE VERSUS STICK TRAVEL FOR BONNER DIGIMITE AND F & M PROPORTIONAL. THE GEAR TRAIN IS DISCONNECTED FROM MOTOR FOR THIS TEST. THE FEEDBACK POT ARM IS KEPT STATIONARY AT NEUTRAL.



GRAPH OF MOTOR VOLTAGE VERSUS STICK TRAVEL FOR SAMPEY SERVO. THE GEAR TRAIN IS DISCONNECTED FROM MOTOR FOR THIS TEST. THE FEEDBACK POT ARM IS KEPT STATIONARY AT NEUTRAL.

is transmitted in a different manner. It uses only two frequency modulated tones, transmitted sequentially. The other two channels are derived from the "on" time ratio of the two tones and the repetition rate of these tones. There are only two discriminators in this receiver. The outputs of the discriminators drive servos as before, but in this case, the outputs also drive rate and symmetry detectors whose outputs are D.C. voltages that vary with stick position. These voltages are fed to the other servos which operate in the same manner as the servos driven by the discriminator.

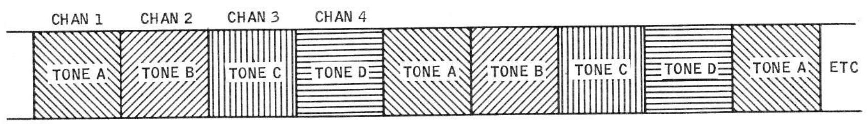
Digital Proportional Systems

The main difference between analog and digital systems lies in the servo and the way it acts. But first, let me say that there exists no true digital system. The word "digital," as used, means that digital techniques are used in circuit design and system operation. For instance, the servo amplifier delivers either full or no voltage to the motor — there is no partial voltage as exists with analog systems. Another major difference exists in the way the information is used by the servo. In the analog system the pulse width or rate is first converted to a varying D.C. voltage and fed to the servo, whereas in a digital system, the pulse is left as is and compared directly with a reference pulse generated within the servo. The difference in the width of the pulses is the error signal, and the motor is then turned on and the reference pulse width is altered by the feedback pot in such a manner as to make it match the incoming pulse.

Now, in a true digital servo system a digital number is sent to the servo. Instead of a feedback pot the servo motor would drive an encoder wheel. Instead of a D.C. motor, the servo would contain a stepper motor. A digital number is comprised of a whole series of pulses or "bits." In the true digital system there can be as many as 19 "bits." The more "bits" there are, the more accurate the positioning would be. It would take 7 "bits" to make a system that would respond to an accuracy of 1%.

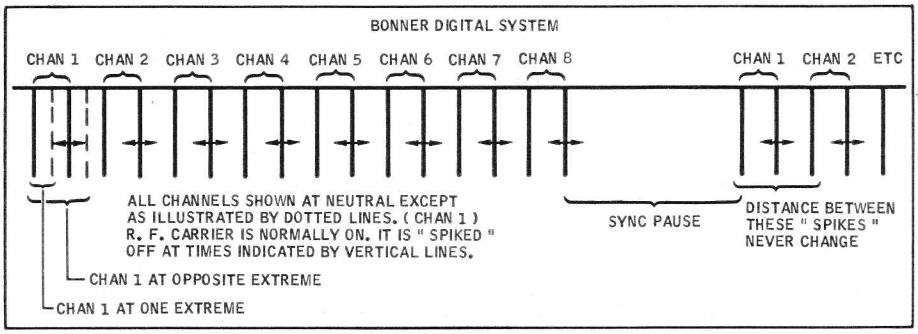
The information, as generated in a model aircraft digital system, is pulse duration modulation (PDM). This is

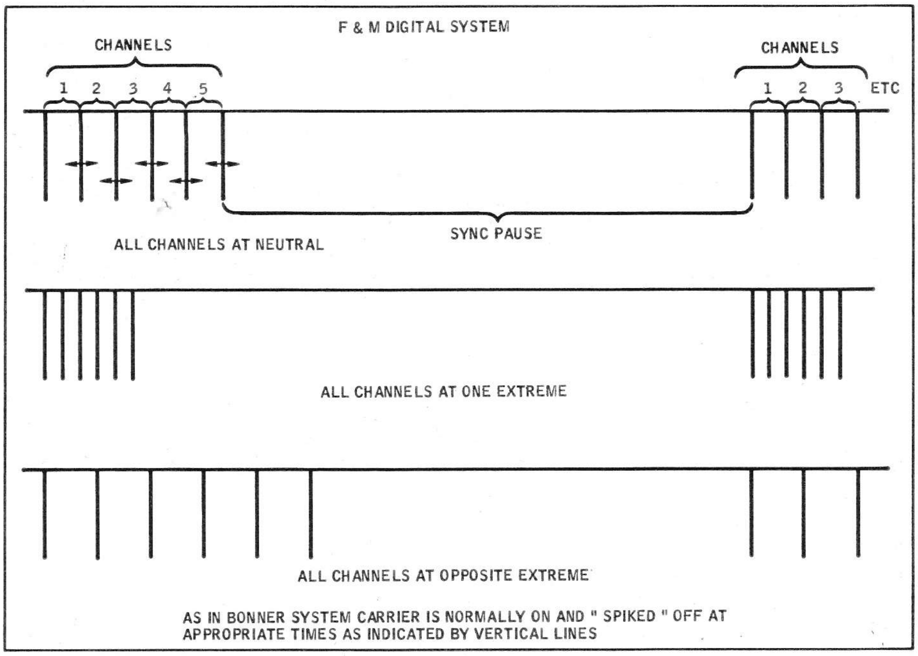
SAMPEY ANALOG SYSTEM

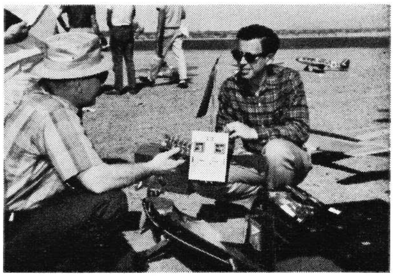


SEQUENCE OF TONES AS GENERATED AND TRANSMITTED FROM SAMPEY TRANSMITTER. TONES A, B, C & D VARY IN FREQUENCY WITH STICK POSITION. TONE BURST WIDTHS REMAIN CONSTANT.

Author's note: No attempt has been made to present data on all of the proportional systems. Two digital and two analog systems were selected for use as examples. The data included on each was supplied by the manufacturer and include test results requested by the author. Orbit Electronics was unable to supply the requested information due to the press of business.



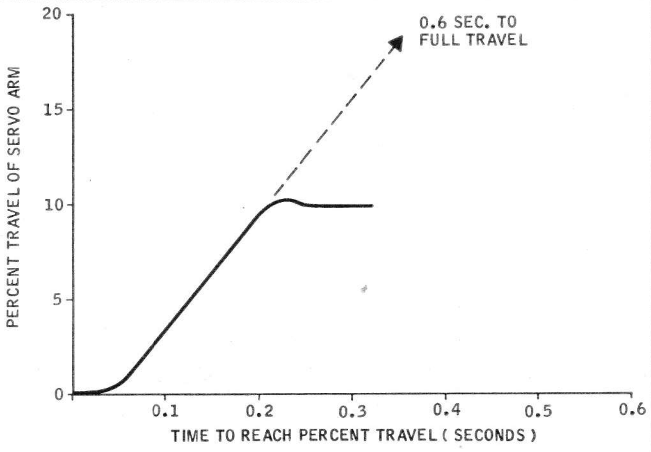




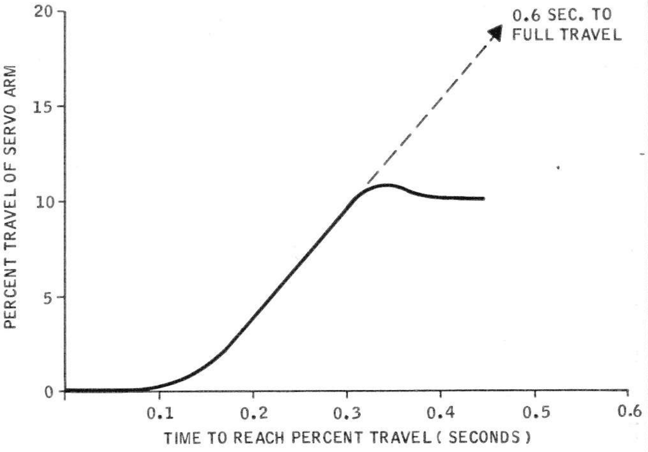
DOUG SPRENG, 32, began modeling in 1948 in the control line field, seemingly always to end up second in major contests to Bob Palmer. Doug started his R/C career with a Berkeley 'Brigadier' RC-38 and Aerotrol receiver, and went on to win his first contest in the rudder only event at the LARKS Open at Bakersfield, Calif. in 1957 — the latter strictly an accident, since Spreng only wanted to fly Don Mathes' "Mambo", and had to enter the contest in order to fly! The following year, he returned to Bakersfield to win his first Class III event with the Mathes designed 'Gambler,' the first of many contest wins in this event that included first place at both the 1960 and 1961 Nationals. In 1960, Doug designed the famous 'Stormer.' Currently, Doug is an electronics engineer at the world famous Cal Tech Jet Propulsion Laboratory, working on the Surveyor Program designed to analyze the crystallographic structure of the moon's surface prior to the first manned landing. A long time friend of RCM Technical Editor Don Mathes, Spreng was a co-designer of the early Digicon proportional system.

then converted to pulse position modulation (PPM) for transmission to the receiver. After detection by the receiver it is then reconverted to PDM, then fed to the decoder which separates each pulse and feeds it to the proper servo. Both PDM and PPM are considered digital techniques by the electronics industry. The method of generating the Pulse Duration Modulated information is called an Analog to Digital conversion. There is such a conversion in the transmitter, where a potentiometer connected to the stick assembly generates a D.C. voltage whose duration (or width) modulates a standard pulse. The same process takes place in the servo amplifier. The feedback pot generates a D.C. voltage proportional to output arm position whose width modulates a standard pulse. This servo-derived pulse is then compared to the incoming pulse from the receiver decoder to generate the error signal which, again, is a pulse, (although it is much narrower than the information or reference pulse) and it completely disappears when the information and reference pulses are identical.

The decoder in the receiver and the encoder in the transmitter makes use of flip-flops and pulse generators which are considered strictly digital devices. So, you see, although digital systems are not in the truest sense of the word



BONNER SERVO
GRAPH OF TIME TO REACH 10% OF TOTAL AVAILABLE SERVO TRAVEL.
TRANSMITTER STICK HAS BEEN STEP DISPLACED 10%.
0.6 SECONDS REQUIRED TO REACH FULL TRAVEL FROM NEUTRAL.



SAMPEY SERVO
GRAPH OF TIME TO REACH 10% OF TOTAL AVAILABLE SERVO TRAVEL.
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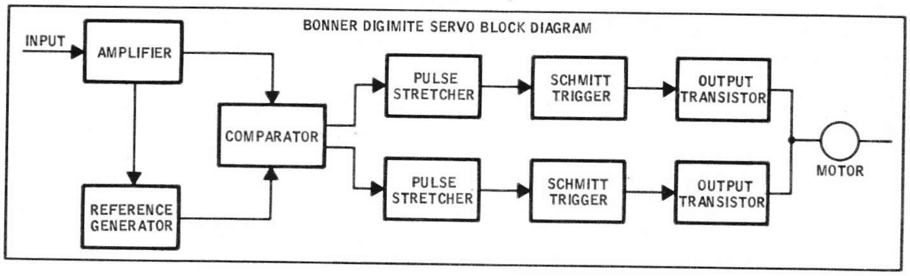
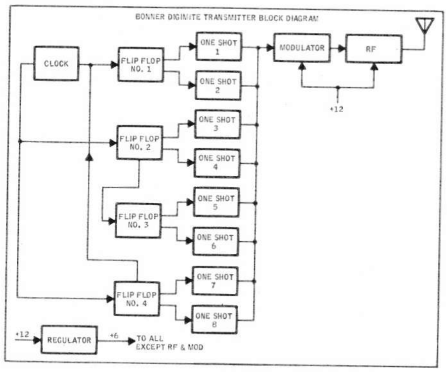
"digital," they are "close enough for jazz."

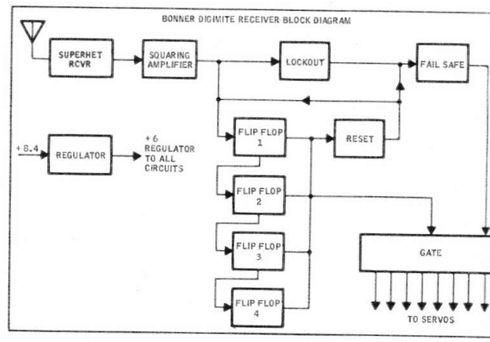
The Comparison

The following information can be considered somewhat controversial, but since this publication has always generated and welcomed controversy, I am sure rebuttals will be forthcoming. I do, however, give this comparison to you as honestly and as free of prejudice and bias as I possibly can.

The graphs illustrate the most important parameters of proportional performance — tightness (or repeatability of neutral), and system response time (how fast does the servo respond to a stick movement). The information has been volunteered by the manufacturers themselves, so I cannot be held responsible for its accuracy. (Ed's note: No attempt is







ANALOG V.S. DIGITAL COMPARISON

Analog	Digital
(a) Cost	
Orbit Proportional (4 channel): $595. Sampey Starlite 500: Approx. $700-$800.	Bonner Digimite: $615 (8 channel) F & M Proportional: $439 (5 channel).
(b) Complexity	
Analog wins hands down here. Oribit and Sampey contain approximately 30 to 35 transistors.	Digital systems are by nature more complex — both systems having consderably more than 50 transistors. In time, though, through design simplifications, this number should be cut almost in half.
(c) Reliability	
I will have to award the theoretical edge to analog by sheer weight of fewer parts — there are fewer timing functions to get out of adjustment.	Although there are more parts to go wrong wth the digital systems, the way in which the parts are used (all on or all off) does help reliability, especially in the servo amplifier.
(d) Maintenance	
Here, again, analog wins by virtue of its relative simplicity. The average do-it-yourself electronics "expert" would have an easier job of readjustment.	Digital systems, because of their critical timing functions, will have to be factory adjusted, or where a precision oscilloscope is available.
(e) Ease of Installation	
All things considered — a dead heat, although analog fans will have to make sure their linkages are completely free.	A tie, but more power for small error signals make fewer demands on linkage freedom.
(f) Ease of Operation	
Again, not much difference, although a slightly different flying technique is required due to slower servo response for small error signals.	It may be easier for the beginner to get used to digital systems, but this is hard to prove.
(g) Servo Action	
Analog systems, due to the need for large filtering capacitors at the input to the servo amplifier, have a slower reaction time for small stick displacements, such as in landing flares. This can be compensated for, somewhat,	The digital system servo response is faster and more constant regardless of air load or linkage drag. I am speaking of the time to react, and not the speed of travel once it is going. Obviously, under load, both types will

by experience. The other objection is the fact that sticky linkages may increase the deadband, as will severe air loads. slow down, but the digital servo will start much more quickly.

(h) General

This is hard to pin down in a few short comments. It depends entirely upon what your standards are. Both types perform well. I will say that digital has the edge in contest precision flying because of its slightly quicker servo action. It should be noted, however, that analog should have better interference rejection due to the tone-subcarriers and discriminators. Analog systems are more prone to neutral shift with temperature due to the "Class A" operation of the servo amplifier. This drift can be compensated for by various means, such as thermistors and silicon transistors.

Digital systems will appeal to the contest flyer — especially the scale buff, because of the additional channels available. Digital's one drawback is that noise, man-made or natural, looks like information to the system. This has prompted both major manufacturers to put in elaborate lockout and fail-safe mechanisms. Digital servos are also less susceptible to drift with temperature due to the fact that the reference generator in the servo should track the pulse generator in the transmitter, thereby cancelling out any temperature caused changes. Since the motor driving circuitry is all on or all off, it contributes no drift affect of its own.

THE PROPORTIONAL CONTROVERSY

TO FAIL SAFE OR NOT

By AL DOIG

Fail Safe . . . necessary or not? The author offers an excellent rebuttal to RCM Editor's point of view.

Fail safe is generally accepted as the act of returning all controls to neutral, and motor to low speed when any detectable failure occurs in the receiver or transmitter. Like motherhood, it has been generally regarded as "good". In a reed set, all controls will automatically return to neutral (barring certain types of power failures) as a consequence of not transmitting appropriate tones. This is in itself a fail safe mode. Fail safe as applied to reed sets is generally an electronic gadget that returns motor to low speed if any command is not received for a specified period of time and is an add-on unit, not normally a part of the radio. The decision to fail safe or not in reeds is a matter of whether one wants to crash under full or closed throttle! The intensity of the crash depends upon luck and the stability of the airplane.

With proportional, however, the problem is more complex. Many systems use some form of pulse width to control servo position. So-called digital systems use this form of coding. As a wide pulse represents one servo extreme and a narrow pulse represents the other extreme, the absence of a pulse is generally interpreted as a narrow pulse and, therefore, a desire for hard-over control. Noise, on the other hand, may appear instantaneously as good information. If a noise pulse, or a cycle of tone signal coincides with a time when information is expected, it is interpreted as a servo position consistent with whatever width the pulse happens to be. A digital system without a fail safe/lockout feature may certainly operate on the face of noise but will be confused because noise will substitute for good information and good information will be shifted from one function to another on a random basis. The servos in this condition will chatter and/or run wildly from one extreme to the other in an erratic manner.

To permit operation of a digital system in the face of ever present noise, some systems contain a function called lock-out. In some way, all systems electronically define "frames" of information. That is, the first pulse or time period of a "frame" may be rudder, the second elevator and so on through however many functions there are in the system. The first pulse of the next frame is again rudder, the next, elevator, etc., etc. Thus, is known how many pulses **should** be in each frame. Lock-out in some way says "if there are more or less pulses in this frame than there are supposed to be, I will stop the servos right where they are until the information **is** proper again. When it is proper I will release control to the incoming information stream". In most sets using this system, after lock-out has been in effect for a predetermined time, fail safe is triggered, sending the servos to a neutral position. The first frame of good information will return control to the transmitter.

The decision to fail safe or not is one of economics, and probability. How much did fail safe cost? What is the probability it saved the plane? What is the probability is would have been saved if fail safe had not been in operation, and what is the cost of the ship?

As an absolute minimum, the complete absence of pulses must return the servos to neutral. As a result of a transmitter failure, hard over controls in all channels is, at least to me, completely unacceptable. Statements that some degree of control is attained through interference if lock-out/fail safe is absent are rather misleading. Control may be so erratic, and indeed may be completely switched from channel to channel in a random fashion, as to be detrimental rather than helpful. I'm not so skillful a flier as to diagnose erratic control action when the ship is headed toward destruction. My mind tends to go blank under these conditions. I'd prefer to have the control do something intelligent rather than count on my doing it! To illustrate the above points, I was flying a Stormer with digital proportional when a wire broke loose from one of the control potentiometers in the transmitter. The

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To Fail Safe Or Not

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system went into fail safe and the plane glided down in the alfalfa without even a broken prop. A field soldering iron fixed the problem and I was back in the air within 15 minutes.

Luck? Yes, but fail safe in this instance saved me 50 bucks worth of kit and material. Fail safe is now worth 50 bucks to me.

Another instance where fail safe helps is one which should not happen but does to the best of them. An instance will illustrate. Cliff Weirick, who is a reasonably experienced flier, fired up his Candy and started to take off. His engine throttled back a couple of times. Cliff looked up to see another flier, whose transmitter had been previously shielded from view, with the same color frequency flag. If Cliff had been able to "control the surfaces through the interference" he would have been about 50 feet in the air when the awful truth became apparent. Fail safe is worth 50 bucks to Cliff Weirick, not to mention the other airplane.

To summarize — I fly a system with fail safe and I'd rather fight than switch.