MICRO MINIATURE INTRAORAL TELEMETRY SYSTEM

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Summary Intraoral telemetry is often-the only method of evaluating dental problems involving environmentally dependent relationships between occlusion, jaw movements, and the neuromuscular system, and between pH, Eh and bacterial ecology. To study these dental problems a small transmitter (the size of a molar tooth crown) with low power requirements and capable of monitoring eight physiologic parameters has been developed. Such transmitters are now being used to evaluate the design of dental bridges and related neuromuscular dysfunction.

Introduction The problems of intraoral telemetry are similar to those found in other types of biotelemetry; however, the requirements for studying occlusal forces and jaw movements pushed the design and size of an economically feasible transmitter to the limits of possibility for hybrid circuit fabrication. Until recently intraoral research has been constrained by single channel systems operating continuously for the life of the battery or in response to closure of a make-and-break circuit with tooth contact. However, the transmitter to be described here provides eight channels of information, is of acceptable size, can be magnetically switched on and off for intraoral monitoring of occlusal forces, jaw movements, and pH and Eh measurements.

The transmitter is of an eight channel multiplex PAM/FM time sharing design that samples eight force sensors mounted within the occlusal surface of a simulated molar tooth which houses the entire transmitter. The system operates in the 10OMHZ range, and particular attention has been given to maximizing the RF transmitting range using a loaded dipole instead of the usual coil antenna.

Transmitter The system is composed of three main elements: The wip tail ring circuit, analog switch and RF module. The wip tail ring circuit is used as a commutator to operate a series of FET switches. There is one switch for each sensor and one additional switch for a sync pulse. These FET switches are operated sequentially by the wip tail ring circuit to form a nine pulse commutated signal. The solid state strain sensors have an output of twenty millivolts maximum, this is amplified by five and the resulting signal is applied to the RF module.

System operation can be most easily understood by reference to the transmitter block diagram as shown in figure 1 and circuit diagram figure 2 The moment power is supplied a large positive pulse from the self-start circuit is applied to the first transistor base triggering the first transistor into conduction, operating the first analog switch. With no further positive bias on the base the transistor turns off. In doing so the trailing edge of the switching pulse becomes positive; it is this positive portion of the pulse which turns on the next transistor and each transistor in sequence until the pulse returns to its starting position. Since the self-start circuit is inoperative except at the pulse initiation and a diode effectively isolates the self-start circuit impedance, the wip tail ring circuit continues to operate in the normal manner.

The amplitude of the commutated signal from the analog switch is two hundred millivolts. This voltage is due to the transmitter size configuration which precludes the use of trimming bridge circuits and the need to eliminate as many components as possible. However, the DC amplifier is biased so that it only amplifies the mid section of the commutated waveform. The sensor signal output from the amplifier now has a 50 per cent change in magnitude (100 MV) compared with a 10 per cent change (20 MV) in the original commutated signal.

The RF module of the transmitter has required special attention due to the difficulties of transmitting a usable signal from inside the mouth. Besides the usual tissue attenuation and movement problems, the transmitter is located within the usual extensive gold framework which is a part of dental bridges. Using a simple tuned coil as the antenna, proved to be unsatisfactory since opening and closing of the mouth detuned the RF oscillator. Therefore, a totally shielded and encapsulated thin film package was designed (see figure 2) using a colpitts oscillator operating at 120 MHZ connected to a low output impedance emitter follower.

Antenna Attempts to transmit information from the mouth using a magnetic loop antenna, failed to radiate enough signal to receive data on a continuous basis. An analysis of the antenna problem involved consideration of the practical size limitation of both the transmitter module and the antenna. Due to body attenuation the upper limit of transmitter frequency of 120 MHZ was decided upon. At this frequency the wavelength is approximately 10 feet. Since the length of the transmitter antenna must be only a small fraction of this wavelength, the transmission range is minimal.

The relative radiation levels from a small (infinitesimal) electric dipole were computed. At short ranges, up to 2.5 feet (one quarter wavelength), the radial electric field is close to the level of the tangential electric and magnetic fields. Further analysis indicated that for a loop antenna to be equivalent to a 4 inch electric dipole, the loop would have to have a diameter of 7 inches and would have a self-resonant frequency lower than 100 MHZ. Direct comparison between a half-inch tuned 100 MHZ coil and a four inch electric dipole showed that the dipole signal would have 80 times the field strength and 9 times the range of a magnetic loop.

The maximum length of the antenna that could be used intraorally was found to be 4 inches. With the transmitter module having a low output impedance, the radiation was improved by loading the antenna. Figure 3 shows the results of loading the antenna both in free space condition and in the intraoral. position. The gain in field strength was 23.5 db in free space. In the intraoral case, the 4 inch antenna wire was suspended inside a 0.20 inch diameter plastic tube. Placing the transmitter and antenna inside a subject's mouth, the capacity increased to 3.5 PF as indicated by a decrease in the optimum loading inductance. The added capacity is lossy which is indicated by the increased bandwidth. The radiation path is also lossy as indicated by the 18 db decrease in optimum field strength. The gain in field strength intraorally using a 0.72 microhenery loading inductor was 27db.

Demodulator The telemetry system uses FM/PAM modulation. Full pulse amplitude (Sync Pulse) nets 0.25 MHZ of FM deviation. The eight data bits are 0.3 to o.45 of the sync pulse. The PAM rate is approximately 300 HZ and the pulse duty cycle is approximately 0.4 milliseconds.

The receiver is a conventional FM superhet with a single cascade RF stage, a three stage IF with the last two stages being limiters and containing two DC coupled common emitter transistors, discriminator, AFC amplifier, video amplifer and a +8 volt regulator.

A block diagram of the data decoder system is shown in Figure 1. The sync pulse is extracted from the signal by the sync separator and the sync pulse is used to reset the counter and sync remover. The clock pulses are generated by the clock separator and are used to drive the keyed clamp with the clock pulse corresponding to the sync pulse being removed by the snyc remover. This string of eight-clock pulses is delayed by the delay multivibrator and used to drive the counter and sample gate matrix.

The signal is buffered by an emitter follower, clamped by the clock pulses, and buffered by another emitter follower to supply the clamped PAM signal to the boxcar detectors. The counter, comprised of flip flops A, B, and C (figure 1), counts or divides down the clock pulse and is reset to zero with the buffered sync pulses. The counter output and the clock pulses are used in the sample gate matrix to generate eight sample pulses to coincide with the data pulses. The data pulses are sampled by the boxcar detector and amplified by the DC duplifier. The DC amplifier and the boxcar are biased to +2.5 volts and the DC amplifier output is ±2.5 volts.

The timing waveforms are shown in figure 4. The uppermost waveform is the signal from the receiver showing the full amplitude sync pulses and the eight-data pulses in the clock pulses waveform D, the sync pulse has been removed. Waveforms A, B. and C, are the outputs of the counter flip flops, and lower waveform is the sample gate number two.

The transmitter as mounted in a model of a subject's mouth is shown in figure 5. The eight solid state strain sensors are buried in the occulusal surface in a predetermined configuration to ensure that the eight sensor outputs can be resolved into position and force data. Four NS212 16 M/AMP hour batteries are enclosed in a metal case with a screw cap (figure 6).

Conclusion The multichannel transmitter which has been described represents an optional compromise between an ideal transmitter and a practical, economically feasible transmitter for intraoral telemetry. It may be used for other biotelemetry applications requiring small size and multichannel data RF transmission.

System Specifications

Frequency Range	110 to 130 MHZ
Modulation	FM
Number of Channels	Nine (eight Data Channels)
Frequency Response	36 HZ
Sample rate	0.4 milliseconds/channel
Power supply	6 V DC 4 M3212 batteries
Battery Drain	3.5 M/AMPS
Operating life	60 minutes
Continuous operation	
Size (transmitter System only)	0.5" x 0.35" x 0.2"

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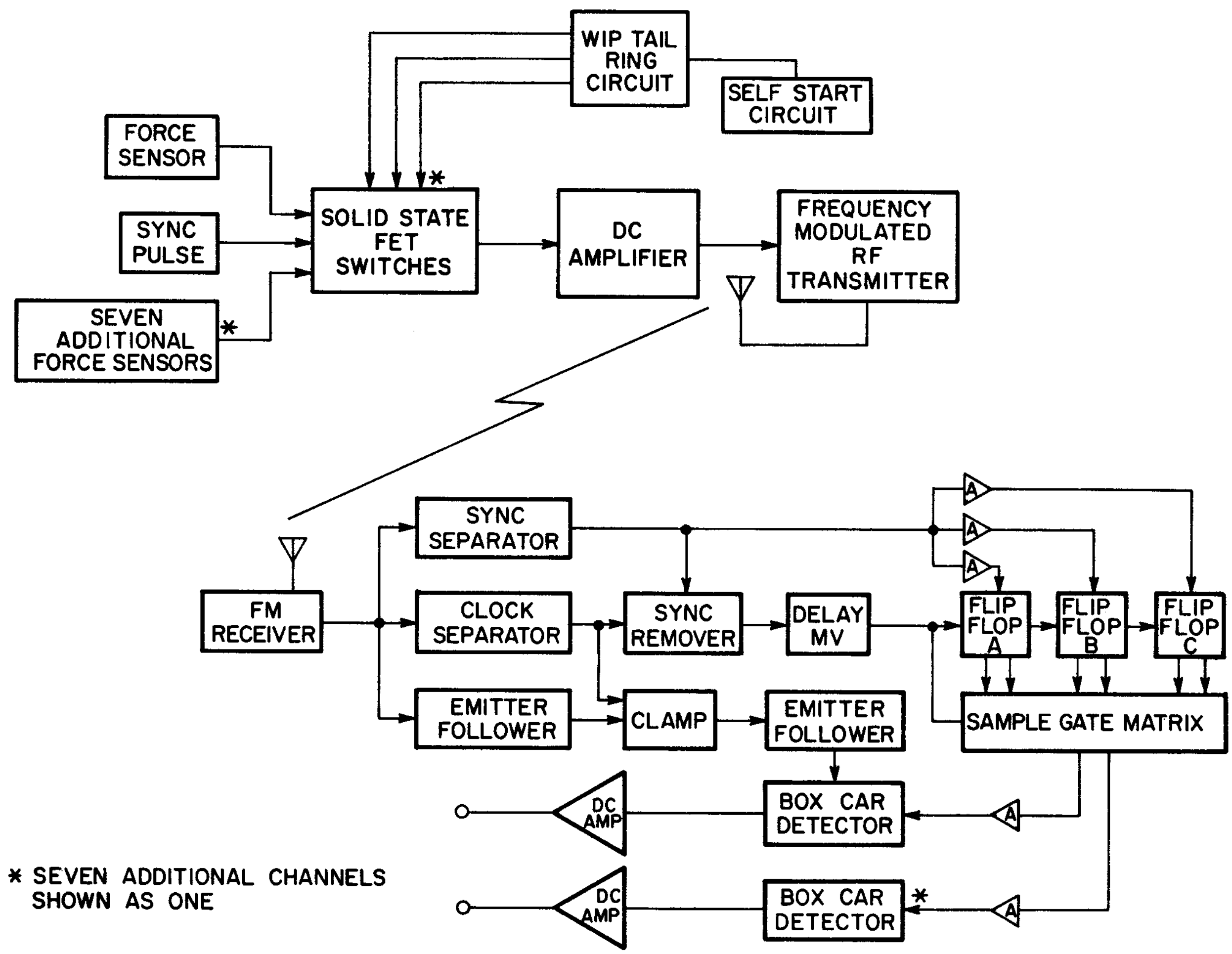
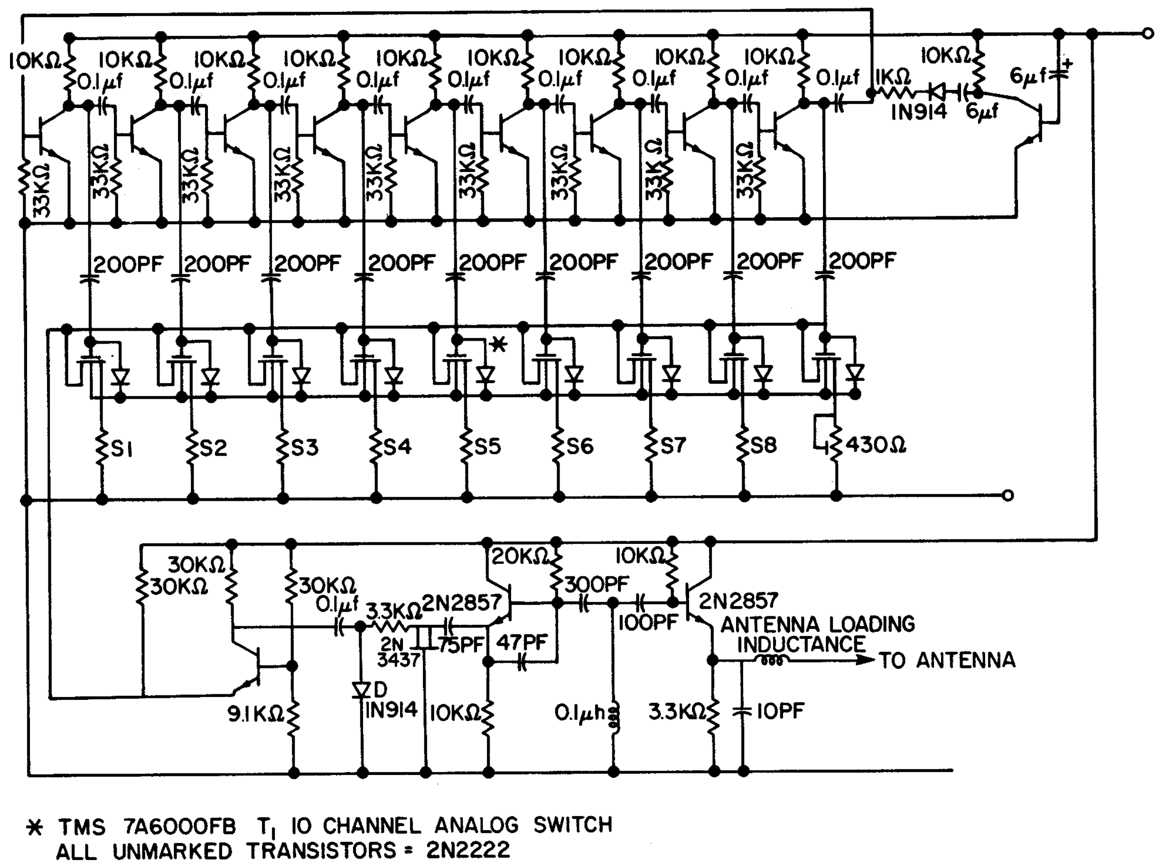


TELEMETRY SYSTEM BLOCK DIAGRAM

FIGURE 1.



EIGHT CHANNEL TELEMETRY TRANSMITTER CIRCUIT DIAGRAM

FIGURE 2.

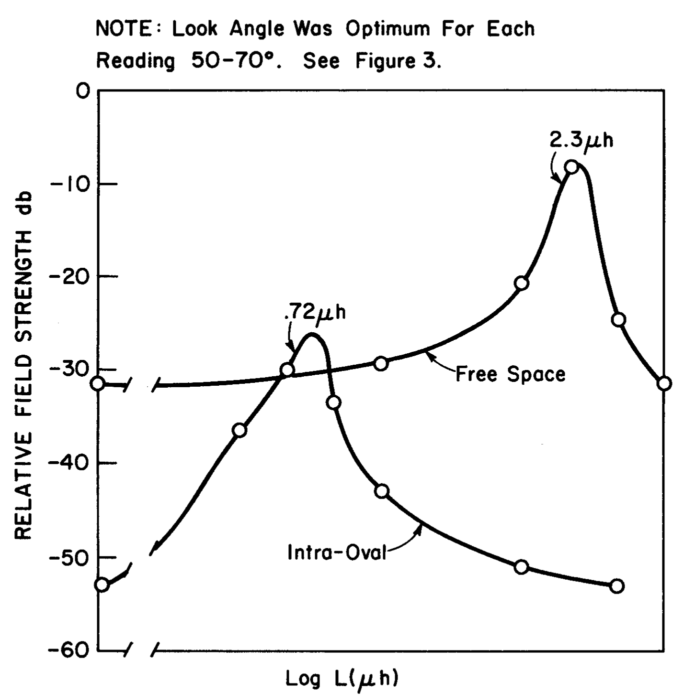
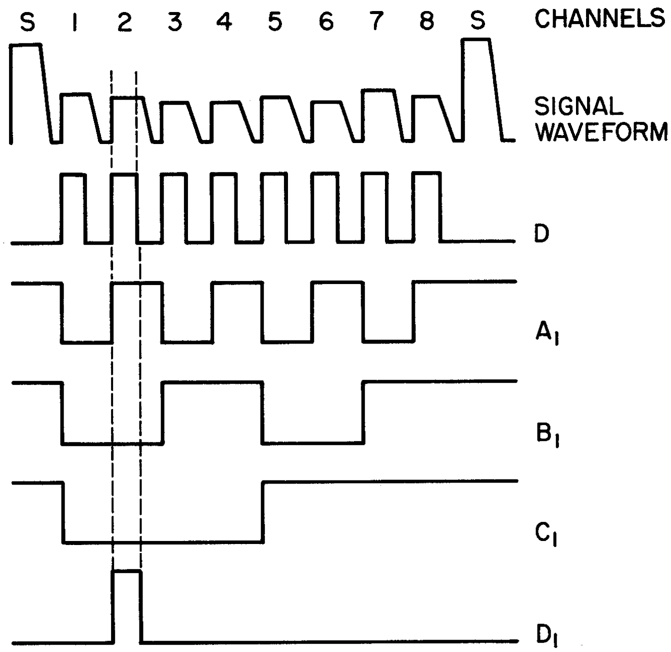


FIGURE 3.



1	2	3	4	5	6	7	8	CHANNEL
A_0	A_1	A_0	A_1	A_0	A_1	A_0	A_1	SAMPLE
B_0	B_1	B_0	B_1	B_0	B_1	B_0	B_1	GATE
C_0	C_1	C_0	C_1	C_0	C_1	C_0	C_1	INPUTS

TIMING WAVEFORMS

FIGURE 4.

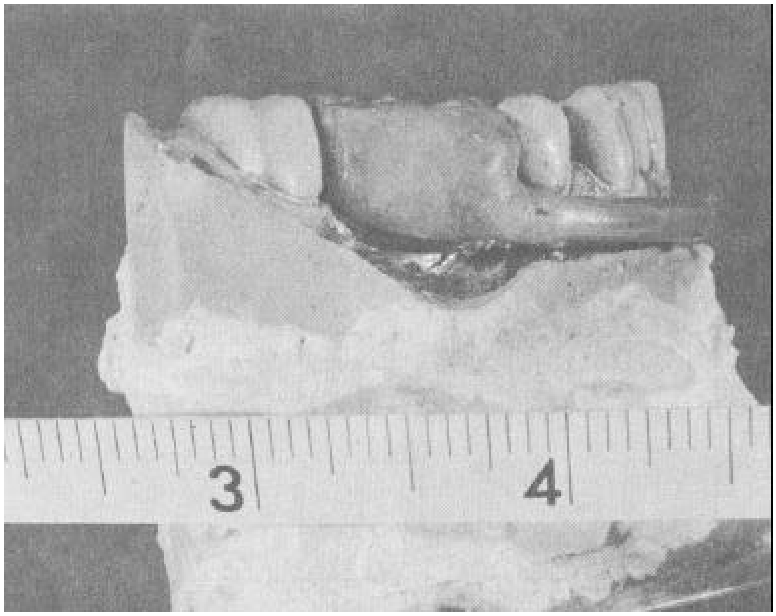


FIGURE 5. TELEMETRY TRANSMITTER. FITTED ON MODEL

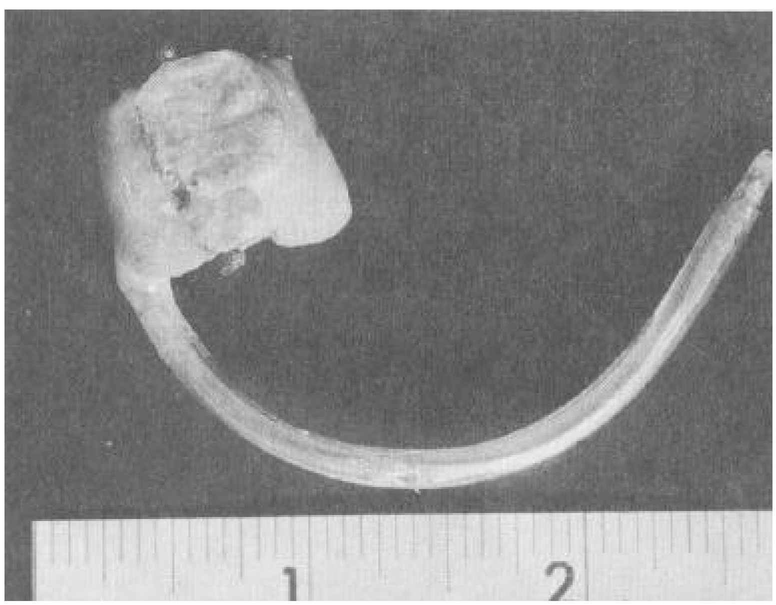


FIGURE 6. TELEMETRY TRANSMITTER