ABSTRACT

An accelerometer telemetry system incorporated in a finger ring is used for monitoring the motor responses of a subject. The system includes an accelerometer, battery and transmitter and provides information to a remote receiver regarding hand movements of a subject wearing the ring, without the constraints of wires. Possible applications include the detection of fatigue from the hand movements of the wearer.

6 Claims, 14 Drawing Figures
FIG 1

FIG. 2a

FIG. 2b

FIG. 8a
VOLTAGE ACROSS C5

FIG. 8b
PULSE TURN-ON

FIG. 8c
STRAIN GAGE ACTIVATION

FIG. 8d
RF OUTPUT
**FIG. 5**

- ACCELEROMETER
- ASTABLE MULTIVIBRATOR
- RF OSCILLATOR
- SAMPLE AND HOLD
- AMPLIFIER

**FIG. 6**

- RECEIVER
- DEMODULATOR
- READOUT
ACCELEROMETER TELEMETRY SYSTEM

ORIGIN

The invention described herein was made under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72 Stat. 435; 42 U.S.C. 2457).

FIELD OF THE INVENTION

This invention relates to accelerometer telemetry systems, and, more particularly, to a self-contained miniaturized accelerometer telemetry system incorporated finger ring, used in monitoring of the motor responses of the ring wearer.

BACKGROUND OF THE INVENTION

In certain critical activities, such as the piloting of an aircraft or activities involved with flight control, it is desirable to determine when the operator performing these activities is becoming fatigued. Such fatigue, which may be physical or psychological, can, of course, have a serious effect on the judgment and/or reaction speed of the operator. Studies have shown that an individual's motor activities, as evidenced by hand tremor and other hand motions, change in relation to degree of fatigue. Information regarding hand motions can be obtained in a number of known ways, but such information is obviously most reliable and thus useful when gathered without interfering with the normal routine of the subject. Thus, massive, bulky systems as well as systems requiring wires or other direct interconnections with a subject have limited application in situations where the presence of a sensing device or interconnecting wires would curtail normal activities or otherwise affect the results obtained.

SUMMARY OF THE INVENTION

According to the present invention, a miniaturized telemetry system is provided which continuously monitors the hand movements of a subject and transmits the resultant information to a remote receiver. The telemetry system includes a miniaturized semiconductor strain gage coupled to a seismic mass for detecting the movements in question and for producing an electrical output signal in accordance therewith. The strain gages are preferably activated by short duration pulses, rather than continuous activation, so as to conserve power. The output signal is used to modulate the time interval between output pulses of a radio frequency transmitter. The entire sensing and transmitting package, including a power source, is contained in a case or housing which supports a centrally located seismic mass. Strain gages will produce a voltage proportional to the deformation resulting from movement of the seismic mass; this tension/compression relationship is achieved in an arrangement. As shown in FIG. 8b, the narrow width of beam is in tension and the latter of beam is fixed at other compressional and tension zones.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1, a self-contained accelerometer telemetry system, generally denoted 10, is illustrated. The system basically comprises an accelerometer 20, a transmitter 30 and a battery 40 all packaged in a casing or housing, 50 which is the size and shape of a finger ring. A cover 60 is screwed into an upper opening in ring housing so as to completely enclose the system electronics therein.

Accelerometer 20 is shown in greater detail in FIGS. 2a and 2b and, as illustrated, includes a chemically etched ring 21 and a central beam 23, the latter of which supports a centrally located seismic mass 27. Attached to beam 23 of accelerometer 20, on either side of seismic mass 27, are first and second semiconductor strain gages 25. Movements of seismic mass 27, indicated by arrow 29, are converted into stresses in beam 23, these stresses being detected by strain gages 25 and converted into corresponding electrical signals. The resistances of strain gages 25 are directly proportional to detected stresses, so that a current passing through the gages will produce a voltage proportional to the detected stresses according to the formula where \( \Delta E = I \Delta R \), where \( \Delta E \) is a voltage change, \( I \) is the current and \( \Delta R \) is the change in resistance of strain gages 25. The use of a constant current \( I \) is preferred but is not necessary for the circuit to function properly.

Beam 23, on which strain gages 25 are mounted, is a double-clamped beam, that is, the beam 23 is fixed at both ends. In order for a voltage divider strain gage circuit, shown in FIG. 7 and described hereinbelow, to function properly, one strain gage 25 must be in compression while the other strain gage 25 is in tension. This tension/compression relationship is achieved in the prior art by positioning strain gages 25 orthogonally, with one gage parallel to the longitudinal beam axis and the other perpendicular to that beam axis. However, the narrow width of beam 23 precludes such an arrangement. As shown in FIG. 3a, the double clamped beam 23 has four compressional zones, de-
noted C₁, C₂, C₃, and C₄, and four tension zones, denoted T₁, T₂, T₃, and T₄, when seismic mass 27 moves in the direction of arrow A. Similarly, as shown in FIG. 3b, beam 23 has four compressional zones C₁', C₂', C₃', and C₄', and four tension zones T₁', T₂', T₃', and T₄' when seismic mass 27 moves in the direction of arrow A'. It will be appreciated that a compression zone changes to a tension zone when seismic mass 27 moves from one extreme position to the other (C₁ changes to T₁', C₂ changes to T₂', etc.). Thus, the desired tension/compression placement is achieved by positioning strain gages 25 as shown in FIG. 4e and 4f.

The electrical signals resulting from the changes in the resistances of strain gages 25 form the inputs to transmitter 30 in FIG. 1. Referring to the schematic block diagram in FIG. 5, the principal components of the transmitter 30 are shown. The transmitter includes an astable multivibrator 75 which provides pulses to energize accelerometer 20, as well as to activate a sample-and-hold circuit 70 and to gate an RF oscillator 85, which provides a frequency, for example, for the FM band (88–108MHz), and which feeds an output antenna 87. Transmitted RF bursts of constant width and amplitude are time modulated in accordance with the resistance changes produced by accelerometer 20. By using bursts rather than continuous transmission, a low duty factor is realized and power is conserved. The overall operation of transmitter 30 is described hereinafter.

Referring to FIG. 6, the time-modulated RF bursts transmitted by antenna 87 of FIG. 5 are received by a receiver antenna 88. A telemetry receiver 90 of conventional design generates a single pulse for each RF burst received. A demodulator 95, which is also of known design, converts the pulse train at the output of receiver 90 into an analog signal representing hand accelerations as reflected by the movements of seismic mass 27. This analog signal is recorded or displayed by conventional recording or display devices, represented by readout 97, for analysis and comparison to a standard established for a particular subject. The telemetry receiver 92 can be, for example, a Konigsberg Instruments Model TR1-2 while the demodulator 95 can be a single channel demodulator similar to that described in Fryer, “Implantable Biotelemetry Systems,” NASA Publication SP-5094, 1970. Readout 97 can be, for example, a meter, a pen recorder, a tape recorder, or an oscilloscope.

Referring now to FIG. 7, a schematic circuit diagram of transmitter 30 of FIG. 5 is shown. Although FIG. 7 depicts transmitter 30 having discrete components, it is to be understood that the transmitter could even be made smaller by utilizing integrated circuitry.

The transmitter circuit of FIG. 7 provides for sampling the resistance of strain gages 25 using a pulsed input. The voltage resulting at point 26, which is derived in a manner described in greater detail hereinafter, passes through transistor Q7 during the sampling period and is stored by capacitor C5. Thus, the charge on C5 will be reflective of the results of the previous sampling of strain gages 25. The voltage present on capacitor C5 is tracked by a high impedance follower formed by transistors Q1, Q2 and resistors R1 and R2 connected as shown. A capacitor C1 couples the output of the high impedance follower to a signal amplifier comprising capacitors C₃, R₃, R₄, and a transistor Q₃, the signal amplifier providing a gain or approximately five. Capacitor C1 provides a coupling cutoff frequency of approximately 0.4 Hz, which is adequate for the detection of even slow movements. A transistor Q₄, and resistors R₅, R₆, and R₇ provide temperature compensation for a transistor Q₅, which transistor generates a constant current output that varies with the signal coming from the preceding amplifier stage. A capacitor C₆ connected to the collector of transistor Q₅ charges through resistors R₁₁ and R₁₄ until a further transistor Q₆, coupled to the collector of transistor Q₅, is turned on. Current through transistor Q₆ switches on a further transistor Q₇ which is connected to the collector thereof through a resistor R₉.

The collector of transistor Q₇ is connected to a point on the junction between strain gage resistors 25 of accelerometer 20 while the collector of transistor Q₆ is also connected to the base of a transistor Q₈ through a network comprising a capacitor C₇ and two resistors R₁₂ and R₁₃. As illustrated, the collector of transistor Q₈ is connected to the base terminals of two further transistors Q₉ and Q₁₀. Thus, transistors Q₆ and Q₈ form an astable multivibrator, and when transistor Q₈ is switched on, transistors Q₉ and Q₁₀ also switch on through their base resistors R₁₅ and R₁₆. Transistor Q₈ will remain on until capacitor C₇ charges up, whereupon transistor Q₈ will turn off and reset the cycle. The “on” time of transistor Q₈ is determined by the time constant of resistors R₁₂, R₁₃ and capacitor C₇ and is approximately between 25 and 35 microseconds for the component values shown in FIG. 7. Thus, a constant width pulse is produced by the astable multivibrator transistor pair Q₆ and Q₈. The interval between pulses is determined by the charging of capacitor C₆, which is controlled by current generator transistor Q₅. The output of transistor Q₅ is determined, as described hereinafter, by the charge on capacitor C₅, which varies with the resistance of accelerometer strain gages 25.

When transistor Q₉ is turned on the a fixed length of time by transistor Q₈, strain gages 25 are activated. The voltage at point 26 is determined by the divider network formed by the resistances in strain gages 25. Thus, during the turn-on time of transistor Q₉, the voltage at 26 reflects the position of seismic mass 27. Since transistor Q₇ is also turned on at this time, the resulting voltage at 26 is stored by capacitor C₅ and that voltage will determine the time interval until the next pulse, as described hereinafter. When transistor Q₁₀ is turned on by transistor Q₈ during a pulse, a radio frequency oscillator and transmitter, made up of resistors R₁₉, R₂₀, capacitors C₈, C₉, C₁₀ and transistor Q₁₁, produce an RF output across coil L₁. Coil L₁ serves a dual purpose, being both the inductive element in the oscillator tank circuit and the RF radiator (transmitting antenna 87). Power for the circuitry is supplied by a 1.35-volt miniature mercury battery. Capacitor C₁₁, connected across the terminals of the battery, serves as an RF bypass.

Thus, to briefly summarize the operation, a pulsing voltage activates the strain gages, a switching circuit permits a capacitor to sample and store the resultant strain gage output and the stored charge is used to modulate the successive intervals between pulses, each pulse producing an RF burst for transmission. FIGS. 8A, 8B, 8C and 8D show representative wave forms for points A, B, C and D in FIG. 6.

As described hereinafter, the transmitted RF pulses are received, decoded and demodulated by a receiver and demodulator system shown in FIG. 6 into a signal.
representing accelerations undergone by the ring. Amplitude and frequency of acceleration components as well as derived velocity components are all useful in predicting and detecting changes in activity and fatigue. The system may be used in numerous possible modes for extracting fatigue predictive indices. For example, separated frequency components can be used in a measurement of the short term acceleration activity to total activity so as to determine the amount of hand tremor. Separated acceleration amplitude signals can be used to generate a ratio which determines the slowing down of an individual's activity so as to measure exhaustion. A velocity activity ratio can be used to show the slowing of movement and hence to indicate that an individual's ability to cope with control movements has diminished.

In addition to detecting fatigue or other psychomotor manifestations, the invention can be used in numerous other areas such as in time and motion studies, analysis of bilateral distribution of manual workload, the location of infrequently used controls, and in medical and prosthetic applications.

In cases where transmission distance is considered more important than battery life, a frequency-modulated continuous wave signal could be transmitted instead of a pulse-time-modulated signal.

Although the invention has been described with respect to an exemplary embodiment thereof, it will be understood that variations and modifications can be made within the scope or spirit of the invention.

What is claimed is:
1. A miniaturized accelerometer telemetry system for monitoring the hand movements of a subject comprising:
   an accelerometer for detecting accelerational movements and for producing an electrical output signal in accordance therewith;
   transmitter means;
   modulator means for modulating the output of said transmitter with the output signal produced by said accelerometer;
   a housing, adapted to be worn on the person, for housing said accelerometer, said transmitter means and said modulator means;
   said accelerometer comprising an annular ring and a central support beam extending diametrically across said ring, a seismic mass affixed to said beam at the center of said ring so as to permit axial movements of said seismic mass, and first and second semiconductor strain gages, bonded to said beam on opposite sides of said mass, the electrical resistance of said gages varying in relationship to the stresses endured in each of said beams.

2. A miniaturized accelerometer telemetry system for monitoring the hand movements of a subject comprising:
   as accelerometer for detecting accelerational movements and for producing an electrical output signal in accordance therewith;
   transmitter means;
   modulator means for modulating the output of said transmitter with the output signal produced by said accelerometer;
   a housing, adapted to be worn on the person, for housing said accelerometer, said transmitter means and said modulator means;
   said modulator means comprising a sample-and-hold circuit connected to the output of said accelerometer, multivibrator means for pulsing said accelerometer and said sample-and-hold circuit, and amplifier means for connecting the output of said sample-and-hold circuit to the output of said multivibrator means; and
   said transmitter means comprising a pulse time modulation transmitter connected to an output of said multivibrator means.

3. A miniaturized accelerometer telemetry system for monitoring the hand movements of a subject comprising:
   an accelerometer for detecting accelerational movements and for producing an electrical output signal in accordance therewith;
   transmitter means;
   modulator means for modulating the output of said transmitter with the output signal produced by said accelerometer;
   a housing, adapted to be worn on the person, for housing said accelerometer, said transmitter means and said modulator means;
   said accelerometer including a seismic mass, a mount for said mass, and at least one strain gage for detecting the strain endured in said mount responsive to movements of said mass and for producing an output signal in accordance therewith;
   said modulator means comprising means for pulsing said at least one strain gage so as to produce a voltage proportional to the strain induced in said mass, means for storing said voltage, a constant current generator for producing an output that varies directly with the voltage stored by said storing means, an astable multivibrator for producing a pulse train of constant pulses, the interval between pulses in said pulse train being dependent on said output of said constant current generator, and said transmitter means comprising means for producing radio frequency pulses responsive to the output of said astable multivibrator.

4. An accelerometer telemetry transmission circuit comprising:
   an accelerometer for detecting accelerational movements and for producing an electrical output signal in accordance therewith;
   a sample-and-hold circuit connected to the output of said accelerometer;
   multivibrator means for pulsing said accelerometer and said sample-and-hold circuit, said multivibrator means including a control input connected to the output of said sample-and-hold circuit so that the output of said sample-and-hold circuit controls the interval between the pulses produced by said multivibrator means; and
   a transmitter means connected to an output of said multivibrator means.

5. An accelerometer telemetry transmission circuit as claimed in claim 4 wherein said accelerometer comprises first and second resistive strain gages electrically connected to form a voltage divider, a point on the junction between said strain gages being connected to the input to said sample-and-hold circuit.

6. An accelerometer telemetry transmission circuit as claimed in claim 4 wherein said transmitter means includes radio frequency oscillator means for producing radio frequency pulses having a variable interval therebetween, the duration of said interval being controlled by the output of said multivibrator means, said transmitter means further comprising a coil which serves as the inductive element of the tank circuit of said oscillator and as the radio frequency radiator of said transmitter means.