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ELECTROMAGNETIC FIELD EXPOSURE DOSIMETER

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FOREWORD

The electromagnetic field exposure dosimeter is an instrument to measure the amount of electromagnetic radiation that a person is exposed to. This information would be used to help correlate the amount of exposure, or dose, with health problems. A large amount of data would need to be taken with numerous people before a sound conclusion could be made.

The dosimeter was designed and built by Adam C. Feaga, Milton P. Hilliard, and Russell Link, as an electrical engineering senior project at the University of North Carolina at Charlotte. The project adviser for UNCC was Dr. Yogendra Kakad.

The Naval Surface Warfare Center, White Oak Detachment (NSWCWODET) supplied most of the hardware and software used in developing the dosimeter. John F. Scarzello, Daniel S. Lenko, James F. McGuire, and Ronald Vermillion provided technical advice.

Approved by:

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ABSTRACT

The growing concern about adverse health effects caused by electromagnetic radiation prompted the idea for this dosimeter. Data have been presented that link prolonged exposure to electromagnetic radiation from power lines to leukemia and some types of cancer. At present, however, there is a lack of recording instrumentation to measure the prolonged exposure of an individual; thus it is not possible to correlate properly the amount of exposure or dose to health effects. With the recent advances in small, low-power devices, a small measuring device can be developed. Once this is built, a large data base can be obtained to help correlate electromagnetic field exposure to health conditions.

The objective of this project is to develop an instrument which can measure electromagnetic fields over a prolonged period of time. The instrument would be small, say about the size of a radio Walkman, and would be worn throughout the day while taking data, as the individual goes about normal activities. A PC would be used to retrieve the data from the instrument at the end of the day.

The dosimeter comprises a triaxial ferrite-loaded coil sensor, a set of amplifiers and filters, analog-to-digital converters, a microcontroller, and random access data memory. The signals from the sensor are filtered into three frequency ranges: one to measure 60-Hz exposure and two harmonics, another to measure high-frequency pulsed energy, and a third frequency range to record the activity level of the individual. The signals from the filters are digitized and read into a microcontroller. The microcontroller performs a few calculations and controls the flow of the data to either random access memory or to a computer. A computer is used to retrieve the data from the dosimeter, and can store and display the measured data.

CONTENTS

ILLUSTRATIONS

CHAPTER 1

INTRODUCTION

The present design of the portable electromagnetic field exposure dosimeter is a proof-of-concept model. At present, the dosimeter is not portable, because it must be connected to a computer. The dosimeters' microcontroller cannot perform a fast fourier transform on the low frequency data measurements, so the data are sent over a cable directly to the computer, which performs the fast fourier transform. The following report discusses the design of the unit, how it works, and the future plans and designs for the unit.

Figure 1 is a block diagram of the unit. It can be broken down into three main sections. They are the amplifiers and filters, the microcontroller and analog/digital converters, and the computer for data collection.

A triaxial ferrite loaded coil is used as the sensing device. The signals from the sensors are amplified and filtered, with bandpass filters of 10 Hz to 200 Hz and 200 Hz to 10 kHz. The low-frequency bandpass filters are for measuring 60-Hz exposure and the first two harmonics. Radiation in this range of frequencies may come from power lines, television receivers, or household wiring. The high-frequency filters are used for measuring high-frequency pulsed energy, from such sources as turning on a light, or from lightning. Off of one axis of the sensor is a bandpass filter of 0.05 Hz to 4 Hz to measure body motion. This is needed to help correlate the person's activity level to exposure and health.

The seven outputs from the sensor board are then input to a multiplexer and analog-to-digital converter (A/D). A microcontroller is used to control A/D sampling rates, and the flow of data. Some data are stored in RAM, and the rest is sent to the computer. The computer manipulates the real time data, displays them and/or then stores them. The data in the RAM are read by the computer at the end of the measurement period, stored in the computer's memory, and can be displayed.

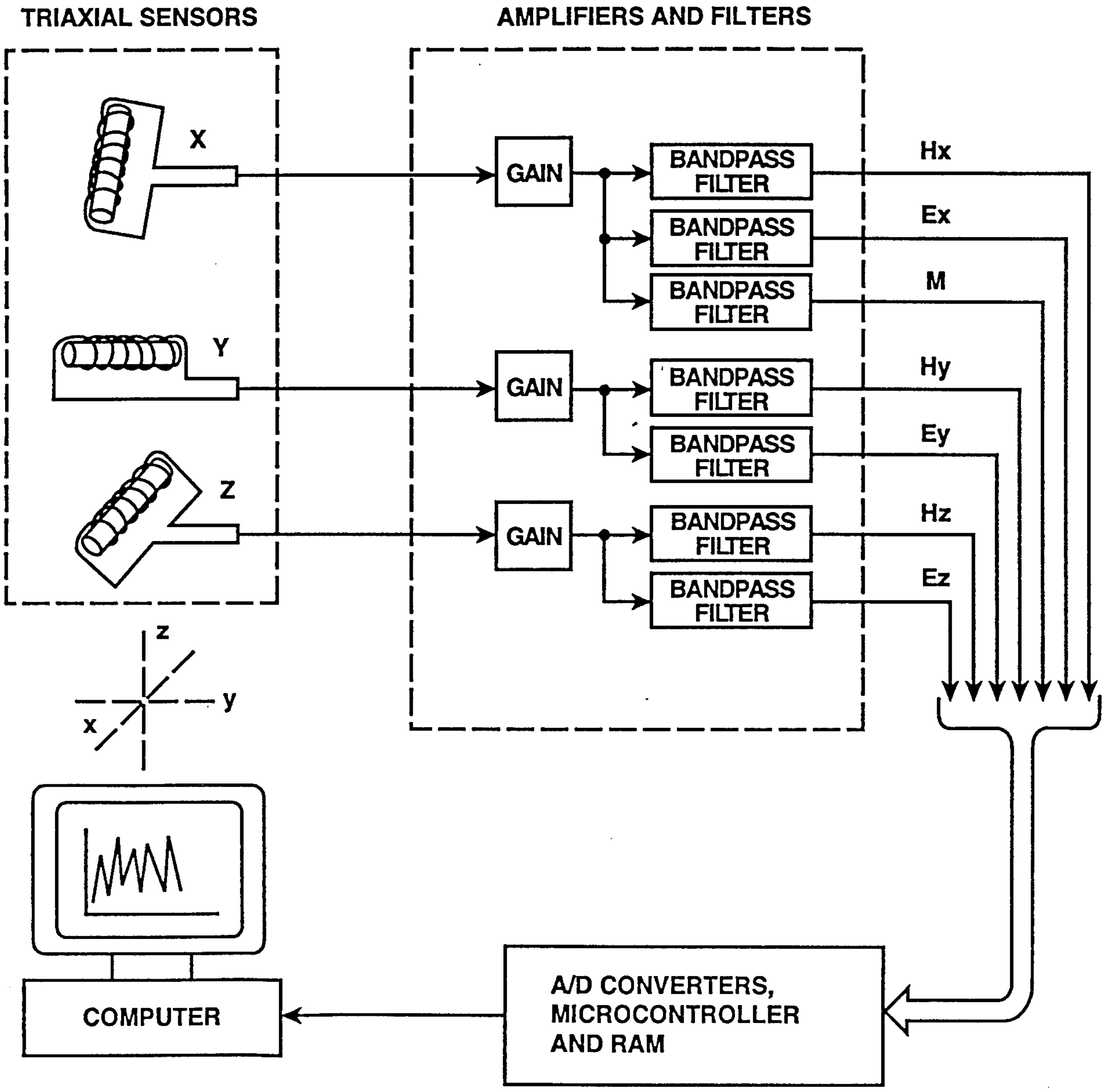


FIGURE 1. DOSIMETER BLOCK DIAGRAM

CHAPTER 2

AMPLIFIER AND FILTERING BOARD

The signals from each axis of the sensor are amplified by a two stage amplifier, and from there they branch to sets of bandpass filters. One sensor axis has three bandpass filters, while each of the other two axes feeds two bandpass filters. Figure 2 is a block diagram of the filter board and Figure 3 is a schematic. An AD795 low-power, low-noise opamp was used in the filter circuits.

The following circuit explanation is for the axis with three bandpass filters. The circuits for the other two axes are identical, except for the fact that they do not have the motion detection filtering.

A two-stage amplifier, opamps #1 and #2, is used to amplify the sensor output. This amplifier acts as a lowpass filter, because as an opamps' gain is increased, its bandwidth decreases. The two amplifiers have gains of 120 and 150, and the AD795 has a unity-gain bandwidth of 1.5 MHz; thus, the bandwidth of the amplifier is 10 kHz. The amplifier is connected to the input of all three of the bandpass filters.

The primary bandpass filter is the 10-Hz-to-200-Hz bandpass filter, which is the top set of opamps in Figure 3. This bandpass filter is used to measure the magnitude of the 60-, 120-, and 180-Hz components of electromagnetic radiation. This range of frequencies comes from household wiring, electrical appliances, and most importantly, overhead power lines. These components are the largest, most common, and most dangerous, so they are the most important signals to be observed.

Opamp #3 is a two-pole, 200-Hz, lowpass filter with a gain of 2. The 23-kohm resistors set the damping ratio to 0.5. The gain of two for the filter is just a natural result of the desired damping ratio and the corner frequency. The signal then passes through a 10-Hz, passive, highpass filter. At this point, the largest measured signals should oscillate between +/-5V.

The A/D can handle only a 0V to 5V signal, so opamp #4 is used to shift the signal level from +/-5V to (0V to 5V). Opamp #4 is really just an adder that adds the input signal to a positive reference signal. The input and reference signals are first divided by 2 by the two 23-kohm resistors before being added together. Ideally, the reference should be 5V, then, the ±5V sensor input signal would be divided by two, and added to the 5/2V or 2.5V reference voltage. The resulting, added output would be a 0V to 5V signal. The 5.1-kohm resistor for the highpass filter provides a path to ground for the 5V reference, so there is a 0.5V DC offset at the 5.1-kohm resistor.

To adjust for the DC offset, the reference voltage was lowered to 4.5V, leaving 0.45V or 0.5V on the 5.1-kohm resistor. The result is that because the input signal is biased 0.5V too high, the reference is shifted 0.5 volt low. If a 0V input signal is used, 0.5V will be on the 5.1-kohm resistor which will be divided by 2, and will be added to half the 4.5V reference, which results in a 2.5V output from opamp #4. The middle of 0V and 5V is 2.5V, which corresponds to the 0V input which is the middle of ±5V. The offset and reference then balance each other for a linear conversion from ±5V to (0V to 5V) for all input signal levels. The A/D requires a low impedance source, which the opamp provides.

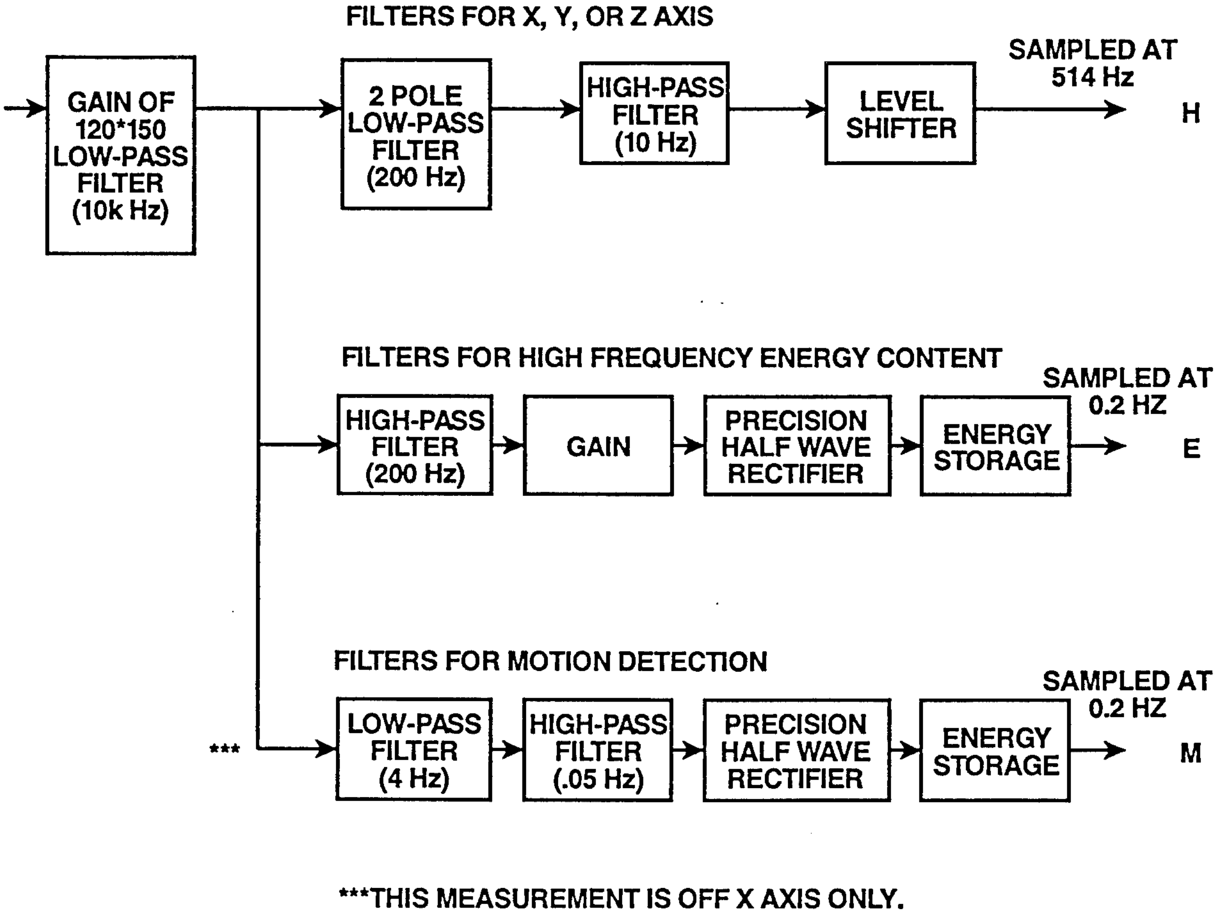


FIGURE 2. AMPLIFIER AND FILTERING BOARD BLOCK DIAGRAM

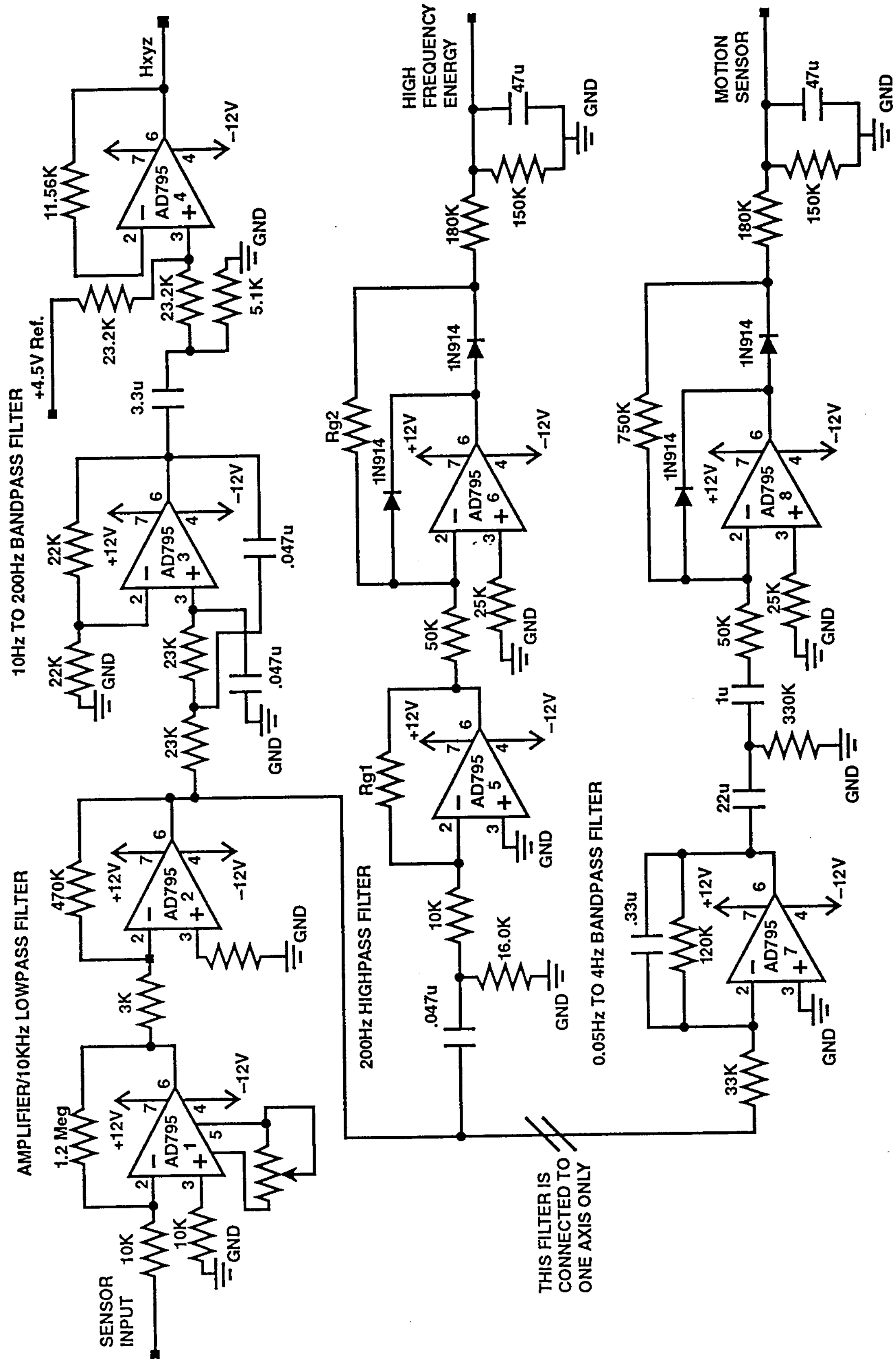


FIGURE 3. SCHEMATIC OF THE AMPLIFIER/FLTERING BOARD

The second bandpass filter is 200 Hz to 10 kHz. This frequency range of radiation may come from lightning, turning on/off a switch or any number of sources with short rise time and short duration electromagnetic pulses. The actual frequency components are not observed, but the energy in the radiation is this range is of interest.

The 10-kHz lowpass is performed by the initial two stage amplifier, opamps #1 and #2. The signal then goes through a passive highpass filter, and the signal is then amplified further by opamp #5. Opamp #5 was placed after the highpass filter so that the amplifier could be AC coupled. This removes possible DC level problems caused by opamp offset or drift, and it reduces noise.

Opamp #6 is a precision half-wave inverting rectifier, which acts as a diode with a 0V forward voltage drop, and it inverts the signal. This rectifier circuit is very linear, and the gain can be set with the feedback resistor. The rectified signal then goes through a lowpass filter with a 5-second time constant. This lowpass filter acts as an integrator which stores the positive energy in the high-frequency signals. The time constant is 5 seconds because the signal is sampled every 5 seconds. When there is high signal activity, the voltage on the capacitor rises. When there are very few high-frequency signals, the voltage decays. The rise and fall times are both approximately 5 seconds. The capacitor also creates a low impedance output for the A/D converter.

Off of only one sensor axis is a 0.05-Hz-to-4-Hz bandpass filter which will detect body motion. This will be used to help correlate a person's activity level with health and electromagnetic field exposure. From past studies, it was found that most body motion is below the 2 to 3 Hz range.

Opamp #7 is used to create a 4-Hz lowpass filter, which is followed by a 0.05-Hz passive highpass filter. The 1-uF capacitor is needed to AC couple the half-wave rectifier. The rectifier is set up with a gain of 15. The energy associated with body motion is stored in the 47-uF capacitor, and is sampled every 5 seconds.

This motion sensing seemed to work very well. When the output was observed on an oscilloscope, the signal level rose when the sensor was moved, and the signal level would rise further with rapid sensor motion. The signal decayed when the sensor was motionless. The capacitor seemed to hold 0.25 V at all times, which was due to a small amount of 60-Hz noise that could not be fully filtered out.

When a person moves, one axis of the sensor measures a changing value of the earth's field. This change is sensed with the motion filter. When the sensor is waved in the air through a large angle, say 45° to 90°, as if someone bends over to pick something up, there is a large change in earth's field. Whereas, if the sensor is held horizontal and moved up and down, as if someone is walking or running, only a small change in the earth's field is observed, as fewer of the earth's field flux lines are crossed or changed. The gain will need to be set more accurately after a study on how people commonly move with respect to the earth's field.

The 200-Hz-to-10-kHz filters would not work properly. They were built and tested, and the circuit worked well with a function generator, but with opamps #1 and #2 and the sensor, there were noise problems. Better sensors are available which would require a much lower gain from opamps #1 and #2. A lower gain would help reduce the noise, and would probably give a more accurate measurement. A better sensor will be used in the next design. The rest of the filters on the filter board worked well after time was spent solving several small problems, like the 4.5V reference, and setting actual bandwidths.

CHAPTER 3

A/D AND MICROCONTROLLER BOARD

The seven outputs from the filtering board are the inputs to the A/D converters on the microcontroller board. Two 4-channel A/D converters, ADS7803, are controlled by an Intel 87C51 microcontroller. The micro-controller controls which analog channel is selected for conversion, the analog-to-digital conversion timing, and then manipulates the digital data. Most of the data are sent to the computer using the microcontrollers' serial port, and the rest are stored in the on-board HM6264 8kbyte RAM. A block diagram of the A/D and Microcontroller board is in Figure 4, and a schematic is in Figure 5.

The microcontroller is the brain of the circuit, since it controls the timing and flow of the data. Pins 1, 2, and 3 on the micro are chip select lines for the A/Ds and the RAM. The eight address/data lines on port 0 of the micro are connected to most of the chips in Figure 5. Port 0 has open drain outputs, so 22k pull-up resistors are needed to load the bus properly. There are read and write on the micro which connect to the A/Ds and the RAM.

The address/data lines, from port 0, are time multiplexed to carry an "address" and data. In a write operation, an address is sent out on the address/ data lines, then the address latch enable (ALE) sends out a pulse, then the data are put on the address/data lines, and then a write signal is sent. The ALE is used to capture the "address" in the 8-bit latch, which holds the number or "address" while the address/data lines are being used to carry the data. The latch is an 8-bit, tristate, D-type latch, number 74HC373. Read operations are very similar to write.

Originally, there were two latches in the circuit. One was for the A/D converters and one the RAM, with a chip select line from the micro controlling which latch was to be used. The problem was that when the latch is disabled, its outputs go into a high impedance state, meaning that they could not hold a set value. The micro is continuously sending out signals to reload the latch with the latest address. During read and write operations, it is actually a pulse that is skipped on the ALE line that holds the last port 0 number, or address, in the latch while port 0 is used for data. This caused problems for proper operation. The solution was to use one latch and connect chip select lines to the A/Ds and the RAM from the micro. The RAM uses all eight bits in the latch as an address, while the A/Ds use only the two lowest-order bits from the latch, and the latch is always enabled. The chip select lines determine what chip uses the data in the latch.

A/D #1 is used to sample the data from the 10-200 Hz bandpass filters, and the microcontroller controls A/D conversion timing. The micro is set up to sample the A/D #1 inputs at 514 Hz or every 2 msec, which is more than double the 200-Hz bandwidth of the signal

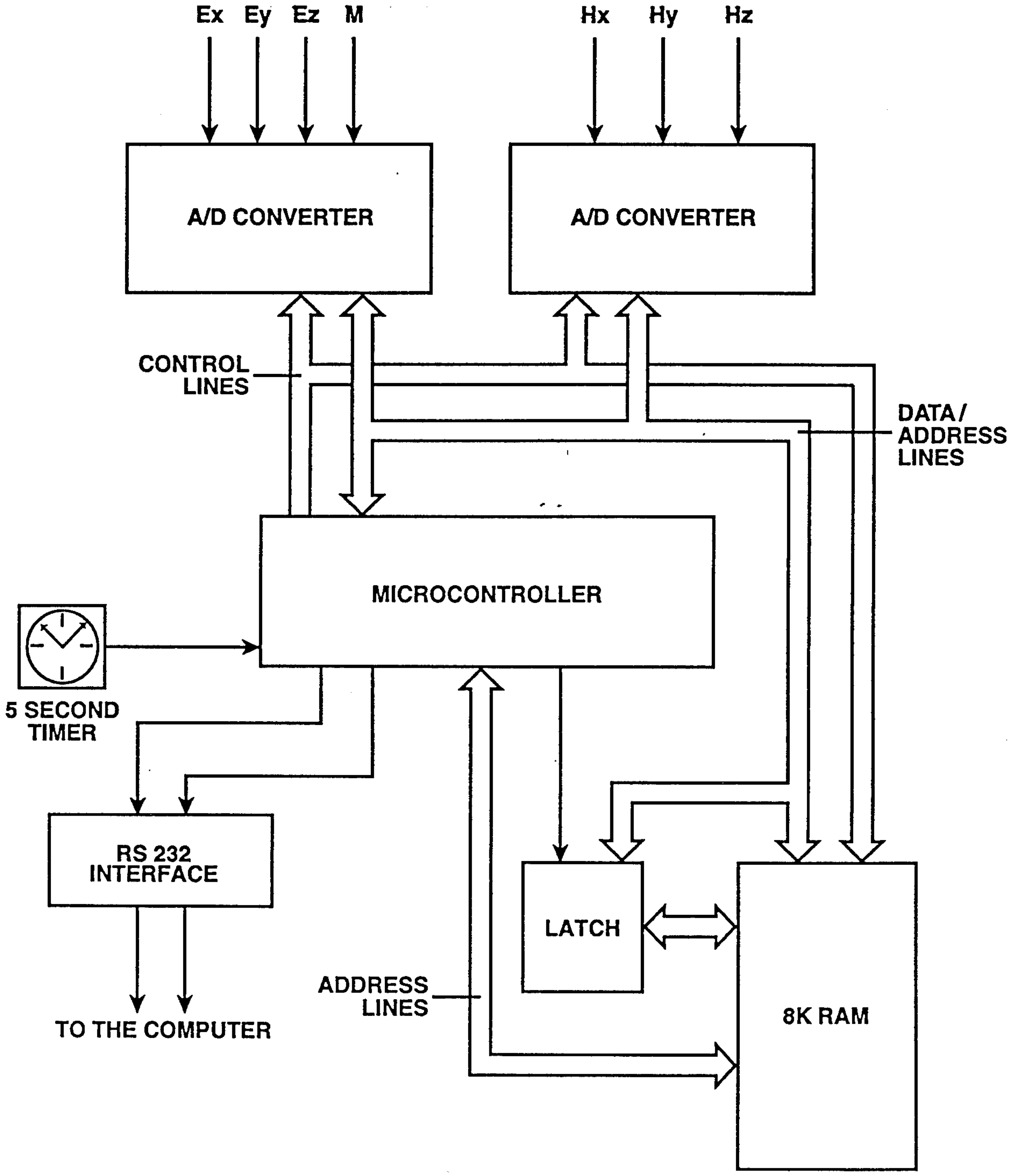


FIGURE 4. MICROCONTROLLER BOARD BLOCK DIAGRAM

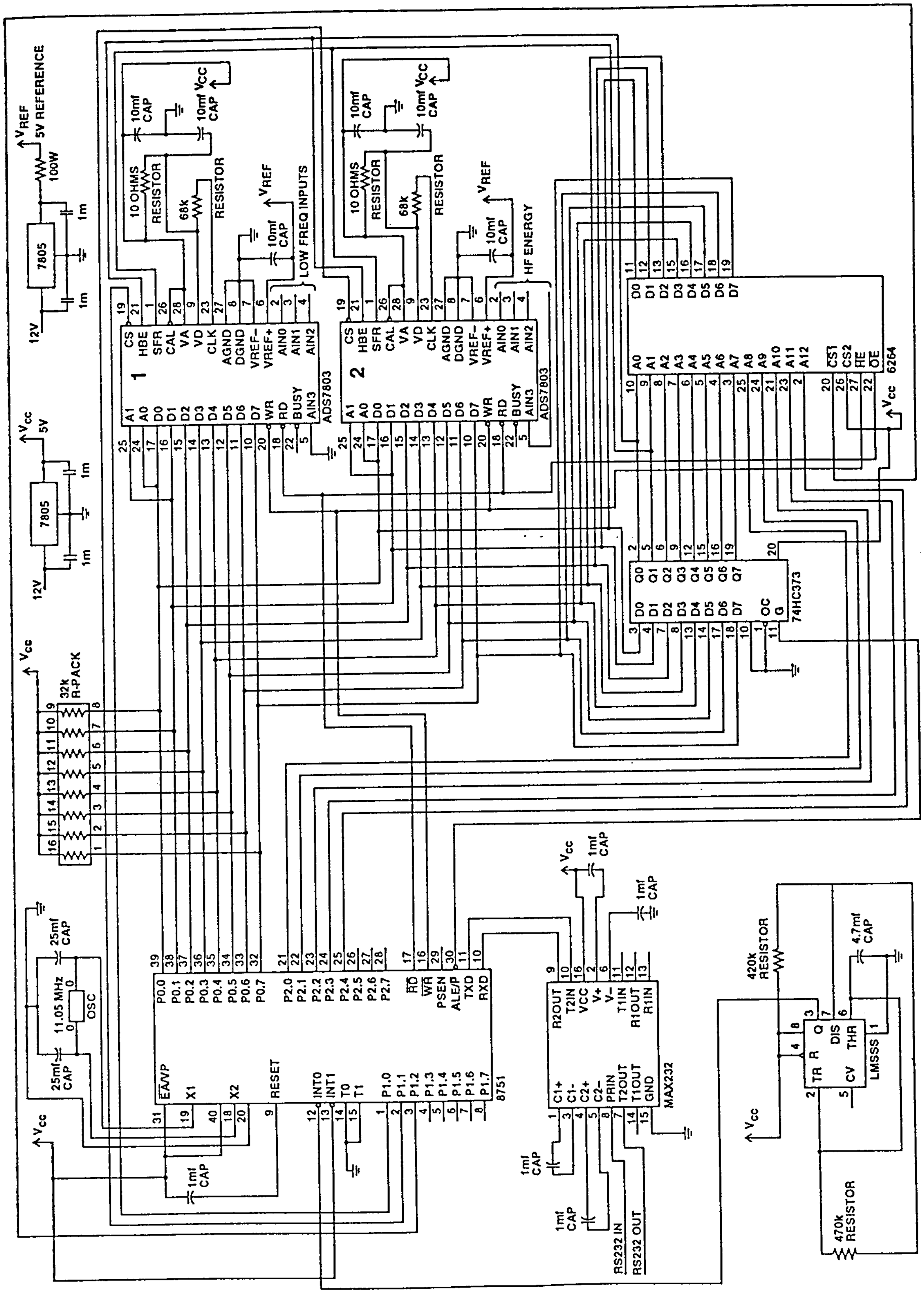


FIGURE 5. SCHEMATIC OF THE MICROCONTROLLER BOARD

being sampled. Thus, the sample rate is greater than the nyquist rate. The micro controls A/D #2 to convert the four energy signals, every 5 seconds. The A/D inputs must be between 0V and 5V for proper operation. The A/Ds are setup to run at 1 MHz, and they can perform a conversion from analog to digital in only 20 usec.

When the micro tells an A/D to start a conversion, the latch holds the "address". This address is two bits which act as two control lines for the A/D. The control lines are the high byte enable (HBE) and the special function register (SFR), and they are connected to both A/Ds. The chip select lines determine which A/D listens to the microcontroller. While the control lines are held in the latch, a data byte which contains the two bits needed to select which A/D input to convert, (pins 24 and 25 on the A/D), is sent from the micro to the A/D. The A/D conversion produces a 12-bit number which must be read into the micro with two 8-bit read operations. The latch holds the value applied to the HBE pin of the A/D while data are read from the chip into the micro.

The microcontroller samples the three A/D #1 inputs every time an internal timer, set up for 514 Hz, overflows. These three inputs become 12 bit digital numbers which are read into the micro. They are squared, added together, and scaled by a factor of one-half to result in at most a 24-bit number. This number is then sent to the computer, which will take the square root of this number; thus, the scaled magnitude of the three-axis sensor signal is obtained. After 1024 samples are sent to the computer, a process that takes approximately 2 seconds, the computer performs a fast fourier transform (FFT) on the magnitude data.

An external 5-second clock is connected to a microcontroller external interrupt pin. When a falling edge from the clock is observed, the microcontroller samples the four inputs from A/D #2. The first three inputs, which are high-frequency energy data, are added together and the resulting 12- or 13-bit number is stored in the RAM as two 8-bit numbers. The fourth A/D input, the motion sensor input, is sampled and sent directly to the RAM as a 12-bit number.

The RAM is an 8 kbyte x 8-bit device which uses 13 address lines and 8 data lines. The lowest 8 address lines for the RAM are held in the latch while the address/data lines are used to carry the data for the RAM. The highest 5 address lines are selected through port 2 of the micro. The output enable of the RAM must be connected to the read line for proper operation, or else there will be data problems.

The MAX 232 chip is a serial interface between the microcontroller and the computers serial port. The microcontroller uses 0-5V TTL voltages, while the computer requires +/- 10V RS-232 voltages. The interface performs the voltage conversions for both the transmit and receive lines, and it is the driver for the transmit line to the computer's serial port.

At the end of the measurement period, a byte is sent from the computer to the micro. When this byte is received by the micro, the micro stops taking samples, and sends the data that are in the RAM to the computer via the serial port. After all the data are sent, the microcontroller shuts itself off.

The microcontroller runs off of an 11.0592-MHz crystal, which allows a baud rate of 19.2 kbaud to be set up on its serial port. Each instruction in the program takes only 1 or 2 usec with this crystal.

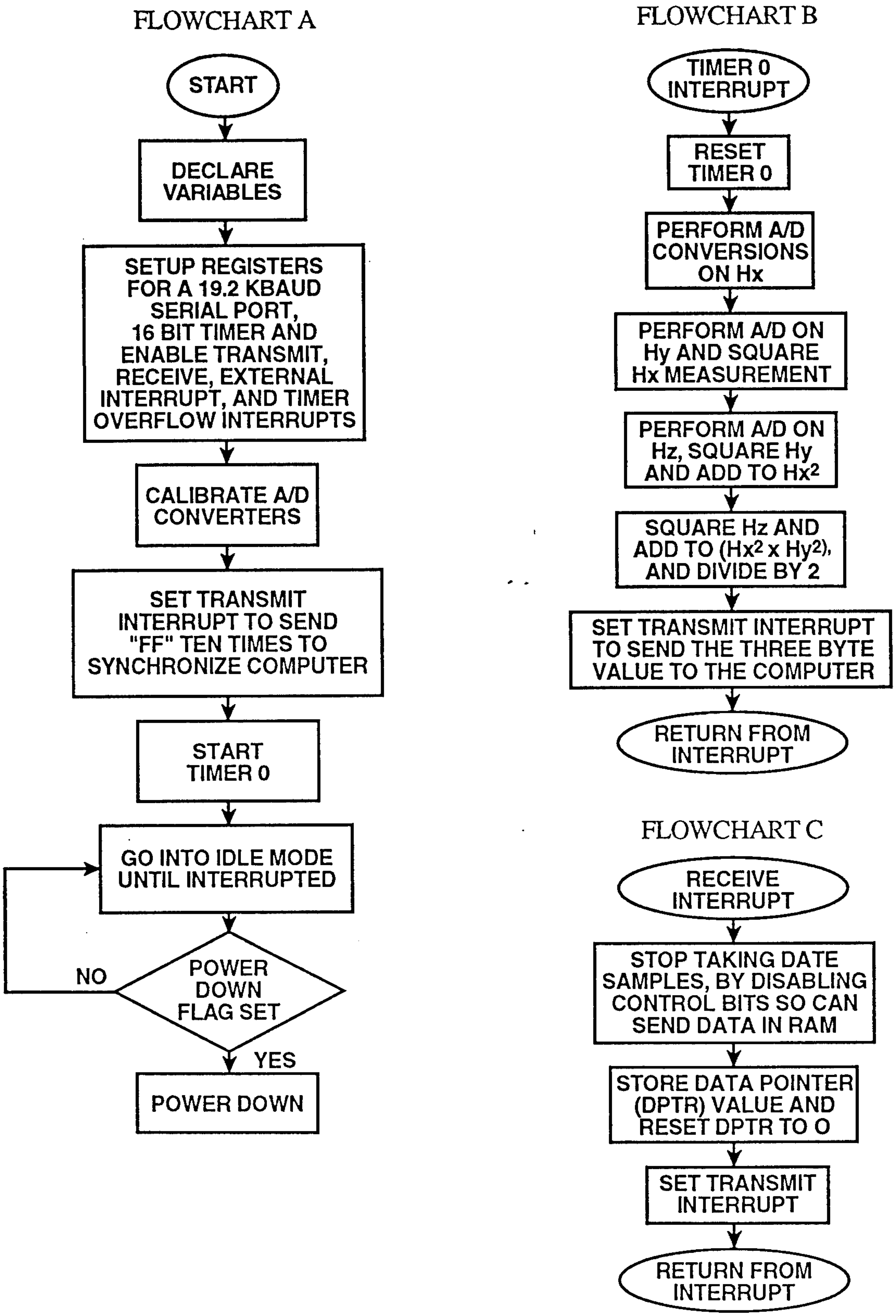
The flowchart for the program that was run in the microcontroller is in Figure 6. Flowchart A of Figure 6 is the main part of the program, and there are four interrupt service routines. Flowchart A initializes the microcontroller and the A/D converters, and then sits in an idle mode until an interrupt is received. At that the interrupt service routine is executed, and then the microcontroller goes back into the idle mode.

There are two timers in the microcontroller. One controls the baud rate for the serial port, and the other is to control A/D timing. When the A/D timer, timer 0, overflows, the timer 0 interrupt service routine (Flowchart B) is executed, which samples the three inputs from the 60-hertz range. The 5-second external clock is connected to external interrupt 0. When the 5-second clock sets the interrupt, the microcontroller samples the four energy inputs, E and M inputs (Flowchart E).

The transmit interrupt routine (Flowchart D) controls the flow of data from the microcontroller to the computer. When the signal is sent from the computer to signal the microcontroller to dump the data in RAM, the receive interrupt routine (Flowchart C) is triggered, and the data transfer takes place.

An in-circuit emulator was used to test the program for the microcontroller. This emulator, which is run by a computer, is plugged into the 40-pin socket that the microcontroller would normally be plugged into. The program and circuit can be tested as one, and the flow and steps of the program can be viewed on the computer as the program is run. The emulator works exactly as the microcontroller chip would, but the registers can be observed, and the program can be thoroughly tested as it operates on internal data and on external components like the A/D and RAM.

The next design of the dosimeter will be to make it totally portable. This means that the dosimeter will have to process and store all the data. The FFT will have to be performed on board the portable unit, primarily to reduce the amount of data that must be stored in RAM. A different microcontroller will be needed , or a digital signal processing chip may be used. Only the 60-Hz, 120-Hz and 180-Hz components of the FFT will be stored in RAM, as these are the largest and most prevalent signals.


FLOWCHART A

FLOWCHART B

FLOWCHART C

FIGURE 6. FLOWCHART FOR THE MICROCONTROLLER PROGRAM

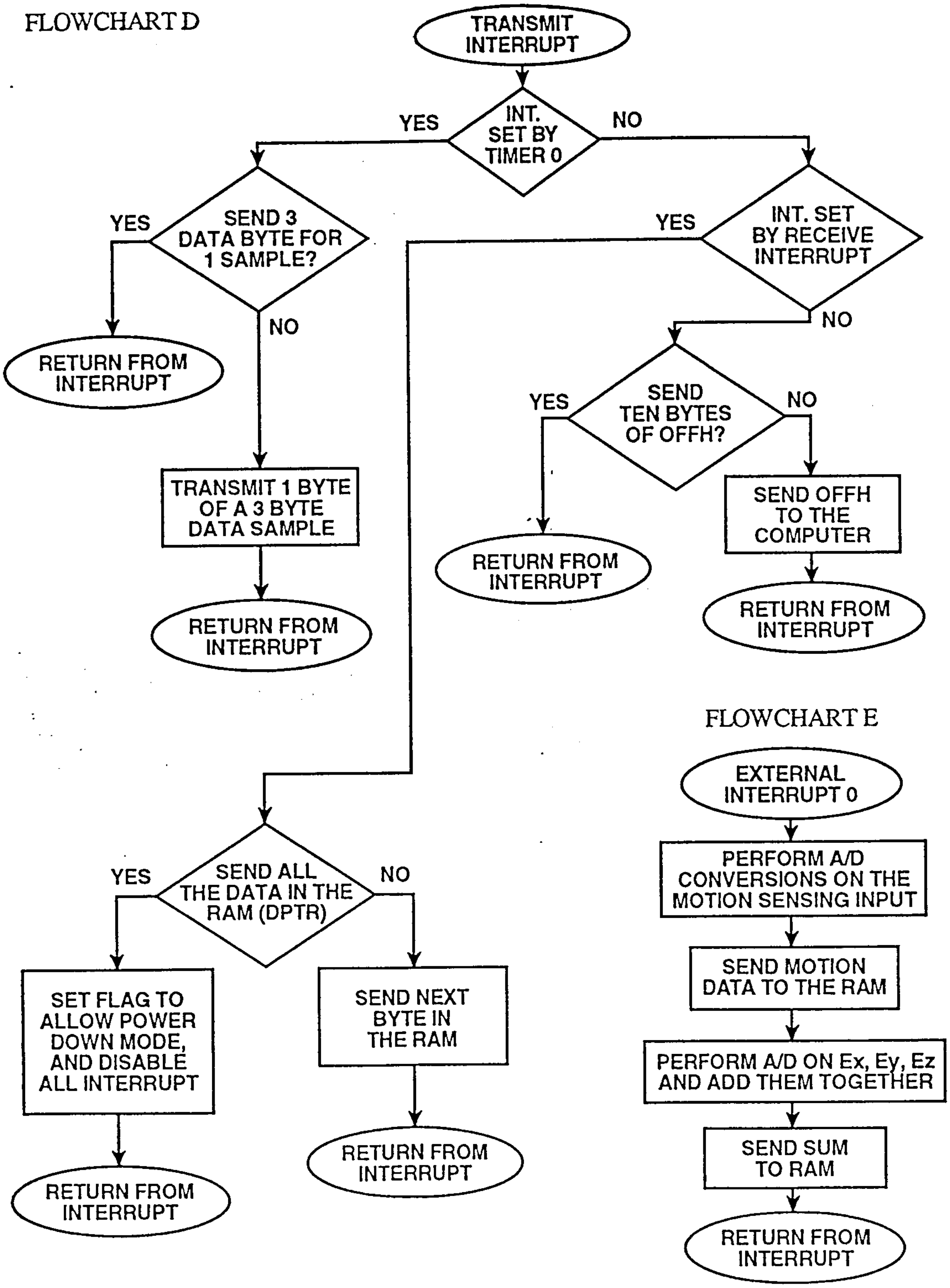


FIGURE 6. FLOWCHART FOR THE MICROCONTROLLER PROGRAM (CONTINUED)

CHAPTER 4

DATA COLLECTION AND ANALYSIS

For the data collection and analysis portion of the project, a 386DX personal computer is used. The computer is interfaced with the microcontroller board via a serial commport. A software package called LabWindows is used to control the data flow on the serial port, and is used to create the graphs. The actual data collection and analysis program is written in Microsoft C, which is then linked to LabWindows.

A flowchart of the data collection program is shown in Figure 7. The first task of the program is to control data collection and storage. The information which is sent from the microcontroller is stored in a buffer in the computer. Once 1024 samples are received from the microcontroller, the computer takes a square root of each number and stores the numbers in an array. Then a fast fourier transform (FFT) is performed on the 1024-number array. The result of the FFT is an array which contains the magnitude of the major frequency components that were measured with the sensor.

A FFT returns both the positive and negative frequency components, but the negative components are ignored, and a 512-number array with the positive frequency components remains. This frequency array is then used to make a magnitude versus frequency plot. The microcontroller sampling rate is 514 Hz, so the nyquist frequency, or the highest frequency that can be analyzed in the FFT, is 257 Hz. Thus, the frequency range of the horizontal axis is 0 Hz to 257 Hz. Due to the fact that there was no equipment available to calibrate the sensors, the scale used on the magnitude axis did not represent a particular unit of measurement. Rather, a scale was implemented to help show the relative strengths of the frequency components measured. When the unit is calibrated, a simple scaling factor can be used to make the magnitude axis equivalent to a particular unit of measurement.

After plotting the frequency information for a data set of 1024 samples, the program then jumps back and retrieves another 1024 samples and repeats the process over again. The program can be easily modified to store the data in memory for analysis at a later time, and the data can be plotted in a variety of formats.

Figures 8 and 9 are two experimental plots that show the magnitude of the frequency components emitted by both a hair dryer and a television receiver. These measurements were taken approximately one foot away from each device while the devices were in operation. As can be seen from the plots, each device emitted a large 60 Hz electromagnetic field as well as slightly smaller harmonics.

After analyzing sets of data samples for a period of time, the computer sends an interrupt to the microcontroller board via the serial port. This interrupt signals the microcontroller to download its energy information which is stored in RAM. Once this information is sent to the computer, the information is then plotted on a body-motion-*vs.*-time plot. At this point, the program terminates and the test is over. As with the frequency plot, the scale used for the magnitude of body motion does not correspond to a particular unit of measure. Rather, it is a scale devised to show relative variation between limited physical activity and aggressive physical activity. Through experimentation, a standard could be set to relate a particular value on the scale with a relative level of physical activity. These data could be easily stored in computer memory as well.

Figure 10 is an example of a relative body motion plot. This plot was obtained through experimentation for demonstration purposes, not from actual body motion. The high peaks in this plot relate to a high level of sensor motion or physical activity, while the lower values relate to a low level of activity.

As was mentioned earlier, the high-frequency energy filters do not work properly, so these data were not stored in RAM. In the next design, this will be corrected.

It is important to note that the data collection program devised for this project centered around demonstration purposes. The way in which the data were collected by the computer and immediately plotted was done so that the unit could be demonstrated easily, with immediate results as part of a senior project presentation.

In a more practical program, the important frequency component information, i.e., 60, 120, and 180 Hz, obtained from the FFT would be stored in a file to be accessed and analyzed at a later time. This type of data collection would better represent the actual storage techniques to be used with the device when it is developed as a self contained unit. The energy data would also be stored in a file. The data collection and display program is easy to modify, and could be changed to meet a person's needs.

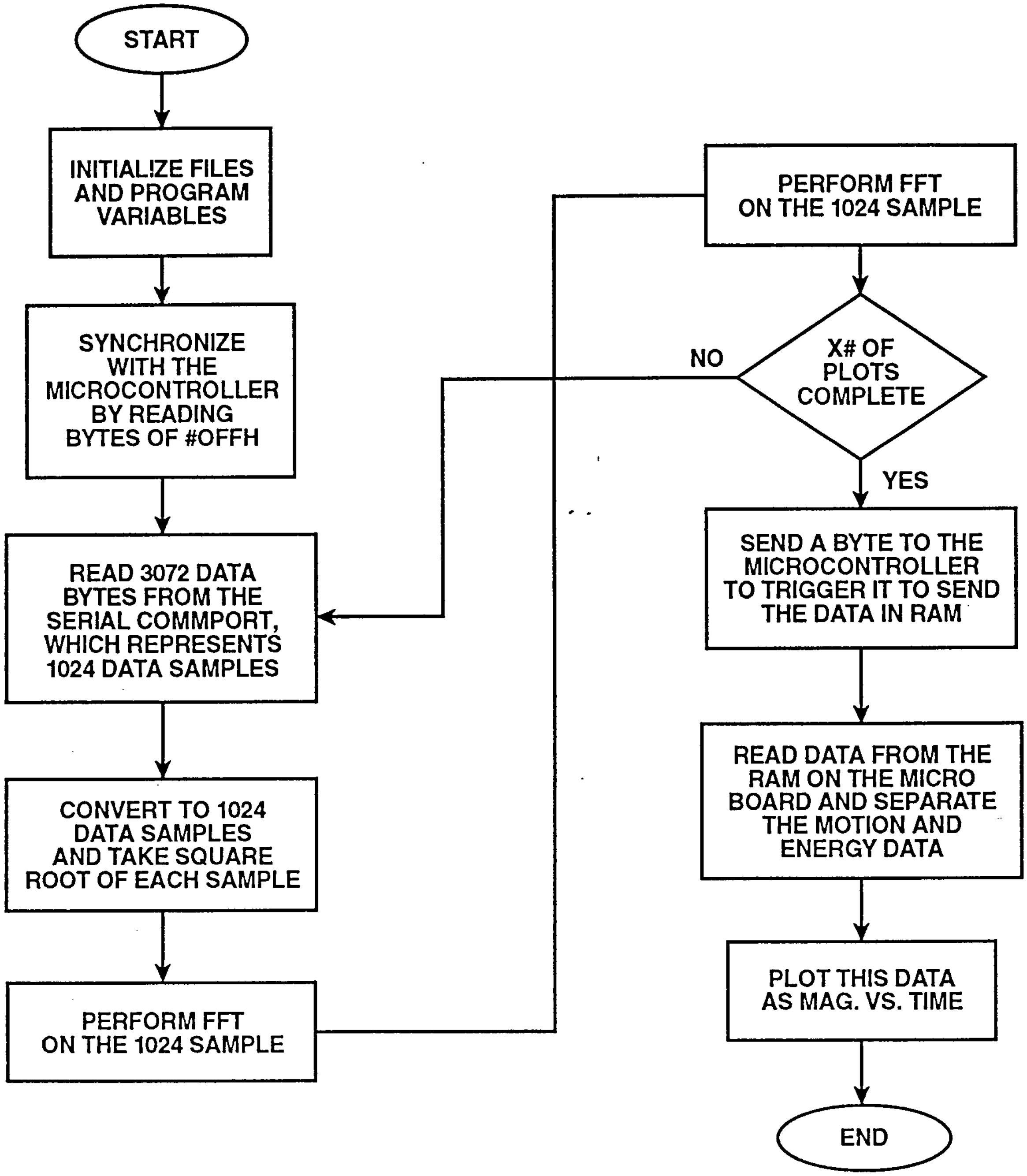


FIGURE 7. FLOWCHART FOR THE COMPUTER PROGRAM

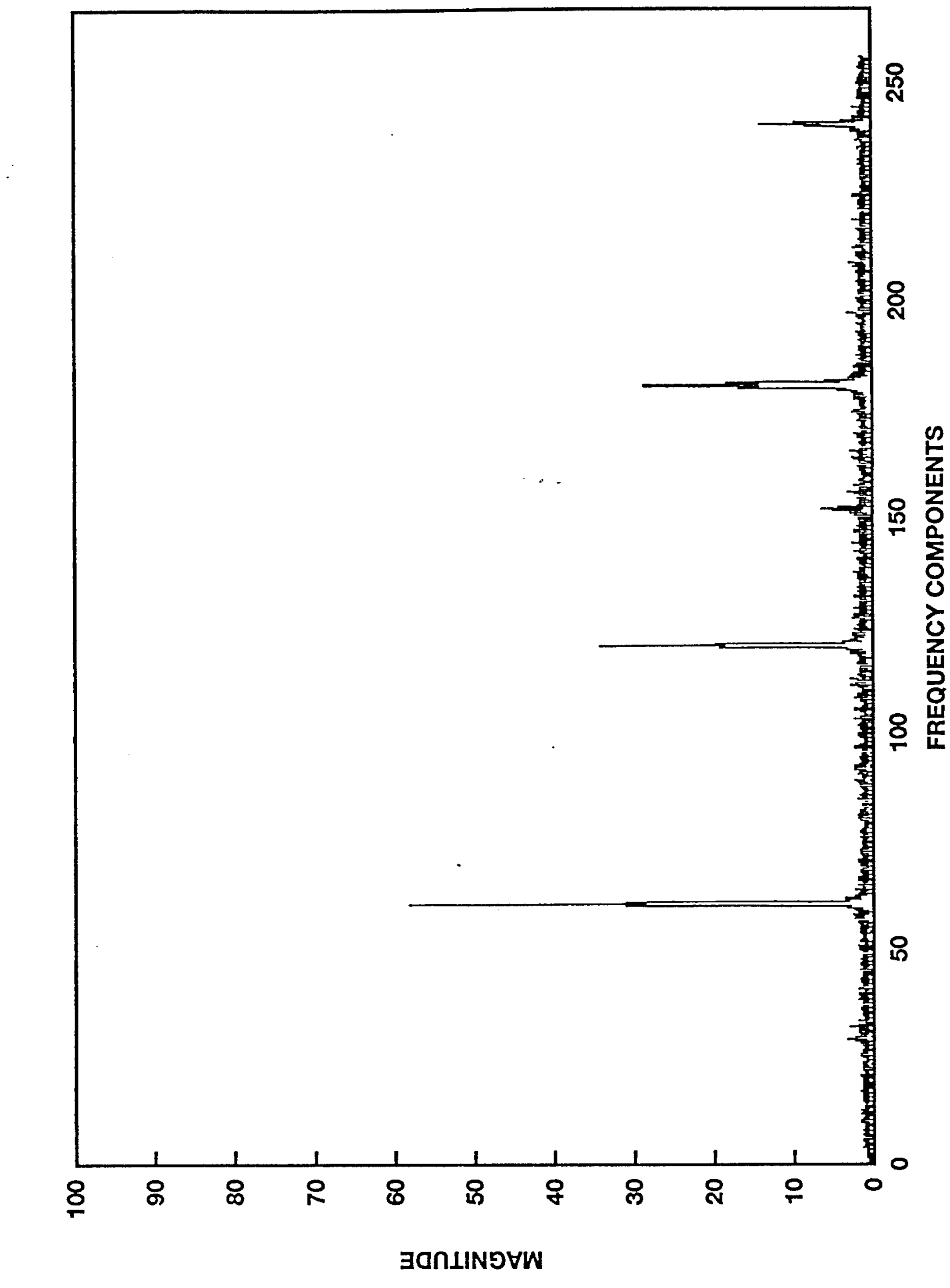


FIGURE 8. HAIR DRYER EXPOSURE AT 1 FT.

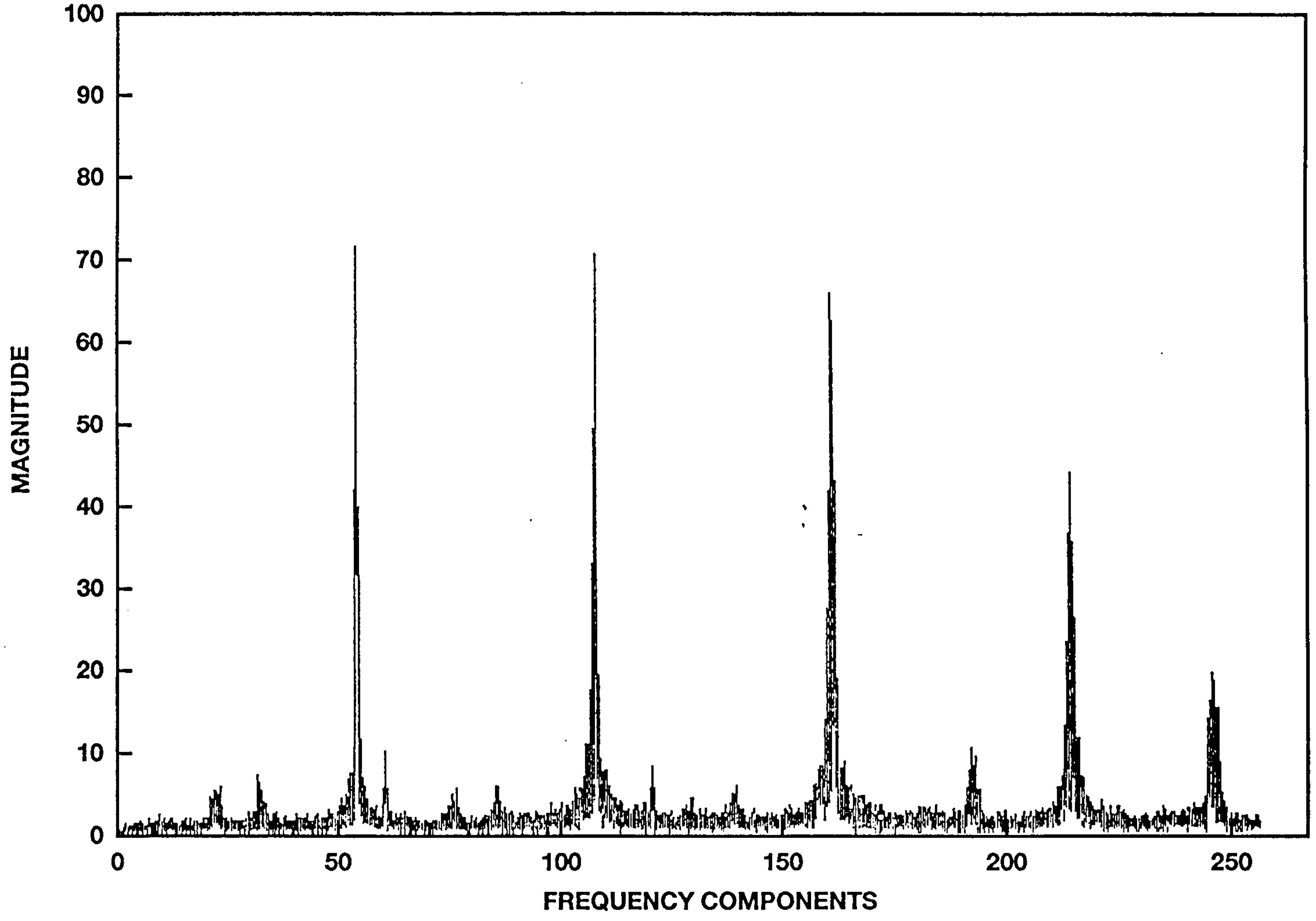


FIGURE 9. TV EXPOSURE AT 1 FT.

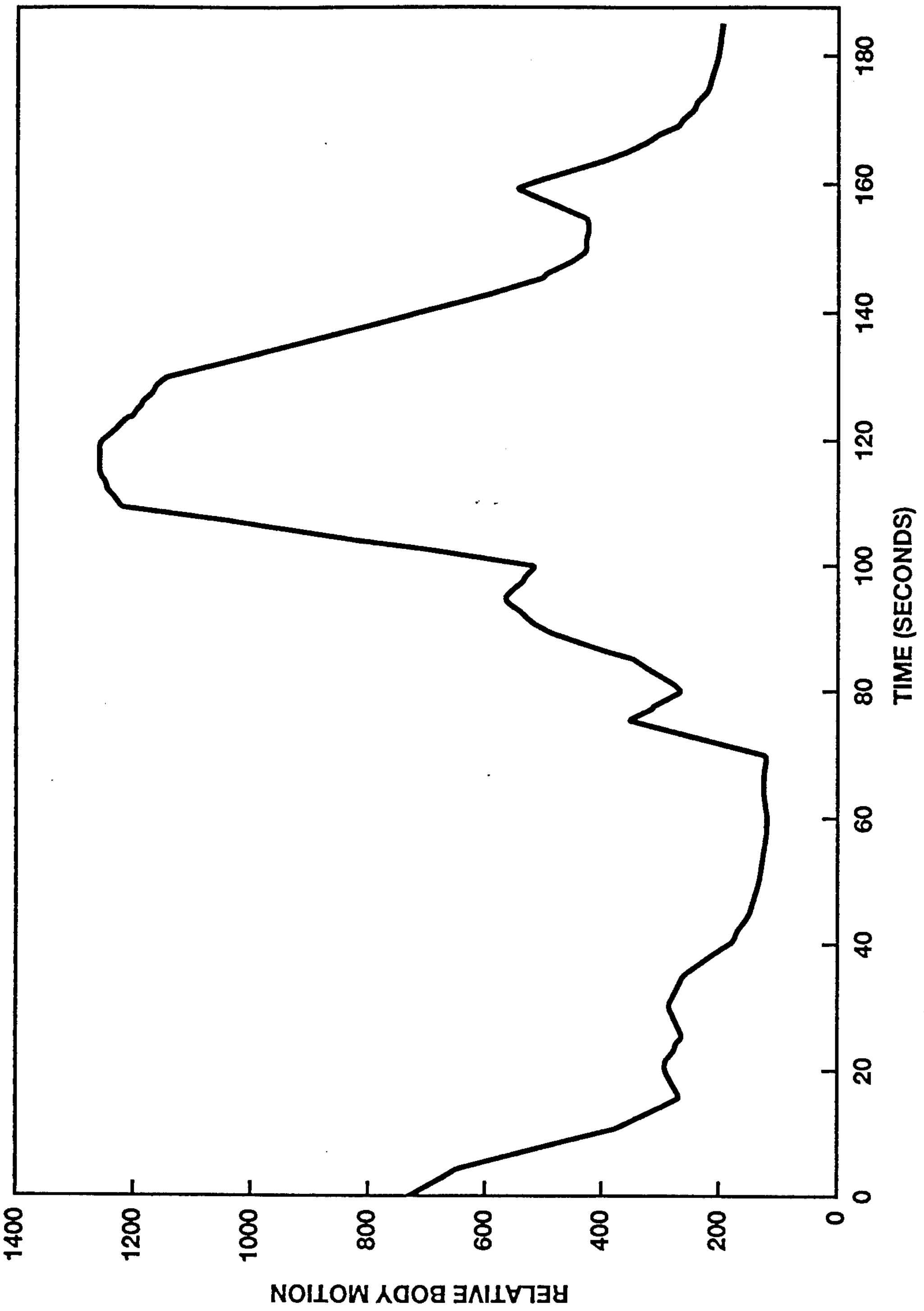


FIGURE 10. ACTIVITY LEVEL

CHAPTER 5

CONCLUSION

Everything except the high-frequency bandwidth filters worked properly, and they probably need only some fine tuning to become operative. Because this is proof-of-concept design, there is more work to be done before the unit is marketable. At present, the dosimeter unit must be connected to the computer at all times. In the final design, the dosimeter will be a small, portable unit that could be carried anywhere, taking measurements continuously as the person goes about normal business, with the data measurements being stored on RAM.

To be a stand alone unit, not connected to the computer, extra memory space would need to be added to the dosimeter, and the FFT would have to be performed inside the unit. Adding memory would be a simple modification; thus, the only major design change would be to perform the FFT on board rather than in the computer. All of the individual samples from the 60-Hz range could be stored in memory, but this would require a very large RAM. The FFT must be performed on the 60-Hz data on board the unit to reduce the amount of information that must be stored in RAM. The FFT data are all one is interested in anyhow, not the actual samples. There are IC chips on the market that can perform a FFT, which would be added to the microcontroller board.

The unit would be a stand-alone unit at this point, and all the data in the RAM could be retrieved at the end of the measurement period with a computer. The measurement period could range from a couple of hours to several days. The computer would simply need to display the data, and store the information for future reference.

The unit could be used in a variety of ways. It has been described as a unit to be worn by a person, but it could also be put on an animal or on a piece of equipment. Farmers may be interested in how high-voltage overhead power lines in a field affect a dairy cow's milk production. The dosimeter would be perfect for this application. The only changes would be how the unit is carried. Nothing electrical would need to be changed. The dosimeter could mounted on a piece of equipment, just to take electromagnetic field measurements in an area, and the unit would not need modification for this application either. Many individuals may want to use the dosimeter for personal use at home or work to find or solve electromagnetic radiation problems, rather than using it in conjunction with a health researcher. The dosimeter could be easily modified to take other sorts of measurements, such as radon exposure or noise hazards.

A patent application was submitted for the Electromagnetic Field Exposure Dosimeter in January 1993. It is Navy Case Number 75176.

CHAPTER 6

RECOMMENDATIONS

There are several possibilities for the next design of the dosimeter to make it a portable unit. The first way would be to make the previously mentioned changes to the present design. This involves trying to add FFT capability to the present design and adding more memory. The problem is that the present unit is fairly large, being 8-inches x 5-inches x 2-inches, room is needed for batteries, and the parts count is relatively high. The unit could easily be built smaller with multilayer PC boards and surface mount IC chips. This would make a manageable unit but not ideal.

A second possibility would be to use a better microcontroller, which has built-in A/D converters, and could perform a FFT. The filtering circuit would not change much from the above design, but the microcontroller board would be much simpler.

The third possibility would be to attempt to use a digital signal processing (DSP) chip. This chip would be capable of performing most of the filtering and could perform the FFT. It would still require a few peripheral chips, like an A/D converter, preamplifier, and simple filtering, and it would still require random access memory. The unit would probably require less power; thus, smaller batteries could be used. It is very likely that a DSP chip would help to reduce the size of the unit. The feasibility of the DSP chip needs to be investigated.

The previously mentioned changes will be implemented in the near future. The computer data processing and display format can be modified easily to suit a person's needs. After a prolonged period of measurements with a wide variety of people, and observing their health, it is hoped that a correlation could be obtained relating the amount of exposure to electromagnetic radiation with a person's health.

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13. ABSTRACT *(Maximum 200 words)*

The growing concern about adverse health effects caused by electromagnetic radiation prompted the ideas for this dosimeter. Data have been presented that link prolonged exposure to electromagnetic radiation from power lines to leukemia and some types of cancer. At present, though, there is a lack of recording instrumentation to measure the prolonged exposure of an individual; thus, it is not possible to correlate properly the amount of exposure or dose to health effects. With the recent advances in small, low-power devices, a small measuring device can be developed. Once this is built, a large data base can be obtained to help correlate electromagnetic field exposure to health conditions.

The objective of this project is to develop an instrument which can measure electromagnetic fields over a prolonged period of time. The instrument would be small, say about the size of a radio Walkman, and would be worn throughout the day while taking data, as the individual goes about normal activities. A PC would be used to retrieve the data from the instrument at the end of the day.

The dosimeter comprises a triaxial ferrite-loaded coil sensor, a set of amplifiers and filters, analog-to-digital converters, a microcontroller, and random access data memory. The signals from the sensor are filtered into three frequency ranges: one to measure 60-Hz exposure and two harmonics, another to measure high-energy pulsed energy, and a third frequency range to record the activity level of the individual. The signals from the filters are digitized and read into a microcontroller. The microcontroller performs a few calculations and controls the flow of the data to either random access memory or to a computer. A computer is used to retrieve the data from the dosimeter, and can store and display the measured data.

14. SUBJECT TERMS

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