REPORT

FINAL REPORT

Evaluation of an Electronics System Concept for Respiratory Protection System (RESPO 21)

To

U.S. Army Chemical Research, Development, and Engineering Center

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FINAL REPORT

TASK 266

EVALUATION OF AN ELECTRONICS SYSTEM CONCEPT FOR RESPIRATORY PROTECTION SYSTEM (RESPO 21)

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INTRODUCTION

The primary objective of this project was to develop a preferred electronics system concept for the RESPO-21 mask. This system concept was assembled and integrated with a lightweight mask for demonstration purposes. The demonstration unit was delivered to CRDEC separately. A secondary task objective was to identify component and subsystem enhancements necessary for the final fielded RESPO-21 system.

The electronics system evaluation focused on three areas: communications assist, blower control, and power source. This report summarizes the technical approach and results obtained for each subsystem. An appendix to this report contains a detailed technical discussion and manufacturers' data sheets for selected components of the communications assist, blower, and power supply subsystems.

DEMONSTRATION SYSTEM DEVELOPMENT

This section of the report discusses the design, testing and evaluation of the individual subsystems comprising the demonstration system. The development begins with the establishment of the design requirements. Following establishment of design goals specific activities included: subsystem design analysis, component evaluation, subsystem design, fabrication and testing.

Communications Assist Subsystem

The communications assist subsystem consists of a microphone, preamp, filter, volume control circuit, radio interface, power amplifier, low battery warning circuit and an output speaker. This subsystem is modular in design and construction. This section addresses the design objectives, tradeoffs associated with alternative implementations, and the final implementation.

Design Requirements

The requirements for the communications assist subsystem are:

- Improve voice communications to 90% intelligibility
- Have a volume adjust control
- Modular design

- Low power consumption
- Small package size.

Design Analysis and Component Evaluation

The basic design for the communications assist subsystem consists of a microphone, an amplifier, noise reduction filtering and an output speaker. A number of commercially-available components were evaluated for this application. This section identifies the components and specific tests performed.

MICROPHONES. The microphone is a key element in the communication assist subsystem. Audio quality, size, noise reduction and interface with the wearer are all key evaluation criteria. Audio quality is subjective and not easily determined using standard analytical measures; therefore, our approach to the microphone evaluation was to conduct listener tests using the microphones in a mask with standard test words. Conductive and acoustic type microphones were evaluated to identify the appropriate technology and to choose the specific candidate components.

Conductive Microphones. The evaluation of conduction-type (bone, throat, ear) microphones shows that, although they do exhibit some noise canceling features, there are several inherent drawbacks with these technologies. Laboratory testing demonstrated that conductive microphones are position sensitive. This is a major drawback for this application. To minimize motion, the microphones are typically held tightly to the wearer by elastic straps. This results in a microphone that is somewhat uncomfortable for the wearer. For example, the THR-3 throat microphone is connected to a ring which fits snugly around the neck and holds the electret element firmly between the throat and large neck muscle. This setup is uncomfortable and could make it difficult to put the mask on. A similar situation exists for bone conduction and ear microphones. Tests show that conduction microphones pick up mechanical vibrations when used in tanks and trucks. Another drawback, especially for the throat and bone conduction microphones, is their large size.

Acoustic Microphones. Several miniaturized acoustic microphones show good potential for this application. These microphones come in bidirectional and omnidirectional versions. One inherent advantage of this type of microphone is its small size. Furthermore, these microphones do not require precise positioning by the user. Many of the acoustic microphones also have built-in noise cancellation through bidirectional inputs. Several of the omnidirectional microphones demonstrated good noise reduction capability in our tests. Tests show that several of the microphones exhibit good voice pickup even when used inside the face mask. Unlike the case of unaided speech using a face mask, electronically-assisted voice is not muffled when the small microphones are used inside the mask. Preliminary tests showed the potential for high intelligibility with some simple bandpass filtering.

Sound quality tests were performed for thirteen of the microphones to aid in the selection. For this test each microphone was temporarily mounted into the face mask with its output connected an amplifier and tape recorder. A representative blower was connected to the air intakes of the mask. The microphone output was recorded as the alphabet codewords (alpha, bravo, charlie, etc.) were spoken. For comparison purposes the tests were performed with and without the blower running. Parameters evaluated included susceptibility to mechanical noise generation, intelligibility, and dynamic range.

Several microphones were eliminated from consideration because of limited frequency response, excessive sensitivity to mechanical noise generation such as vibration or rubbing against the users face, high sensitivity to air flow across the microphone, or excessive size. Preliminary results showed that microphones #4 (Tibbetts Model 85 Omnidirectional Magnetic Microphone), #8 (Gentex Model 3063 Noise-Canceling Electret Microphone), and #11 (Electro-Voice Model M116/AIC Electret Mask Microphone) performed better than the other microphones in the test.

Further tests were performed to narrow the microphone choice. Repeated testing showed that the Tibbetts Model 85 microphone has a limited dynamic range. Although this microphone is small, further comparisons to the other two microphones revealed that it did not yield a clear response. The Gentex Model 3063 electret microphone sounded very clear with a good frequency response over the voice band. It is a very small microphone and has the advantage of being rugged for a miniature microphone. This microphones's only apparent drawback was its sensitivity to bursts of air such as those from the mouth and the airflow within the mask. Placing a windscreen over this microphone solved these problems. In addition to listener tests, several microphone electrical parameters were measured, including: impedance, frequency response analysis, output level and internal preamp evaluation.

The Electro-Voice Model M116/AIC microphone sounds very good and does not exhibit sensitivity to air flow. However, this microphone is too large for installation in the mask and was eliminated as a candidate.

AMPLIFIER. Commercially available voice projection units were purchased and analyzed to obtain some insight into potential design approaches for the RESPO-21 system amplifier. Evaluation of these units helped to determine appropriate output levels, filtering schemes, and power consumption.

One product evaluated was the Earmark Loudmouth II. Its measured current drain is:

- Standby 17mA
- Normal Speech 26mA
- Loud Scratching on Microphone 300mA
- Feedback 450mA

This test data provided a baseline for the communications subsystem power consumption. It was later determined that this data may be lower than actual because of the meter's inability to measure power spikes. A more detailed analysis was performed to determine the peak and average power levels necessary for the communications assist subsystem. The Earmark Loudmouth unit was used with a high volume setting while the output voltage across the speaker was monitored. This evaluation showed that a very loud voice output contained peaks of $\pm$ 6V. This peak voltage was used as an initial guideline for the amplifier circuit design.

To determine battery consumption and output speaker requirements, an average power consumption analysis was performed. The Loudmouth speaker voltage was monitored with an RMS voltage meter interfaced to a data acquisition computer. The input to the Loudmouth was a man's voice reading a newspaper article at a rapid pace for two minute intervals. The computer was sampling at a rate of 100 Hertz during these intervals. The resultant data file was computer averaged yielding results of 0.58 volts RMS for a medium volume setting and 1.07 volts RMS for the maximum volume setting of the Loudmouth.

FILTERING. From the preliminary experiments we determined that simple bandpass filtering would enable the amplifier to achieve high communications intelligibility. Using a breadboard communications circuit, tests were performed with a representative mask and blower to determine the characteristics of the blower's audible noise. Note that airflow noise in this test is different from that filtered by the microphone windscreen. The blower airflow noise is generated throughout the air path from the filter to the mask and reaches the microphone as audible noise which cannot be filtered by the windscreen.

A spectrum analyzer measured the blower output noise frequency content and magnitude. The tests showed that the blower noise has several distinct spectral peaks. One peak occurs at 260 Hz. A second, weaker peak, occurs at 2 kHz. Further analysis showed that much of this noise was generated by airflow turbulence in the corrugated tubing leading to the mask. The use of tubing with a smooth inner surface may reduce the airflow noise such that no additional electronic filtering is necessary. Designing fixed bandwidth filters to remove airflow noise under all operational conditions is not possible since the spectral peaks are a function of blower supply voltage, airflow resistance, and airflow turbulence. Elimination of airflow noise by electronic filtering would require a filter able to track and eliminate the airflow noise as it varies with time.

SPEAKER. The speaker selection process involved a variety of tests and evaluations. Initial estimates identified the speaker range as 40 to 70 mm diameter, 5 to 20 mm thick. In this size range, there are three magnet types available: AlNiCo, ferrite, and cobalt. The speakers are available with various types of cones including stainless steel, mylar, paper, and silicon impregnated (waterproof). All have maximum output power ratings in the range 0.1 to 0.8 watts and impedances ranging from 8 to 600 ohms. Specific parameters of interest for this application are: diameter, thickness, impedance, resonant frequency, sensitivity, maximum power input, weight, and frequency range. The objective of the selection process was to identify candidates that are small and thin but still possess wide frequency response and output power capability.

The selection process focused on commercially available speakers for two reasons: a custom speaker design was beyond the scope of this project and information obtained from the commercial speakers could be used to specify a mil-qualified speaker in the future. Samples of 22 different speakers of different size and shape were obtained for test and evaluation. The test speakers size ranged from 3.5 inches to 1.58 inches, and from flat to those with a protruding magnet.

For our initial screening, a test tape was made of the phonetic alphabet and the numbers 0 to 10, 20, 30, 40, 50, 60, 70, 80, 90, and 100 using the configuration shown below.

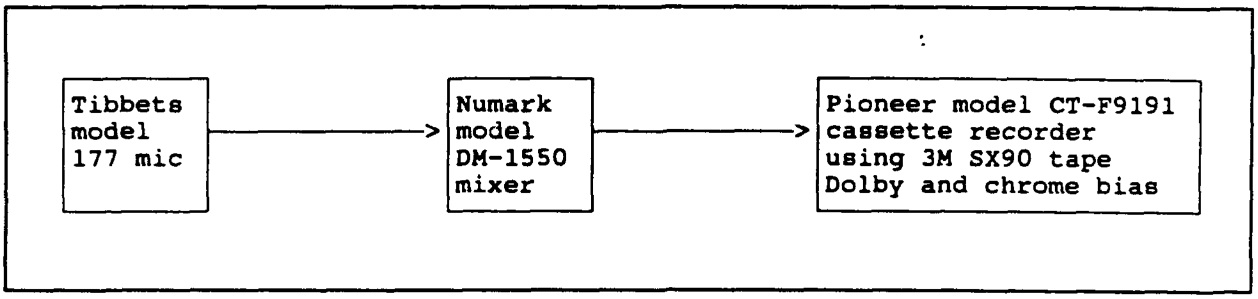


Figure 1. Configuration for the Test Tape of Phonetic Alphabet

The test tape was played back, using the configuration shown below, through each test speaker while the speaker outputs were recorded. The distance between the speaker under test and the recording microphone was one foot. Each speaker was mounted in a 2.3" by 4.5" by 3.7" unvented aluminum enclosure. All equipment settings remained fixed. The results of this subjective test caused six of the speakers to be rejected due to poor audio quality, speaker cone vibration, and/or low output volume.

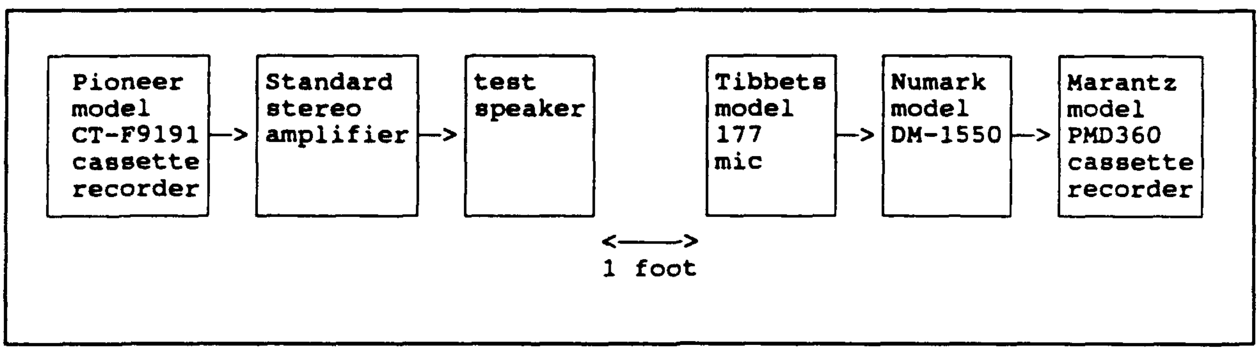


Figure 2. Configuration for the Speaker Evaluation

To find ways of making the speakers chemical agent resistive, another experiment was performed using a chemical agent barrier to protect the speaker. Two types of chemical agent resistive barriers were tested: one mil stainless steel and two mil Teflon. The unvented enclosures from the test tape evaluation were used to hold the test barriers and speakers. These tests indicated that the barriers produce unacceptable vibration noise and attenuated audio transmission. Further investigation into the potential use of such barrier materials was abandoned.

In order to evaluate the acoustical and electrical characteristics of the candidate speakers, two different acoustical tests were conducted. The first test was to determine the audio output of the speakers at 1000 Hz with a 0.5 watts input. The results of these tests were used to determine the efficiency of the speakers and the potential battery usage of the voice amplification system. The second test was to determine the speakers' frequency response in the 200 to 5000 Hz range. This frequency range covers the range of the human voice.

All tests were conducted in Battelle's anechoic chamber. The anechoic chamber provides an acoustical environment in which there are no reflected sound waves. Figure 3 is a schematic showing the equipment used for these tests. The frequency response of the speakers was measured in one-third octave bands from 200 to 5000 Hz. The distance between the test speaker and microphone was one meter. The total microphone system was calibrated with an acoustical calibrator before and after these tests.

For the audio output tests a pure tone of 1000 Hz was fed to the speaker under test. The output voltage of the power amplifier was monitored and kept at 2.00 volts. With the nominal impedance of the speakers at 8 ohms, the power delivered to the speakers was 0.5 watts. The audio output of the speaker was measured using the FFT analyzer which read the one-third octave band sound level at 1000 Hz. Table 1 is a list of the speakers and their measured output. The following is a list of the equipment used to perform theses tests:

- Bruel and Kjaer Type 4165 0.5 inch microphone
- Bruel and Kjaer Type 2619 microphone preamplifier
- Bruel and Kjaer Type 2807 microphone power supply
- Spectral Dynamics SD385 FFT analyzer

- HP Model 7550 plotter
- Wavetek Model 171 wave generator
- Pink noise generator (Battelle built)
- McIntosh MC2505 power amplifier
- Keithley Model 166 digital voltmeter
- Bruel and Kjaer Type 4230 acoustical calibrator
- Eckel Corp. An-Eck-Oic Chamber Model 888-150

For the frequency response tests the power amplifier was fed with a pink noise source (i.e., equal energy per one-third octave band sound source). Because of the fluctuating output of a pink noise source, it was not possible to maintain the same output voltage from the amplifier for all of the speakers. Thus, the frequency response curves should not be used to compare absolute output levels from the speakers. The 1000 Hz pure tone tests should be used for this purpose. The frequency response curves should be used to compare the relative frequency response of the speakers. Figure 4 is a typical one-third octave band frequency response curve for a speaker.

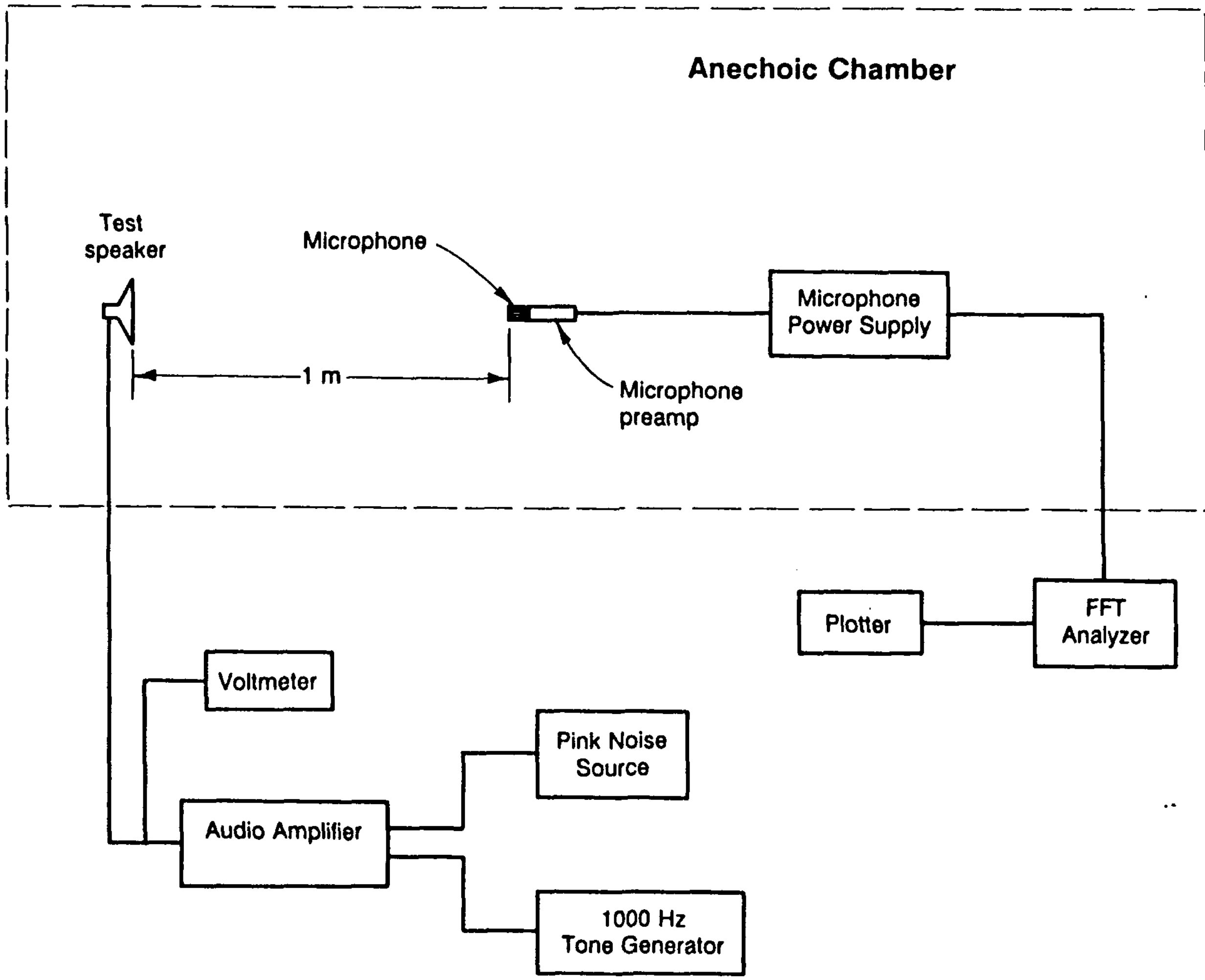


Figure 3. Schematic of Equipment Used for the Acoustical Tests

Table 1. Output Levels From the Test Speakers*

Rank	Speaker	Level
1	SPECO Models 958-8680 & 958-8690	73.8 dB
2	KTC Model 284-0203	73.2 dB
3	Archer Model 910-0112	72.8 dB
4	Archer Model 910-2126 & SPECO Model 958-8670	71.7 dB
5	SPECO Model 958-8660	71.5 dB
6	KTC Model 284-0202	71.4 dB
7	MG Electronics Model B0202	71.2 dB
8	KTC Model 284-0201	69.2 dB
9	MG Electronics Model MSC-300	69.1 dB
10	MG Electronics Model A0201	68.6 dB
11	RDI Electronics Model SR-504	68.3 dB
12	SPECO Model 958-8650	67.5 dB
13	Archer Model 910-2125	66.9 dB
14	MG Electronics Model MSC-299M	66.5 dB
15	MG Electronics Model FS-50S	61.2 dB

* (at 0.5 watts input and at 1 m distance)

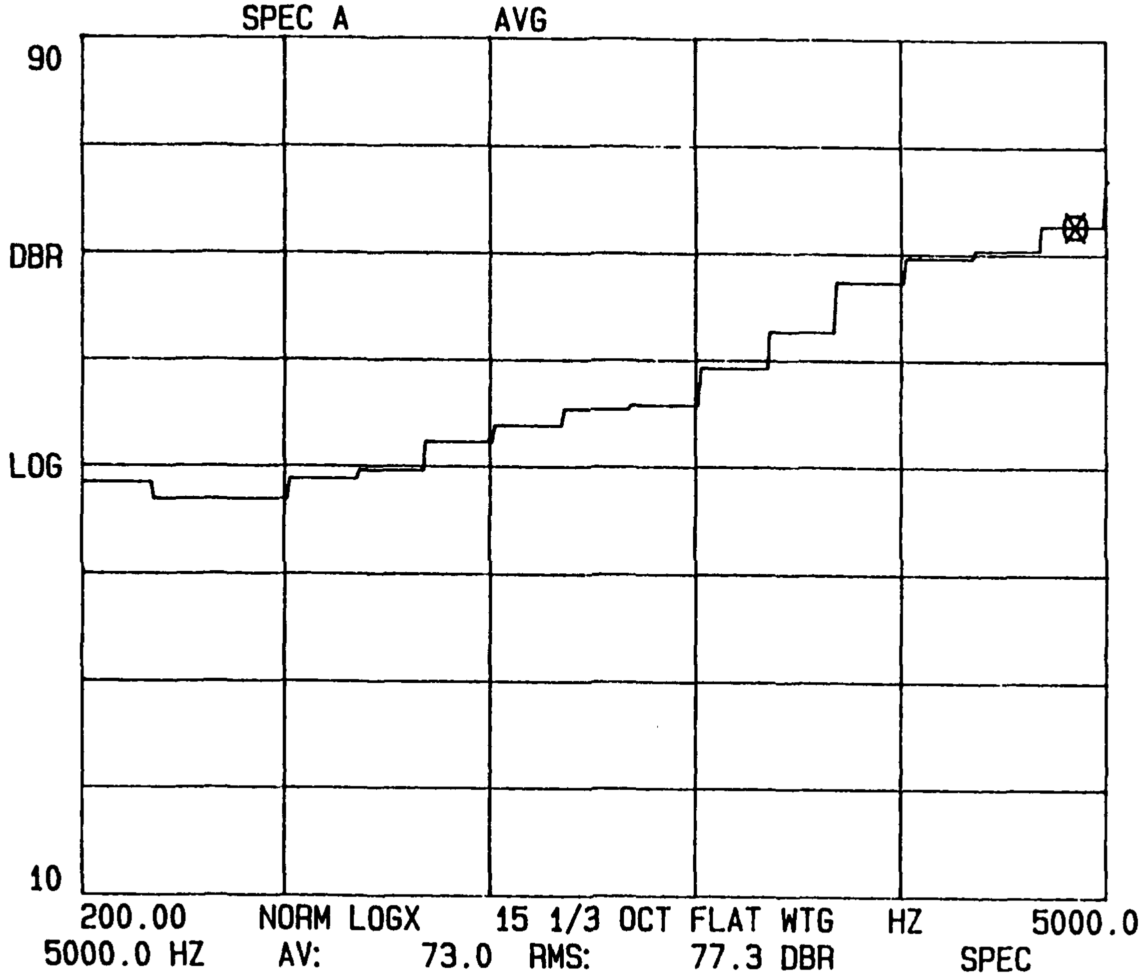


Figure 4. Typical One-Third Octave Band Frequency Response of a Loudspeaker (#3)

The speaker efficiency tests produced a 12.6 dB output range. This range means that the highest ranked speakers put out 4.27 times as much power as the lowest ranked speaker. Ordinarily, this would lead to the choice of one of the highest efficiency speakers available. But, since hearing is logarithmic, this actually only represents about a 17% variance in listener-detectable output. With this in mind and the fact that the speakers which showed higher efficiencies were also the larger speakers, other selection parameters took priority over output efficiency. As a result of this testing, the MG Electronics Speaker Model MSC-299M was chosen for use in this system. This was one of the smallest speakers tested, measuring 2" in diameter and only 5/16" thick, yet it yields an output which is very clear over the voice band. This speaker also has a cone which is made of waterproof mylar and therefore demonstrates the potential feasibility of chemically resistant speaker cones. Further testing of this speaker with the communications circuit breadboard demonstrated good matching with sufficient output volume and clarity.

To determine what average rms power the speaker must be able to handle, an experiment was setup as shown in Figure 5 below.

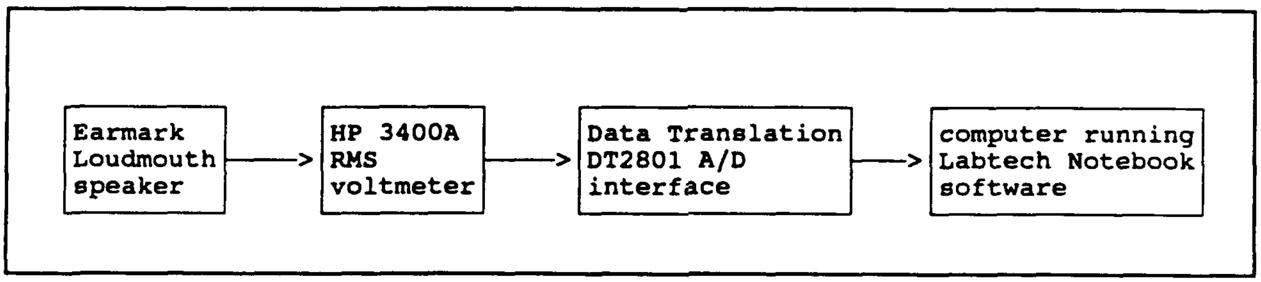


Figure 5. Configuration for Average Speaker Power Measurement

Using an Earmark Loudmouth II voice projection unit as a reference, the voltage across its eight ohm speaker was measured with an HP 3400A rms voltmeter to obtain a true indication of the rms voltage of human speech with all of its amplitude variations and pauses. Two experiments were performed, the first with the Loudmouth II set to a medium volume and the second test with it set to its maximum volume. A newspaper article was read at a fast rate for a period of two minutes while the rms voltmeter output was recorded by the data acquisition computer at 100 samples per second.

The true rms voltages had a peak of 1.7011 volts for the medium sound level and a 2.7986 volts for the maximum value. The collected data file was averaged to determine the average rms voltage for the entire two minute test segment. For the two minute newspaper reading the medium and maximum average rms voltages were 0.58 volts and 1.07 volts respectively. Since the speaker is 8 ohms, the average rms power supplied to it for the medium level setting is 0.042 watts, and for the maximum level it is 0.143 watts. The speaker chosen, like many of the small speakers, is rated for 0.2 watts. Therefore this experiment indicates that this speaker has an adequate power rating, even at the maximum volume level.

RADIO INTERFACE. As part of this task, we designed and fabricated a RESPO-21 to SINCGARS radio interface module. This interface allows a person wearing the mask to connect the mask's internal microphone to the radio's microphone input. A switch on the interface module also disables the mask microphone and permits normal operation through the handset microphone. In either case, the interface module allows use of the handset earphone for radio reception. The push-to-talk switch on the handset is used to activate transmissions regardless of whether the handset microphone or internal mask microphone is used.

The interface is comprised of wiring and switching and contains no active electronics components. The communications assist preamp output connects to the interface module via a twisted pair shielded cable. In future units, this preamp cable may contain more wires for system interface identification to allow connection to a variety of radio inputs. If multiple cable wires were used the interface cable box could include a selector switch to select different radios and intercoms. The end of the preamp cable that connects into the interface box uses a quick disconnect connector to allow rapid switching of radio operators.

Conclusions

Figure 6 is a block diagram of the communications assist subsystem. The preamp stage was designed to accept an input signal from the microphone and amplify it to a level compatible with a military radio input. A miniature noise-canceling microphone manufactured by Gentex was selected based upon its size and test results. Measurement of its output characteristics under various input

Test Results

The communications system circuits were assembled and tested in both plugboard and brassboard forms. Functional testing and performance evaluations included: male and female voice tests, measurement of audible blower noise, and battery life expectancy estimates. The functionality of the printed circuit board was tested by installing the board into its enclosure and verifying all switching, I/O, and control functions. The completed communications subsystem was integrated with the RESPO-21 mask for more detailed testing and evaluation, including speech intelligibility, battery life expectancy, output volume control, and radio interface tests.

Appendix B contains nine figures summarizing the communications subsystem test results. The figures are explained below:

- Figure 1 - The voltage across the speaker as the word "testing" is spoken into the microphone. The vertical scale is 2 V/div and the horizontal scale is 50 ms/div. This graph shows peaks of nearly $\pm$ 6V and predominantly high frequency content (approximately 2 kHz).

- Figure 2 - The voltage across the speaker of the Loudmouth II with speech at a loud volume setting. The vertical scale is 2 V/div and the horizontal scale is 5 ms/div. This is a 5 ms/div version of part of Figure 1.

- Figure 3 - The voltage across the Loudmouth II speaker with normal speech but at 2 V/div and 1 ms/div.

- Figure 4 - The voltage at the microphone terminal of the Loudmouth system. More low frequency content is noted in this plot. The vertical scale is 0.2 V/div and the horizontal scale is 1 ms/div.

- Figure 5 - The current going into the Loudmouth speaker during speech. The scales are 0.1 A/div, 1 ms/div. This displays peaks of $\pm$ 0.3 amps.

- Figure 6 - The zero phase shift relationship between the voltage across and current to the speaker with the top curve representing voltage at 5 V/div and the bottom curve showing the current at 0.5 A/div. The time-scale for both curves is 1 ms/div. This figure shows zero phase shift between the voltage and current.

- Figure 7 - This figure shows the relationship between voltage and current to demonstrate that the load is purely resistive. The voltage scale is 2 V/div and the current scale is 0.2 A/div. The time scale is 0.2 ms/div for this plot.

- Figure 8 - This figure shows the push pull characteristics of the National LM1896 speaker output amplifier. The two output lines are equal in magnitude but opposite in polarity. This provides a drive voltage across the speaker which is higher than that supplied to the circuit. The vertical scale is 0.5 V/div, and the horizontal scale is 0.5 ms/div.

- Figure 9 - This figure shows the current draw from the battery during speech. The vertical scale is 0.2 A/div and the horizontal scale is 10 ms/div.

Blower Subsystem

Design Requirements

The requirements for the blower subsystem are:

- Provide airflow inside the mask
- Reduce breathing resistance for mask wearers
- An airflow adjust control
- Modular design
- Low power consumption
- Small package size.

Design Analysis and Component Evaluation

The basic design for the blower subsystem consists of a miniature blower and a speed control circuit. A number of commercially-available components were evaluated for this application. This section identifies the components and specific tests performed.

BLOWERS. A search of available blowers indicated that only Micronel could provide blowers at the required flow rate and size that have a high enough static pressure rating for this application. Tests with three of the Micronel blowers showed promising results. Further testing, as well as discussions with Micronel and analysis of the blower output data, led us to select the V301MS-6V. This blower was used in air flow testing as well as in the communications circuit testing performed. We investigated potential blower modifications to see if blower performance versus packaging size could be enhanced. Due to its small size, we determined that this blower was adequate without modifications.

Conclusions

The miniature blower subsystem consists of a blower and power source/speed controller. The blower subsystem is designed to improve breathing efficiency by reducing the loading effects of the filter as well as improving the overall comfort of the mask wearer. A miniature blower from Micronel was chosen following an extensive search. The blower control circuit functions as a low dropout voltage regulator. It features an on/off control as well as the choice of three blower speeds (V_{out} = 4, 5, or 6 volts) via an external rotary switch. The speed control circuit includes a potentiometer to allow for the setting of other output voltages. The potentiometer is not accessible to the user since the package cover must be removed. A low battery warning circuit is included in the blower control subsystem. The circuit was tested, through both breadboard tests and fabrication of a brassboard. Specific tests included battery life tests, blower air flow versus output voltage, determination of speed setting levels, and low battery warning threshold. Following testing, a printed circuit board was designed and fabricated for use in the demonstration system.

Test Results

Blower control circuit functionality was tested by installing the board into its enclosure and verifying all switching, I/O, and control functions. The blower subsystem was integrated with the RESPO-21 mask system for further testing of the blower control, battery life expectancy, and audible noise generated by this subsystem.

Power Source Subsystem

Design Requirements

The requirements for the power source subsystem are:

- Provide regulated DC power to the communications and blower control circuits
- Have capacity for a six hour mission
- Modular design
- Small package size, light weight
- Use standard batteries.

Design Analysis and Component Evaluation

The basic design for the power source consists of a battery pack and low battery indicator circuit. A number of commercially-available components were evaluated for this application. This section identifies the components and specific tests performed.

BATTERIES. The battery selection for the blower and communication assist subsystems was driven by three parameters: output voltage, required capacity, and size. The information gathered on batteries originally focused mainly on military $LiSO_2$ batteries. Specifically, the BA-5567/U battery was analyzed. An estimate of power requirements for the specific mission time showed that the blower circuit required approximately 150-200 mA and the communication circuit required 80 mA during normal speech. For modularity and to keep the blower circuit electrical noise isolated from the communications circuit, we decided that separate power supplies for each subsystem would be used.

The Micronel blower requires six volts to operate at its nominal ratings. The battery voltage must therefore be higher than six volts to allow for blower control circuitry losses. The communications assist electronics requires a minimum of 4-5 volts to operate. Because battery voltage drops over time, the initial battery voltage has to be substantially higher to compensate for the voltage drop. The battery energy capacity requirement is predominantly driven by the desired mission length. To keep the battery size small, a high energy density battery chemistry is required, but it must also be safe and operate at low temperatures.

Various combinations of lithium-based chemistries offer high energy density and low operating temperatures. The basic voltage available from a lithium chemistry cell is around three volts with no power drain. To obtain the high voltages required, lithium cells such as the military BA-5567/U could be placed in series. This requires a safety diode for each cell to prevent reverse current from flowing in a damaged cell and causing an explosion. The addition of a safety diode to each cell represents a 0.35 - 0.7 volt drop across each diode which subtracts from the available output voltage. If three cells were placed in series to obtain 8 - 9 volts output, the total voltage lost would be 1.05 - 2.1 volts. This voltage drop is undesirable condition, since it requires additional cells to obtain the desired output voltage. The alternative is to use a higher voltage battery.

SAFT America Inc. makes several high voltage military $LiSO_2$ batteries, but they are too large and heavy for this application. Two other lithium chemistry batteries were considered: the Ultralife Lithium Power Cell and the Powerdex battery.

The Ultralife Power Cell, model NEDA 1604LC, is a nine volt battery manufactured by Ultralife Batteries, Inc. It is the same size as a nine volt transistor battery but has over twice the capacity of an alkaline type. This battery utilizes a lithium manganese chemistry, which complies with the U.S. Department of Transportation's exemption DOT-E 9355, thereby permitting shipment by all forms of transportation. This battery is also recognized by Underwriters Laboratories. The shelf life is greater than five years and it has fair cold temperature performance. The capacity of the Ultralife is 1.2 Ah.

The Powerdex battery is manufactured by GOULD Electronics. It is also a lithium manganese dioxide nine volt battery but comes in a different shaped package than the Ultralife. The Powerdex is a flat battery, having dimensions of 3.7" x 3" x 0.21". Its capacity is 1.0 Ah and it has a shelf life of more than five years. These batteries contain less than one gram of lithium which also complies with the Department of Transportation's exemption from regulated shipping.

The Powerdex batteries have a unique flat shape but their circumference is somewhat large. This size increases when a battery holder is added. The battery holder is necessary as these batteries are fragile when not encased. The Ultralife batteries have a larger capacity, are more rugged, and are smaller. In an emergency, nine volt alkaline transistor batteries could be substituted for the Ultralife, but with a reduced mission time. As with all transistor batteries, the terminals can be easily shorted out, but in the Ultralife contains a built in safety shutdown that limits the short-circuit current to less than 10mA. It is for these reasons that the Ultralife battery was selected to be the power source for both the blower and the voice assist units.

The Ultralife NEDA 1604LC nine volt battery is rated at 1.2 Ah to 5.4 V at 900 Ohms and has a maximum discharge rate of 120 mA continuous. This battery is 1.75" x 1.02" x 0.66" in size (standard battery package). Further analysis showed that one battery would be needed for the communications circuit while three would be used in parallel for the blower circuit to achieve the six hour mission requirement under various ambient conditions.

BATTERY CONDITION MONITOR. A battery condition monitor could take one of several forms. The simplest form is a low battery warning indicator that is activated once the battery voltage drops below a preset value. The advantage of such a system is simplicity. The disadvantage is that it doesn't alert the user of the battery condition prior to a battery low indication. Other types of battery monitors would give an indication of present battery condition by displaying the battery voltage on some form of indicator. The disadvantage of this method is that the indicator needs to be interpreted and a low battery condition may go unnoticed. A combination of both forms may also be considered.

There are several types of indicators that could be used with the above form of detectors. A Light Emitting Diode (LED) could be turned on when the battery voltage drops below a preset value. This is a simple system but has a couple of disadvantages. Some LED's can be washed out in sunlight or become a beacon at night when the battery voltage gets low at an inopportune time. Also, once the LED is on, it places an additional power requirement on the battery. If a blinking LED is used this would reduce its power consumption and would be more likely to be noticed by the user. The LED could also be made to be activated only by the push of a button (push to test) so that it is prevented from coming on in stealth situations. This would of course be at the cost of more space on an already crowded enclosure edge. Putting a small LED inside of the mask was considered but rejected because it was felt to be a distraction and could ruin night vision.

A miniature meter movement is another type of indicator that could be used. Its advantage is that it would give an actual indication of battery condition. Its disadvantage is that it is subject to interpretation and potential misreading. The meter could be calibrated in regions such as: green - battery good, red - low battery. Other disadvantages are that meter movements are relatively fragile and would have to be illuminated at night to be seen.

A Liquid Crystal Display (LCD) bargraph is another form of realtime battery voltage indicator. It too is subject to interpretation but would be more resistant to shock. It would add complexity in the form of a driver circuit and its ability to function at cold temperatures could prove to be a limiting factor. It would also have to be illuminated or backlit for night time viewing.

Minelco Inc. makes a line of permanent magnetic memory indicators that, once pulsed, maintain the display with no power consumption. These indicators are mil-qualified and are about $180 in single quantities. The type of batteries used would have to be able to withstand a 50 mW pulse for 25 mSec to activate the indicator. The display is easily reset by turning the knurled knob clockwise.

An audible battery low indicator is also a possibility but has some of the same disadvantages as an LED, such as no present battery condition, constant battery drain after it turns on, and position disclosure.

With all of these options considered, it was decided for this effort that a low voltage monitoring integrated circuit would be used with an LED indicator as the battery monitor. This provides a rugged and simple circuit for the RESPO-21 system. The other options are too costly, either in terms of complexity, space or dollars. It was also decided that weaker communications output with some slight distortion or lower blower output power were not so crucial as to require battery voltage monitoring. A Harris Semiconductor chip was found which will sink 7 mA of current when the battery voltage drops below a set value. This threshold value is set using two resistors (three if hysteresis is desired) and no extra current limiting resistor is required for the LED.

Conclusions

The original design approach for the Power Source Subsystem revolved around a single, regulated and filtered power source for all RESPO-21 electronics. As the design of the communications and blower control circuits matured, an alternative power source configuration using separate battery packs included in the communications and blower control packages was considered. During circuit testing we observed that the two circuits are better suited to operate over different voltage ranges. After a comparison of the advantages and disadvantages of each approach, we selected separate battery packs primarily to limit electrical noise and interference by keeping the blower control source separated from the power for the communications circuit. The communications subsystem uses a single Ultralife nine volt lithium battery. The blower subsystem runs off a variable regulator which is powered by three Ultralife nine volt lithium batteries.

Test Results

The power supplies used for the communications and blower control circuit were tested to determine battery life. The blower circuit power supply was tested at room temperature and at -20 °F. These tests involved running the blower through the filter at the high (six volt) setting and monitoring the Ultralife battery outputs over time with a strip chart recorder. A similar test was also performed using three Duracell nine volt batteries to evaluate their load capacity.

These batteries also underwent life testing with the blower control system to verify their ability to deliver sufficient power over the course of a six hour mission. At room temperature the batteries were able to support the blower at its highest setting (six volts) for over 13 hours with a gradual dropoff afterwards. See the battery test data in Appendix B for more details.

There are three Figures (10-12) included in the Appendix B which are associated with the battery tests that were performed with the blower.

- Figure 10 shows the voltage out of the three Ultralife batteries as well as the voltage to the blower with the control set to high (6 volts). The battery voltage was measured at the cathodes of the battery protection diodes where all three come together. The actual voltages at the battery terminals are therefore 0.3-0.4 volts (diode drop) higher than that shown on this plot. This plot shows that at room temperature these batteries could support the blower at the high setting for over 13 hours.

- Figure 11 shows the voltage response of three duracell batteries using the exact same test procedure as that for Plot 10. Note that the duracell batteries were only able to maintain the blower voltage at six volts for 5-6 hours.

- Figure 12 shows the results of a test like that of the previous two except that the system was placed in a -20 °F environment. For this test the blower was first set to the low speed (four volts). Both the blower and the batteries had difficulty operating at this low temperature. After seven hours the system was removed from the cold chamber to evaluate how it would respond after having been run in the cold environment. The blower setting was set on high for the remainder of the test. As the plot shows, the batteries rebounded strongly and supplied six volts to the blower for another 12 hours before beginning to drop off.

Subsystem Packaging

Design Requirements

The requirements for the packaging are:

- Modular design
- Small package size, light weight
- Rugged.

Design Analysis and Component Evaluation

The RESPO 21 system concept requires that the subsystems be modular. This requirement suggested that two separate packages would be used. One package includes all of the communications assist components except the microphone and radio interface switch (speaker, amplifier, filter, control circuit, radio interface, low battery circuit, battery). The other package includes the blower battery pack, blower control circuit, and low battery detector circuit.

Product searches, similar to those performed for the microphones, speakers, etc., were performed for the other ancillary components which make up the rest of the system. Various enclosures, connectors, switches, windscreen materials, speaker grills, and cables have been evaluated. Samples were ordered and evaluated to aid in the selection process.

ENCLOSURES. Two separate enclosures are required: one for the blower control subsystem, and the other for the communications subsystem. Commercial enclosures were chosen over custom machined or molded enclosures because of time constraints and potential iterations of circuit board mounting and connector/switch placement during the integration phase of this program. Plastic enclosures were selected to save weight. Because of its size, shape, and internal circuit card slots, the Hammond Model 1591BBK plastic enclosure was chosen as the best candidate. Since an ordinary plastic enclosure does not provide shielding, it became necessary to install some partial shielding in the communications box to prevent interference from external sources.

A third enclosure was chosen to house the radio interface wiring and switching. This enclosure is a small aluminum box. The majority of its surface is covered with connectors and a switch which allows the user to choose between the handset and mask microphone. This enclosure was chosen for its size, shape, and ruggedness.

SWITCHES. The voice assist module requires one separate ON/OFF switch. As is the case in many audio electronic products, the ON/OFF switch could have been set up to be controlled at the counterclockwise end of the volume control. We selected a separate switch to avoid forcing the user to readjust voice amplification every time the module is turned on. This would require the user to talk to adjust the volume level. Since there may be situations when this would not be desirable, separate control was used. The blower control system incorporates its ON/OFF switch in the blower speed selector and therefore does not need a separate ON/OFF switch.
The types of switches considered were:

- Toggle
- Slide
- Push Button
- Rocker
- Touch
- Magnetic Reed
- Membrane

There are various advantages and disadvantages associated with each of these which are summarized below. The push button switch was selected because of its ease of operation while wearing protective clothing, its ability to be waterproofed, and its low footprint.

Table 2. Advantages and Disadvantages Associated with Various Switches

Type	Advantages	Disadvantages
Toggle	■ Operable while wearing protective clothing. ■ Switch position indicates whether unit is on or off. ■ Can be a waterproof switch or protected by a rubber boot. ■ Low footprint.	■ Could be accidentally switched if not protected by a switch guard. ■ Lever height could be excessive.
Slide	■ Low profile. ■ Not easily accidentally switched especially if recessed.	■ Not easily waterproofed. ■ Large footprint.
Push Button	■ Operable while wearing protective clothing. ■ Can be waterproofed by a rubber boot. ■ Small footprint.	■ High profile. ■ Could be accidentally switched if not protected by a switch guard.
Rocker	■ Low profile. ■ Switch position indicates whether unit is on or off. ■ Can be a waterproof switch or could be protected by a rubber boot.	■ Could be accidentally switched. ■ Large footprint. ■ May be hard to maintain enclosure waterproof integrity with switch installation.
Touch	■ No contacts to become intermittent or wear out.	■ More complex circuitry. ■ Extra power drain. ■ Large footprint. ■ Not easily operated while wearing protective clothing.
Magnetic Reed	■ No holes in enclosure. ■ Waterproof. ■ Low profile.	■ Custom switch. ■ Depends on enclosure shape. ■ Analog control not possible. ■ Very large footprint.
Membrane	■ Waterproof.	■ Could be accidentally switched with no way to protect. ■ Large footprint.

CONNECTORS. There are two connectors on the communications module and one on the blower control module. One of the communications connectors is for the microphone input, the other is the preamp output to the radio/intercom interface module. The connector on the blower control module provides power to the blower. All connectors are two conductor, shielded type.

LEMO USA Inc. sells K and E series environmentally sealed quick connect-disconnect type connectors. These are metal connectors that come in a variety of shell materials, including brass with chrome matte, brass with nickel matte, stainless steel, brass with black chrome plating, and aluminum which can be anodized in various colors. The LEMO connector options include variable cable sizing, plug and receptacle covers, and cable strain reliefs. The main disadvantage of the K and E series connectors is their size. The plug length is 37 mm. A second disadvantage is that the K and E type plugs are not available with a 90 degree bend. LEMO does however carry non-environmental B and S series elbow plugs.

ITT Cannon offers a seven conductor MIL MIKQ6-7S quick disconnect connector that has a plug length of 1.2 inches. Its disadvantage is that it does not come with less than seven contacts and the cable must be ordered as a custom installation. Also, the receptacle/plug pair is quite expensive at $180.00.

The Daniel Woodhead Company makes a miniature series of quick disconnect plastic molded connectors. These were rejected because the cable shield cannot be connected to the plug shell.

Nanonics Corporation expects to introduce a 'C' series nanominiature circular connectors in June 1992. These connectors are very small; for example a seven pin plug is only 10.42 mm long. They are made of stainless steel, are environmentally sealed, and will be available in straight or 90 degree.

Microtech, Inc. has several series of ultraminiature multicontact connectors. The LD series is a moisture resistant variety and comes in straight or right angle type, the straight being only 0.72 inches long. The disadvantage of these connectors is that they come in a gold plated finish.

All of the connectors for the RESPO-21 system must be rugged and able to withstand potential pulling from the cables. The microphone connector does not need to be a quick connect-disconnect style, whereas the preamp output and blower power should be quick disconnect to allow rapid interface to a radio or intercom, and quick blower power pack replacement. After evaluation of many types of connectors, the Microtech LD series connector was chosen. Although it does have the disadvantage of being shiny gold plated and utilizes a threaded type connection, its small size, moisture resistive package, and relatively low cost made it the best candidate. Also the gold contacts are non-corrosive, reliable, and are covered up by a flap when the packages are placed into their bib pockets.

Conclusions

The Hammond Model 1591BBK plastic enclosure was chosen because of its size, shape, and internal circuit card slots. The Augat push button switch Model MPS203N was chosen due to its size, ease of operation while wearing protective clothing, its ability to be waterproofed, and it low footprint. The Microtech LD series miniature connector Model DR-45-6 was chosen because of its small size, moisture resistive package, and relatively low cost.

Demonstration System Testing

Completed system testing was performed with several users to evaluate the overall effectiveness of the blower control and communications systems. It was agreed by all who wore the system that the blower subsystem helped to increase the comfort level and eliminated moisture inside of the mask. The communications subsystem was also evaluated by several users with and without the blower running and at various voice output volume settings. The communications assist provided a distinct improvement in voice transmission and intelligibility. Recorded tests were performed with two male and one female voice to support the performance evaluation. These voices were recorded through the radio interface and at the output speaker, with the blower on and off. In these tests, the system demonstrated good voice transmission and high intelligibility.

RECOMMENDATIONS

In addition to preparing the demonstration system, a secondary objective of this project was identification of component and subsystem enhancements necessary for full scale development of the RESPO-21 system. Throughout the development of the demonstration system, a number of components and design alternatives were evaluated. Potential enhancements of these components were noted for use in the next version of RESPO-21. This section of the final report summarizes these potential enhancements to the system.

- **VOX.** A voice-operated transmit (VOX) circuit could be added to the communications system to reduce power consumption and eliminate the transmission of noise when the user is not speaking. This may permit significant reduction in required battery capacity if the user's active speaking duty cycle is low.

- **Characterization and Reduction of Blower Noise.** The audible noise generated by the airflow from the blower through the ducts into the mask area represents a significant source of noise for the communications system. This noise is within the range of human hearing bandwidth but not necessarily at a single frequency. This noise has been reduced to a tolerable level in the current system via conventional filtering. Additional noise attenuation may be possible through the use of alternative filter designs incorporating digital signal processing or a reduction of airflow turbulence inside the mask ductwork.

- **Batteries.** The demonstration system uses commercial lithium batteries. As advanced battery chemistries become available, reductions in battery size and weight may be possible.

- **High Efficiency Voltage Regulators.** A more efficient low-voltage regulator design would enable the blower to operate at closer to the minimum battery voltage, extending battery life for a given capacity battery. The demonstration system uses a low-dropout linear regulator, alternative designs include switching and pulse-width-modulated regulators.

- **Surface Mount Circuits.** If further evaluation of miniature speakers and a custom enclosure allows packaging size reduction, miniaturized surface mount circuit boards could be utilized to further reduce size constraints. In this effort the circuit cards were not the driving factor behind the enclosure sizes. But, if further component evaluation yielded subsequent miniaturization, surface mount circuit technology would enhance further size reduction, especially in the case of the communications assist circuit.

- **Packaging.** Improvements in packaging density offer potential improvements to the system in terms of size and weight. Developing a custom enclosure and high efficiency miniature speakers would allow the package envelope for the communication and blower subsystems to be reduced, provided additional circuit complexity was not required.

APPENDIX A

INVESTIGATION AND ANALYSIS
COMMERCIAL COMPONENTS ANALYZED

APPENDIX A - Investigation and Analysis

Commercial Components Analyzed

Bone Conduction Microphones

- **Setcom Corp.** - Charlene Gibson @ (415) 965-8020, received and analyzed information, ordered and received two model GM-312A bone microphone units (top-of-head bone mic), limited analysis done due to improper interface

- **New Eagle Communications Group, Inc.** - Darrell Goodnow or Jeff @ (800) 541-4792, received and analyzed information, ordered single model HR1 headset unit (mastoid bone mic), canceled order due to change in direction concerning microphones

- **Telex Magnum** - Looked into getting information concerning Ear-Mike but stopped due to desire to avoid ear-fit microphones

Throat Microphones

- **Earmark** - Charlie Winchester @ (203) 777-2130, received and analyzed information, ordered three model THR-3 throat microphone units, analyzed units in lab with Loudmouth II voice projection unit, microphones were found to be very position sensitive

- **David Clark Company, Inc.** - Tom Smith or Bill VanLennep @ (508) 756-6216, received and analyzed information, ordered one model 1882G-01 electret throat microphone unit, order canceled due to change in direction concerning microphones

Electret

- **Audiosears Corp.** - Nancy Rice or David Fox @ (800) 533-7863, received and analyzed information, ordered and received model 2251 self-contained electret microphone with amplifier, microphone not used in tests because of its large size

- **Electro-Voice, Inc.** - Larry King @ (616) 695-6831, received and analyzed information, ordered and received one each of the model 978-0710 aircraft

- **Accusonics Systems Corp.** - Tony Mazzeo @ (516) 328-3300, received and analyzed information, ordered two each of models G03A01-PF and G03A03-PF speakers, speakers were received and tested, speakers sound good but are too large and much too heavy for potential use

- **Alectron Corp.** - Paulette Demont @ (214) 988-3831, received and analyzed information, nothing was ordered because of a large minimum order quantity

- **Celestion Industries, Inc.** - (508) 429-6706, received and analyzed information, all speakers are in enclosures, nothing ordered

- **Universal Electronics** - (708) 673-5885, received and analyzed information, no speakers smaller than 4" in diameter, nothing ordered

- **Tei Electronics, Inc.** - (800) 327-8811, received and analyzed information, no small speakers available, nothing ordered

- **Minneapolis Speaker Co., Inc.** - (612) 825-1010, received and analyzed information, have 6-12 watt speakers that are small in diameter but not thin enough, nothing ordered

- **Atlas/Soundolier** - (314) 349-3110, received and analyzed information, no speakers smaller than 4" in diameter, nothing ordered

- **Plye Industries, Inc.** - (219) 356-1200, received and analyzed information, handle mostly car speakers, nothing ordered

- **Oaktron Corp.** - Jerry Disch @ (608) 328-5560, received and analyzed information, handle military speakers which are too large, nothing ordered

- **Altec Lancing** - (405) 324-5311, received and analyzed information, no speakers smaller than 4" in diameter, nothing ordered

- **CTS Corp.** - Gaetana Weir @ (512) 546-5184, received and analyzed information, handle some small speakers including a 3", 5 watt model, speaker is too thick, nothing ordered

- **Med Tek** - Steve Partsch @ (714) 774-8484, received and analyzed information, company makes speakers that are housed in hand-held controls for hospital beds, not sold separately, nothing ordered

- **Gefco** - H. Brian Gefvert @ (708) 223-8171, received and analyzed information, works with custom speakers only, nothing ordered

- **Tadiran Electronic Industries, Inc.** - (516) 621-4980, received and analyzed information, has a good variety of lithium inorganic batteries but nothing in a suitable size/current rating, nothing ordered

- **UltraLife Batteries, Inc.** - (315) 332-7100, received and analyzed information, company makes a 9V lithium power cell with good energy density, ordered and tested several Model NEDA 1604LC batteries

- **Gould Electronics** - Dr. Ralph J. Brodd @ (216) 953-5065, received and analyzed information, company makes wafer thin 6V lithium batteries with good energy density, several model 6A1400 batteries were ordered, received, and evaluated

- **Plainview Batteries** - (516) 249-2873, received and analyzed information, company specializes in NiCad batteries but handles some lithium, nothing in a suitable size/current rating available, nothing ordered

APPENDIX B

TEST DATA

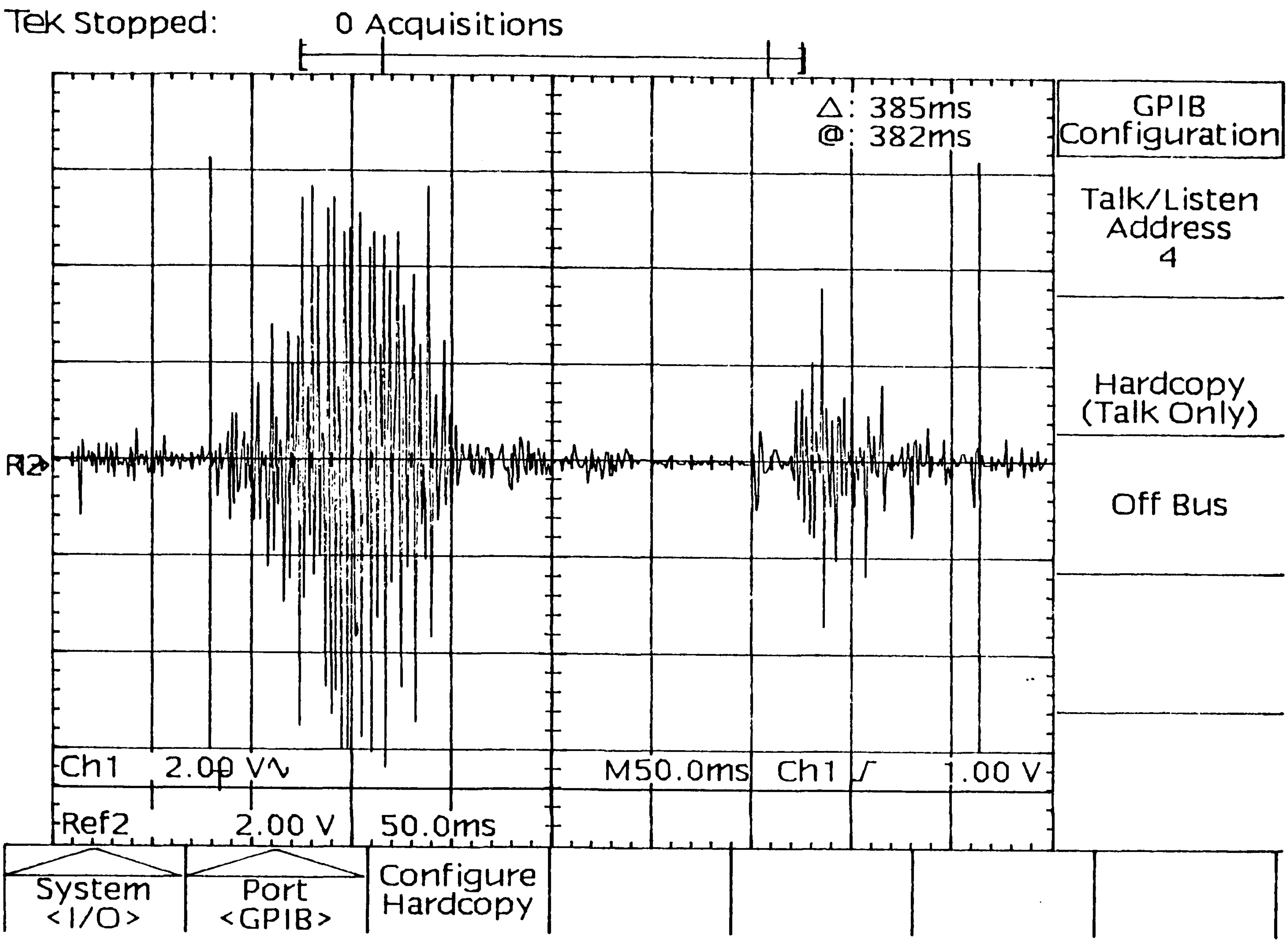

Tek Stopped:
0 Acquisitions
Δ: 385ms
@: 382ms
GPIB Configuration
Talk/Listen Address 4
Hardcopy (Talk Only)
Off Bus
R2
Ch1 2.00 V
M50.0ms Ch1 1.00 V
Ref2 2.00 V 50.0ms
System <I/O>
Port <GPIB>
Configure Hardcopy

Figure 1

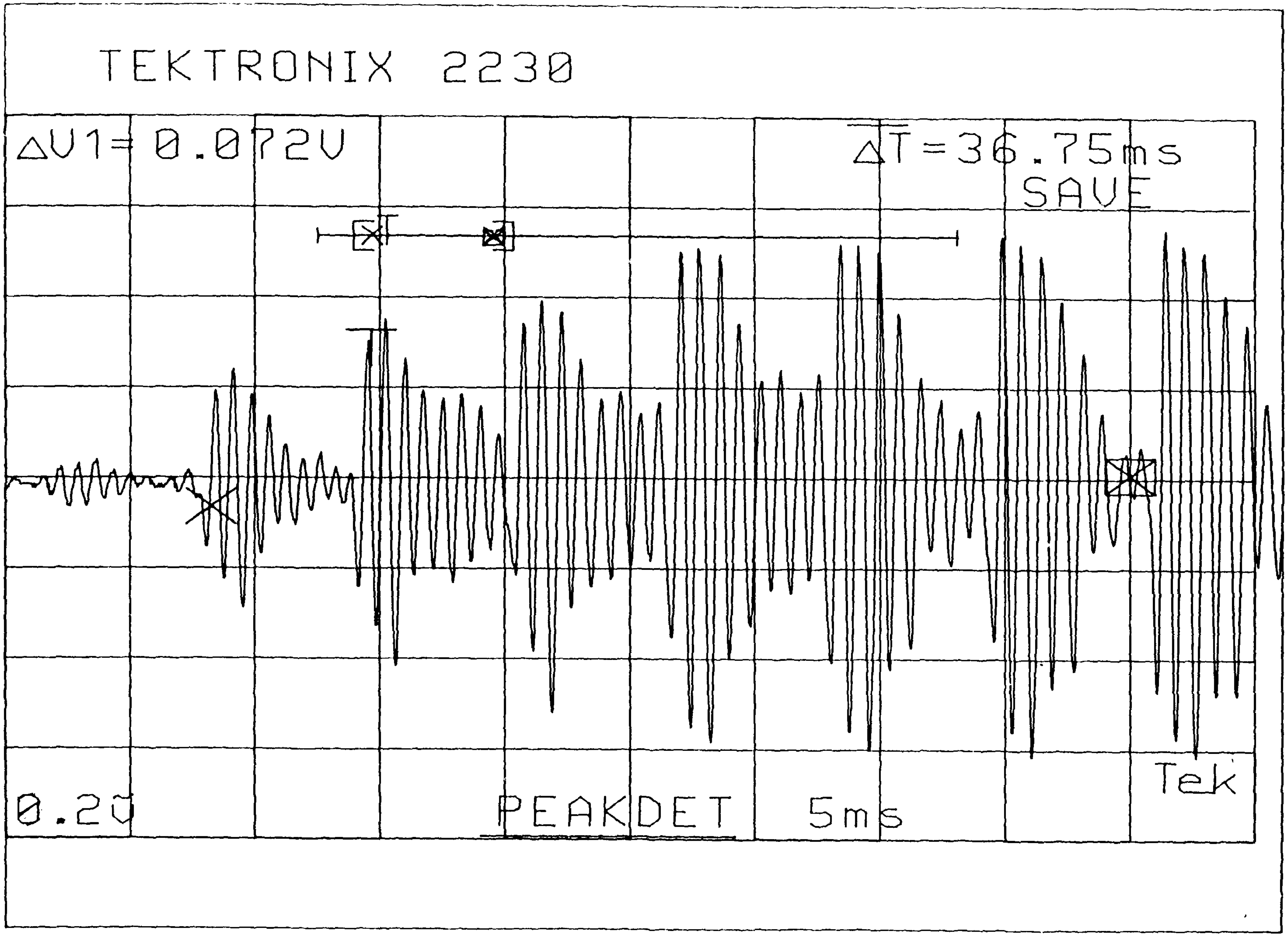


Figure 2

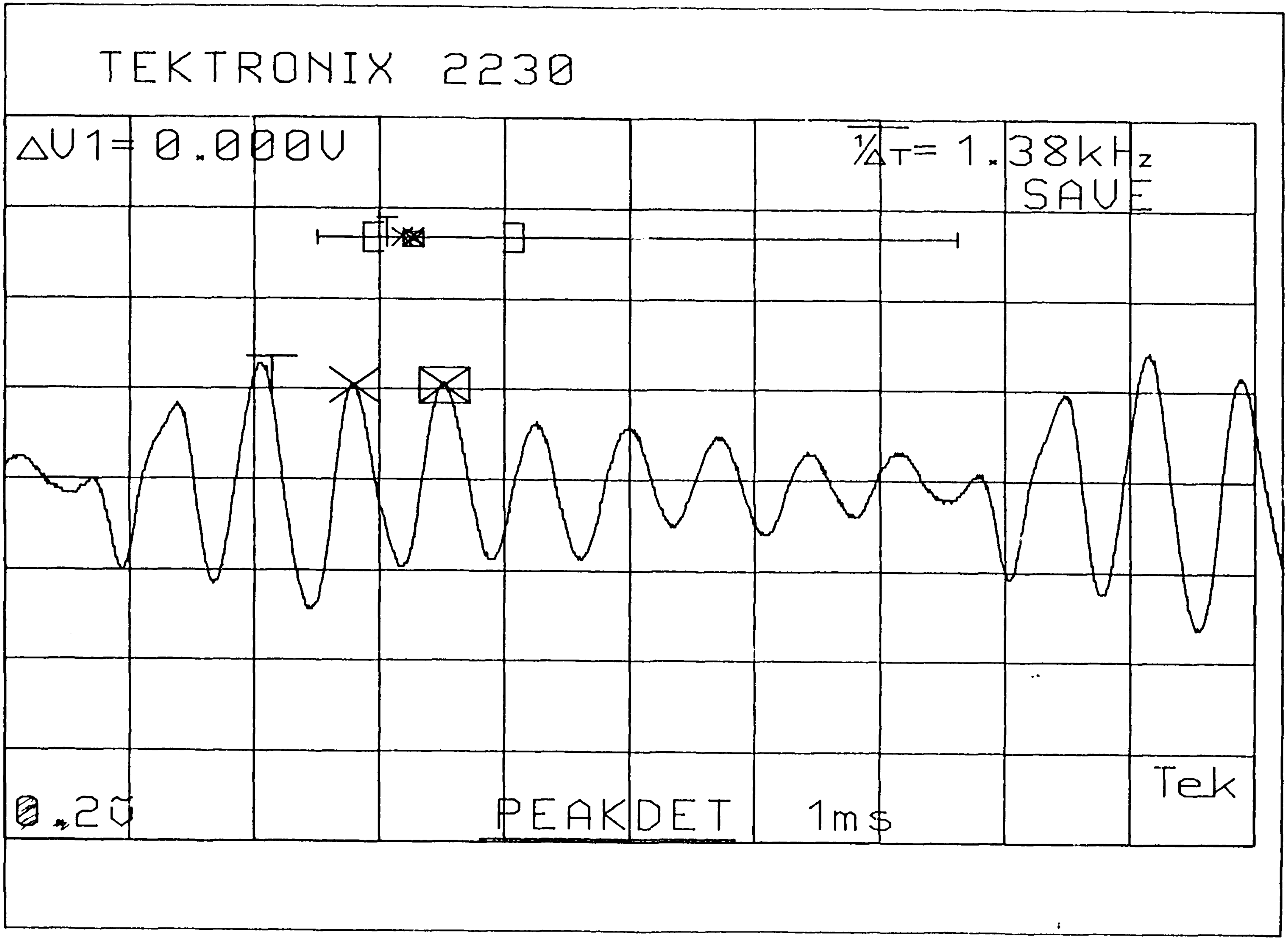

TEKTRONIX 2230
ΔV1= 0.000V
1/ΔT= 1.38kHz
SAVE
0.2V
PEAKDET
1ms
Tek

Figure 3

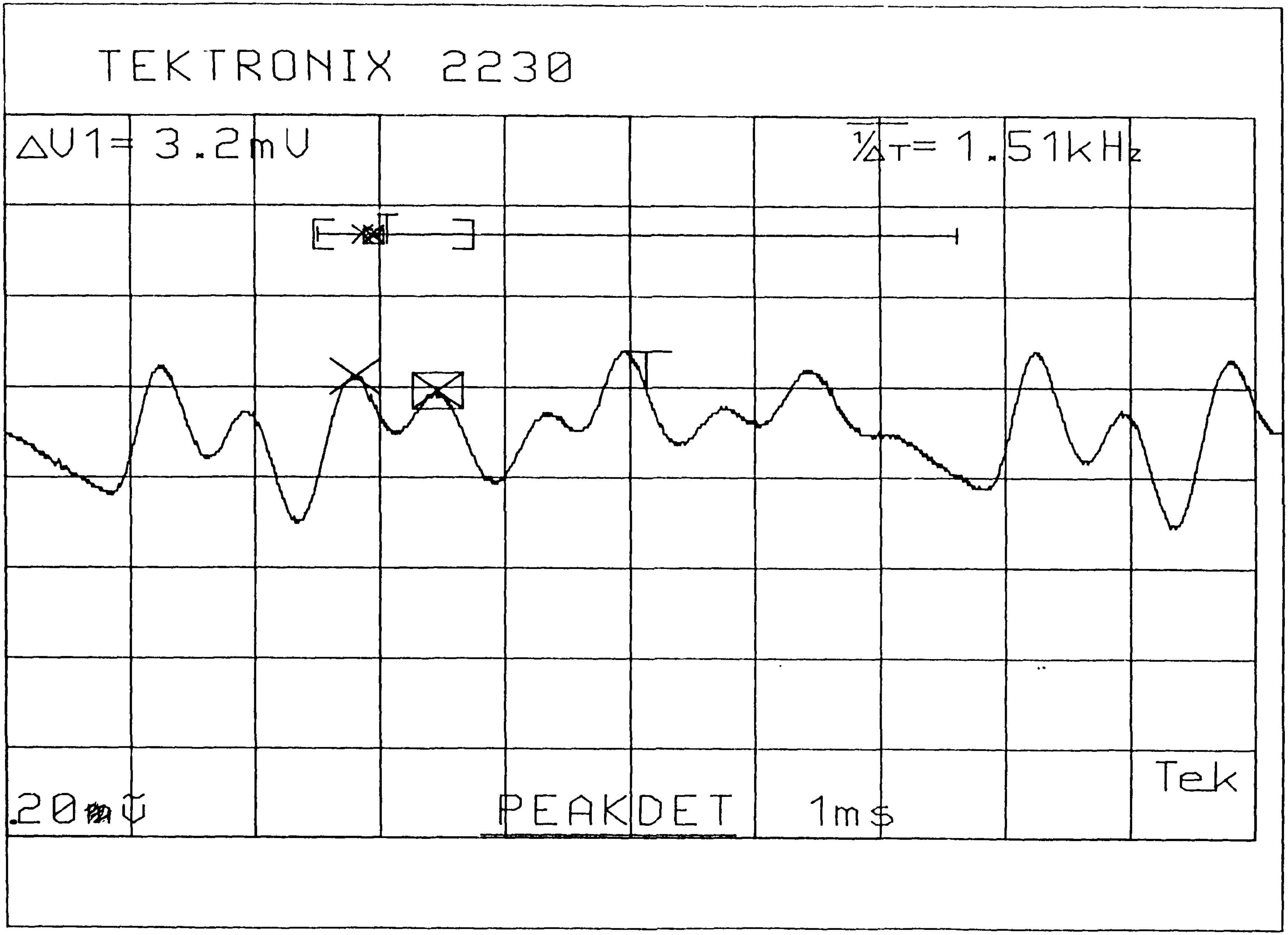


Figure 4

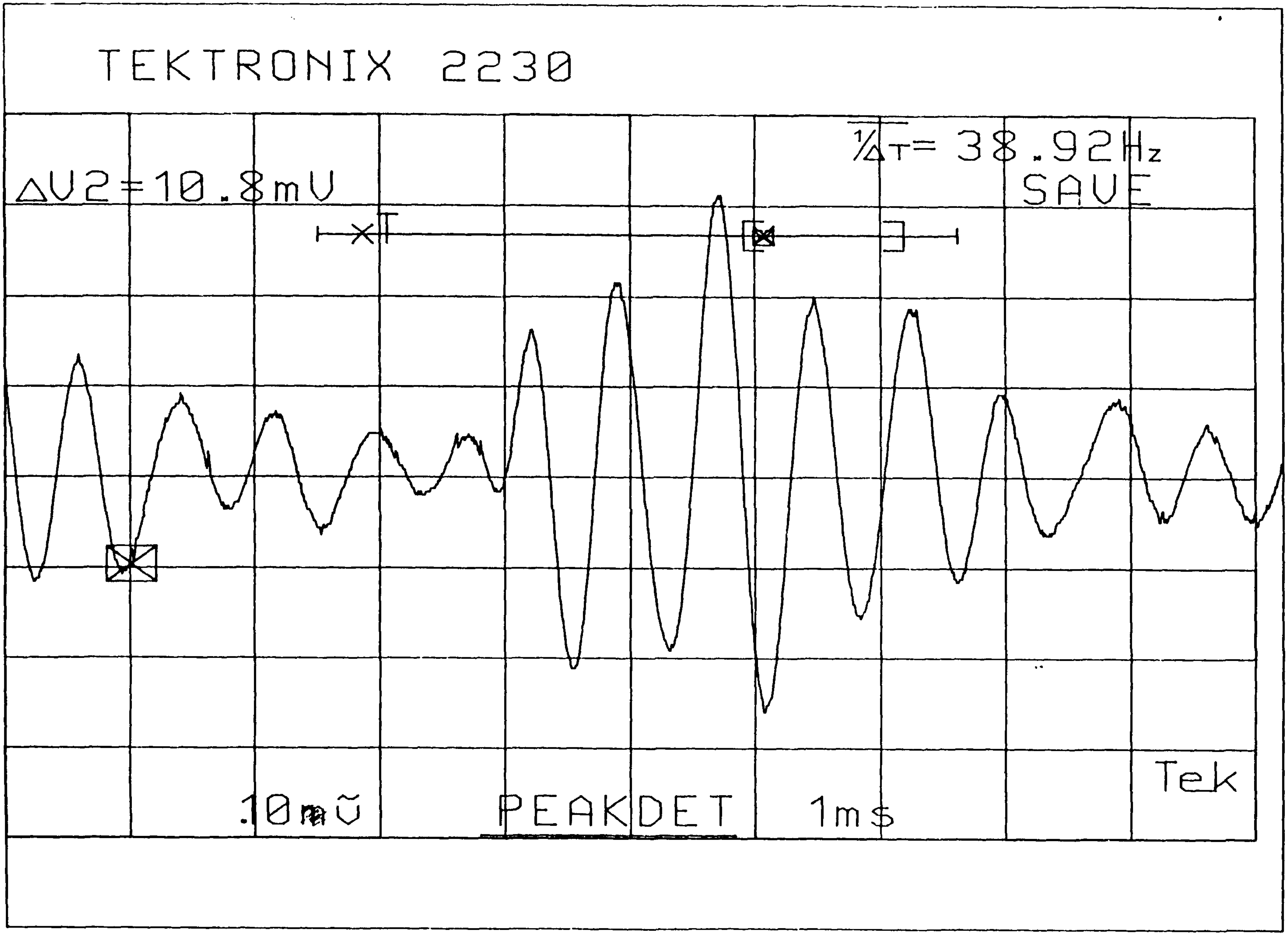


Figure 5

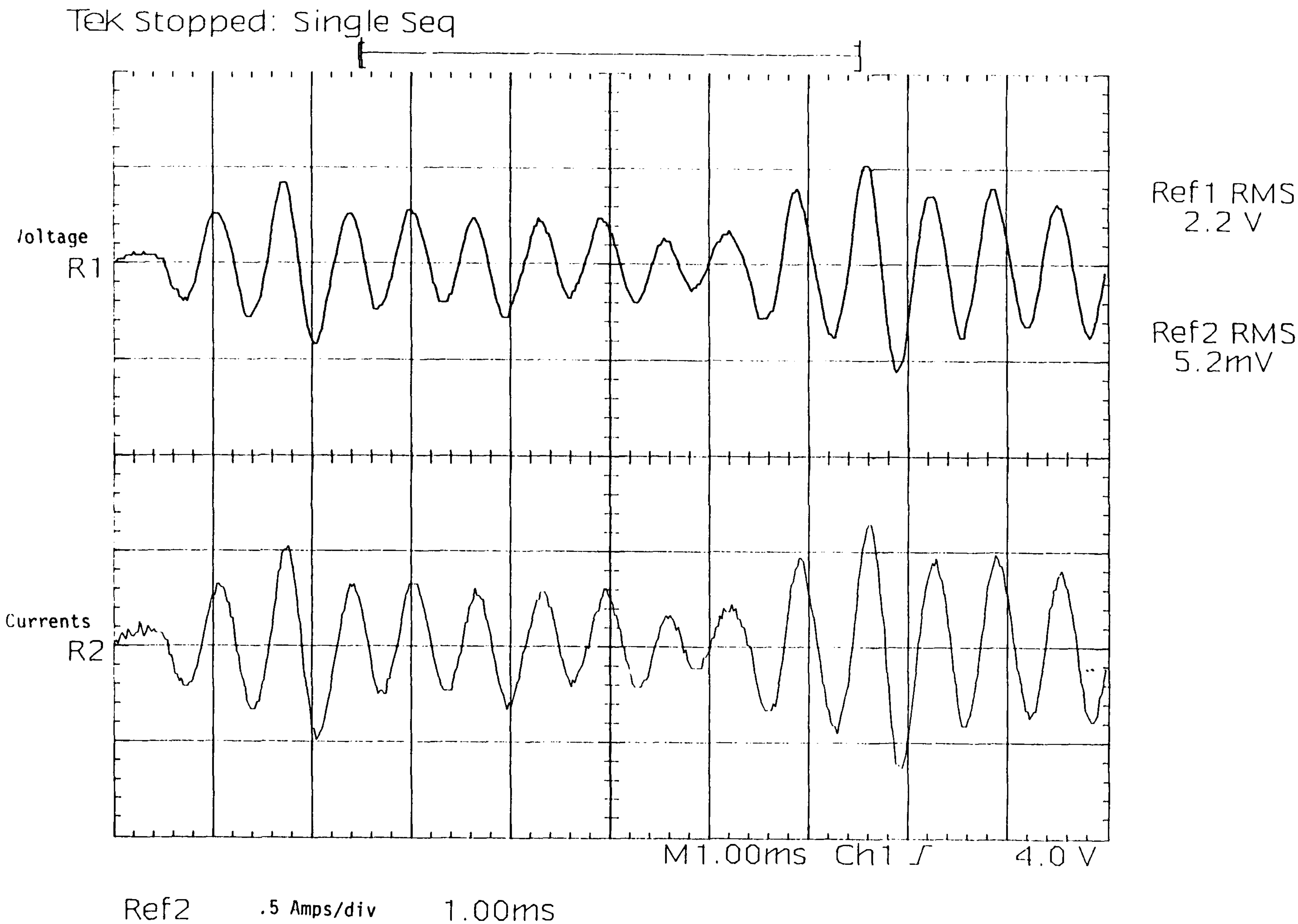

Tek Stopped: Single Seq
Voltage
R1
Currents
R2
Ref1 RMS
2.2 V
Ref2 RMS
5.2mV
M1.00ms Ch1 ∫ 4.0 V
Ref2 .5 Amps/div 1.00ms

Figure 6

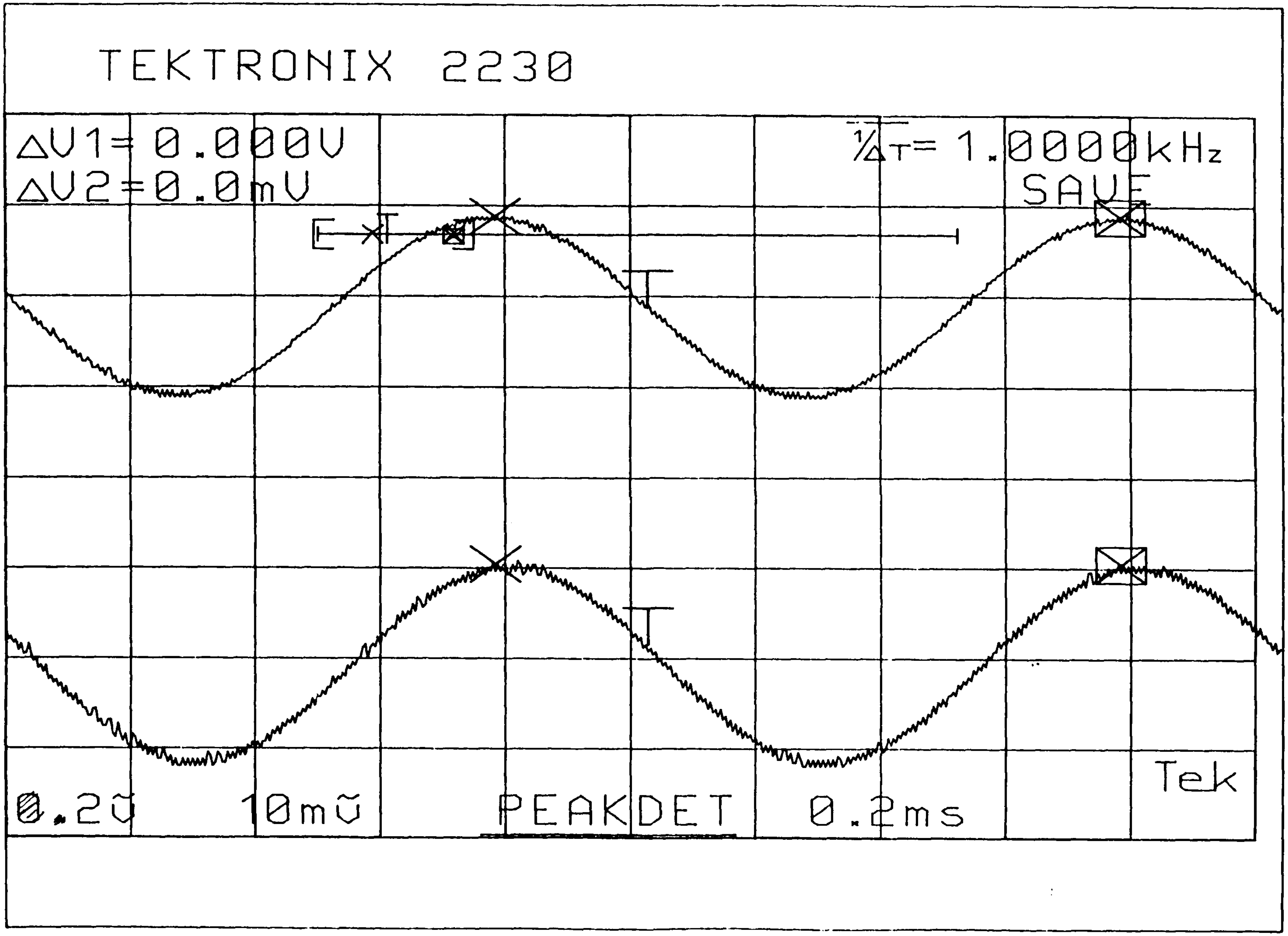

TEKTRONIX 2230
ΔV1= 0.000V
ΔV2=0.0mV
1/ΔT= 1.0000kHz
SAVE
Tek
0.2V
10mV
PEAKDET
0.2ms

Figure 7

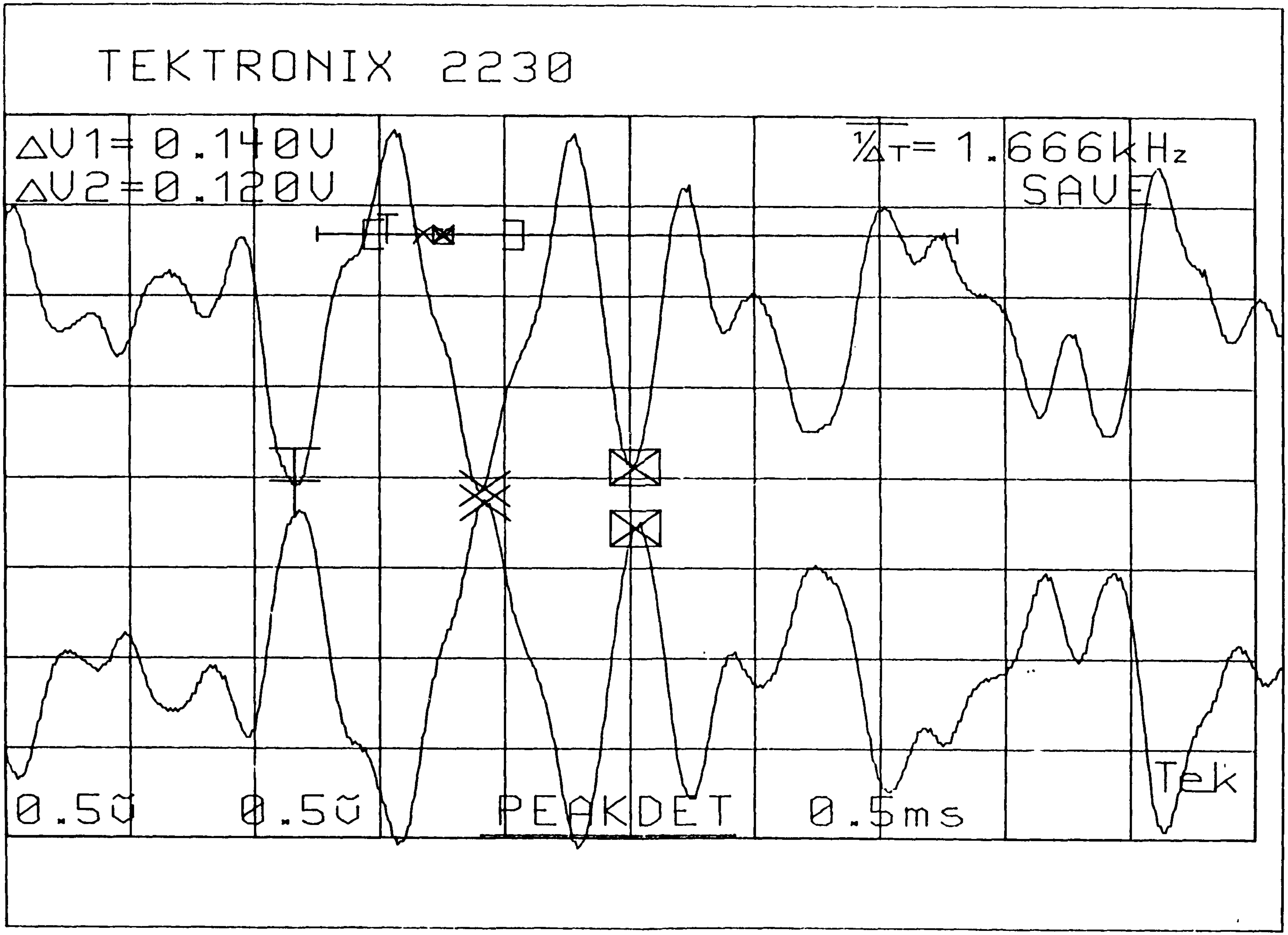

TEKTRONIX 2230
ΔV1=0.140V
ΔV2=0.120V
1/ΔT=1.666kHz
SAVE
0.5V 0.5V PEAKDET 0.5ms
Tek

Figure 8

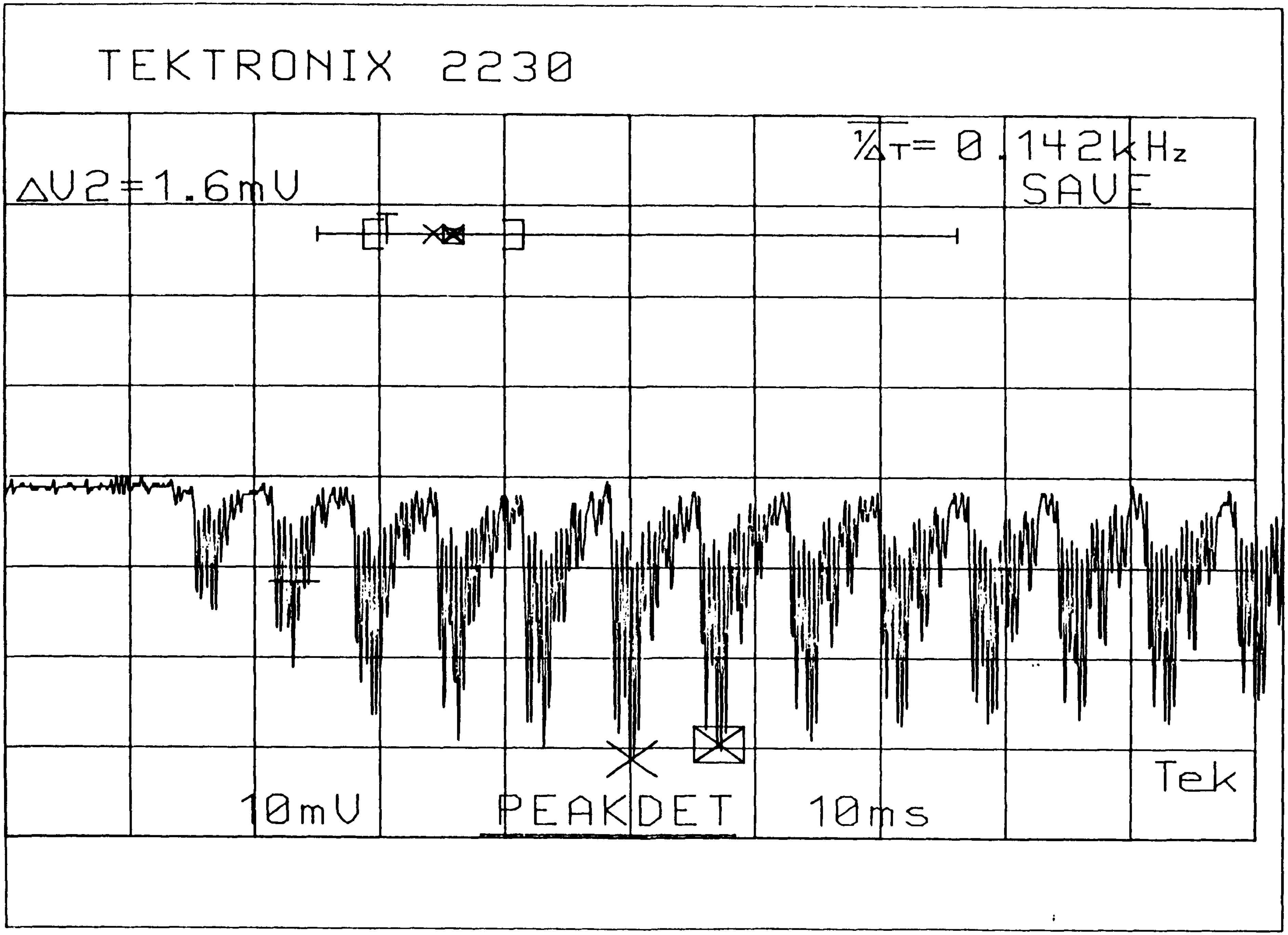

TEKTRONIX 2230
ΔV2=1.6mV
1/ΔT= 0.142kHz
SAVE
10mV
PEAKDET
10ms
Tek

Figure 9

Battery Tests – Blower Control System

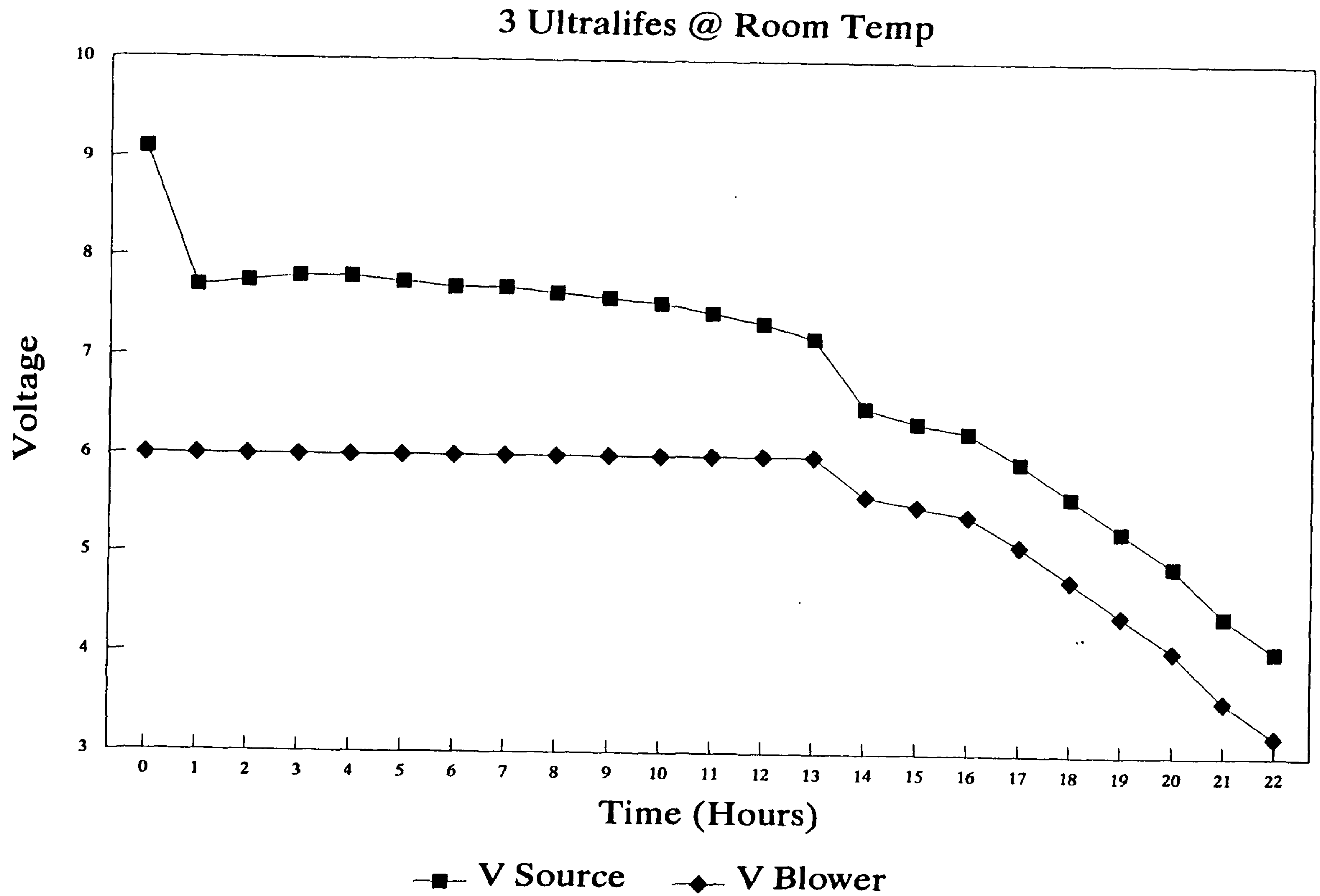


Figure 10

Battery Tests – Blower Control System

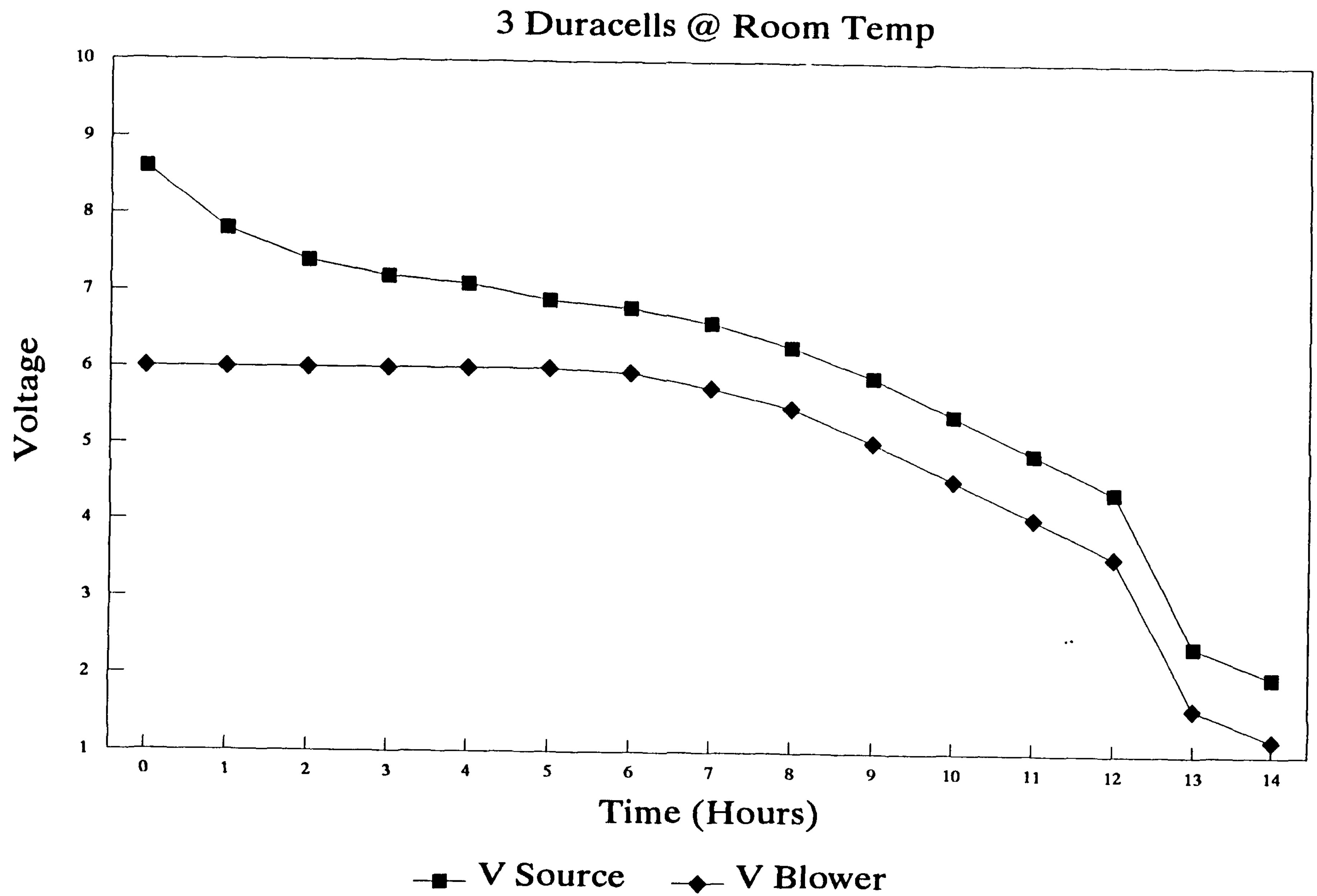


Figure 11

Battery Tests – Blower Control System

3 Ultralife's – Cold Test – 29 C

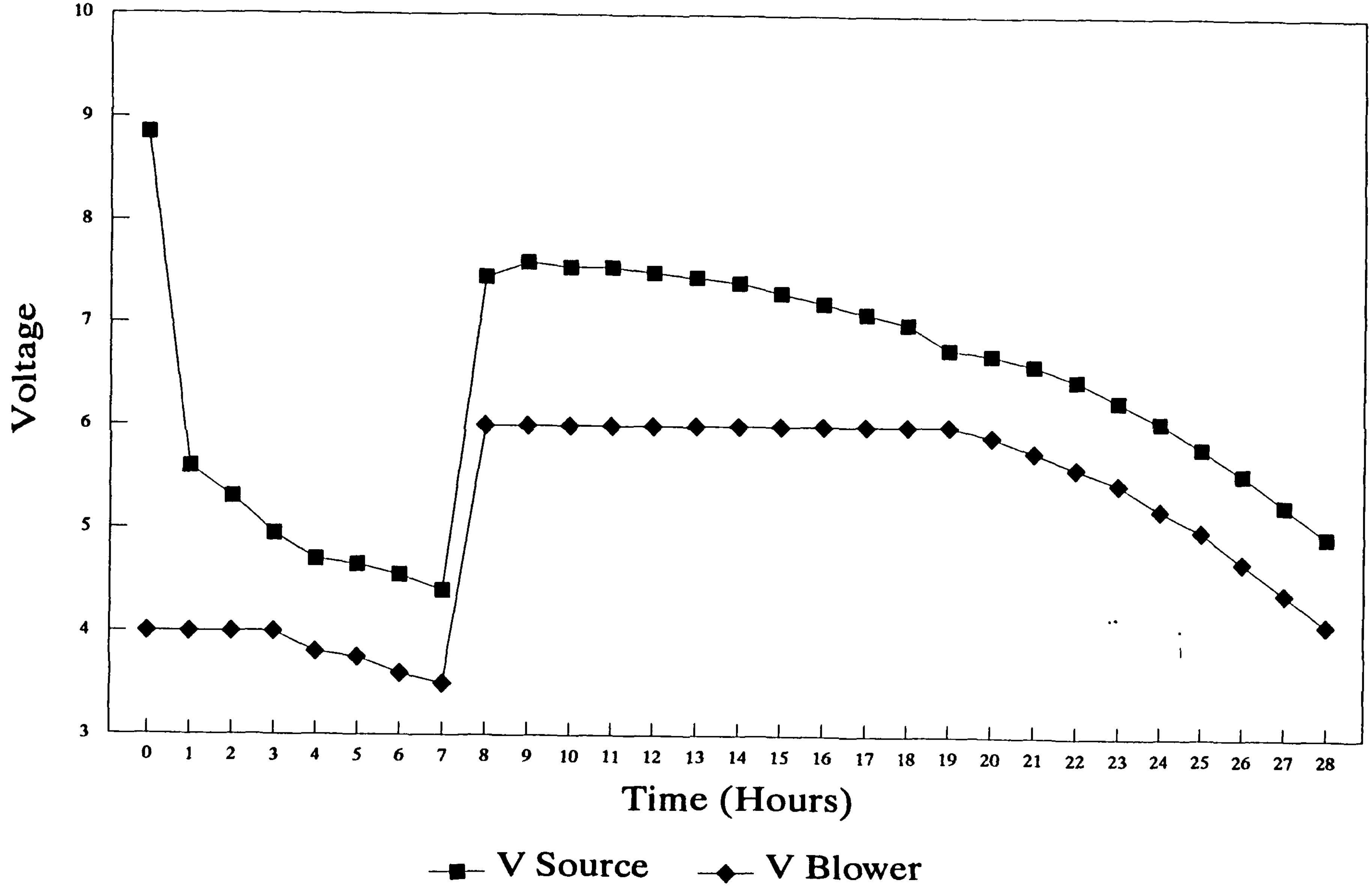
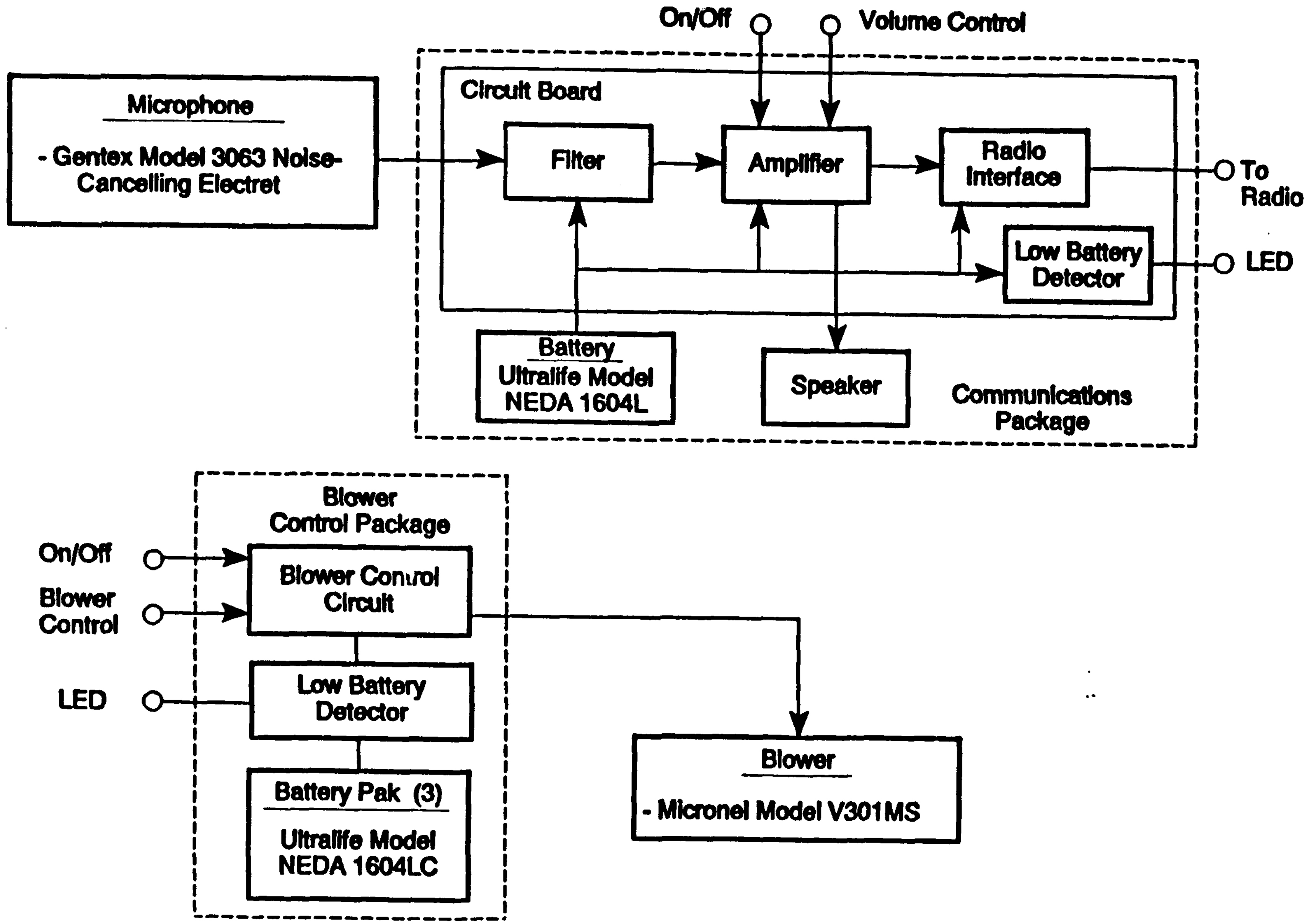


Figure 12

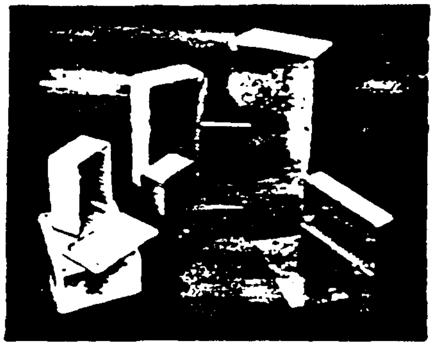
APPENDIX C

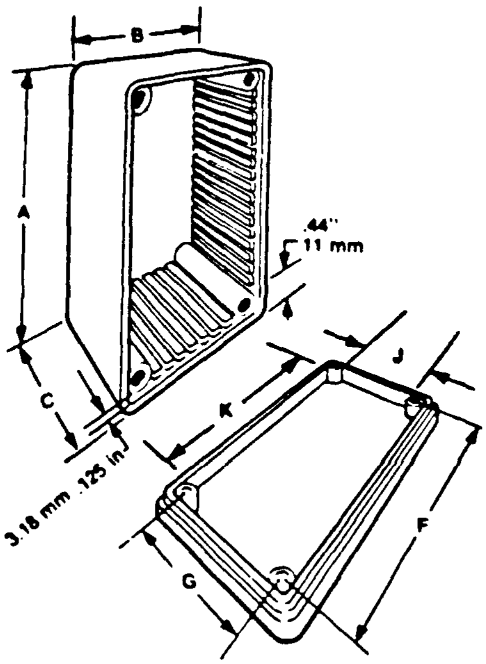
DESIGN DOCUMENTATION



RESPO-21 Electronic System Block Diagram

Plastic Instrument Boxes



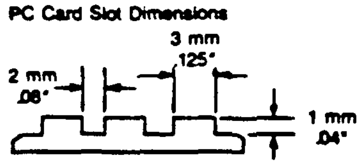


Average wall thickness 0.062".

ABS FLAME RETARDANT BOXES

- Molded in an improved medium impact ABS thermoplastic with flame retardant properties.
- Carries a UL flammability rating of 94 V-0 at 1.47 mm thickness and a continuous use temperature rating of 60° C.
- Comes in colors: blue, black, grey and beige.
- Comes with M3 x .5 x 10 mm, Philips head screws, countersunk lid, and tapped integral brass bushings.
- Interlocking flange on the lid.
- Integral card guides accept .062" p.c. cards.
- Cat. No. 1591E has removable center brace.
- Comes with ABS lid in matching color. Optional clear plastic or metal lids are available.

PC Card Slot Dimensions

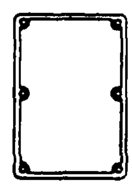


EMI/RFI SHEILDED BOXES

- Same material, features and flame retardant properties as standard ABS boxes.
- EMI/RFI shielded with a nickle-acrylic conductive coating.
- For complete information on EMI/RFI shielding specifications, contact your Hammond sales office.
- Sold with shielded ABS lid in matching color.

OPTIONAL LIDS

- Boxes are sold only with standard ABS plastic lid in matching color.
- Optional clear plastic or metal replacement lids may be ordered separately from the "Optional Lids" table below.
- Standard ABS lids are "no return" items and should be discarded if not used.
- Clear plastic lids are not shielded.

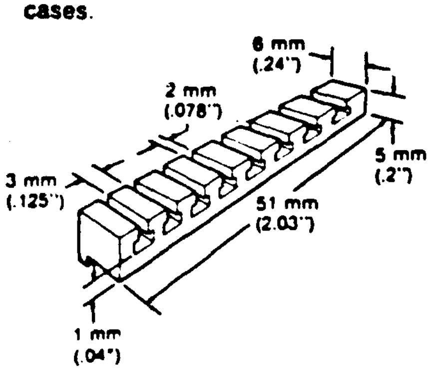


ABS and clear plastic lid. Add 4 mm (.156") to overall height of box.

E series have 6 lid mounting holes and removable center brace

P.C. CARD ADAPTERS

- P.C. Adaptors allow mounting of cards at right angles to the slots molded into Hammond plastic cases.



Cat. Nos.	Quantity
1591Z6	6 p.c. adaptors
1591Z100	100 p.c. adaptors

Standard ABS Box & Lid Cat. No.	EMI/RFI Shielded Box & Lid Cat. No.		Dimensions A	B	C	F	G	PC Card Clearance J	K	Optional Lids Order Clear Lid■	Order Metal Lid
1591L...■	1591RL...■	mm	85	56	35	71	42	34	63	1591	1591
		ins	3.34	2.20	1.38	2.79	1.65	1.34	2.48	LC	LM
1591A...	1591RA...	mm	100	50	21	86	36	28	78	1591	1591
		ins	3.93	1.97	.82	3.38	1.42	1.10	3.07	AC	AM
1591B...	1591RB...	mm	112	62	27	98	48	40	90	1591	1591
		ins	4.41	2.44	1.06	3.86	1.89	1.57	3.54	BC	BM
1591C...	1591RC...	mm	120	65	36	106	51	43	98	1591	1591
		ins	4.72	2.55	1.41	4.17	2.0	1.62	3.86	CC	CM
1591D...	1591RD...	mm	150	80	46	136	66	58	128	1591	1591
		ins	5.90	3.14	1.80	5.35	2.59	2.28	5.04	DC	DM
1591E...	1591RE...	mm	190	110	57	176	96	88	168	1591	1591
		ins	7.47	4.33	2.24	6.92	3.78	3.46	6.61	EC	EM
1591G...	1591RG...	mm	121	94	30	106	79	71	98	1591	1591
		ins	4.75	3.69	1.18	4.17	3.11	2.80	3.86	GC	GM
1591H...	1591RH...	mm	166	71	25	151	56	48	143	1591	1591
		ins	6.52	2.78	.98	5.94	2.20	1.89	5.63	HC	HM
1591S...	1591RS...	mm	110	82	40	96	68	60	88	1591	1591
		ins	4.33	3.23	1.58	3.78	2.67	2.36	3.46	SC	SM
1591T...	1591RT...	mm	120	80	55	106	66	58	98	1591	1591
		ins	4.72	3.15	2.17	4.17	2.60	2.28	3.86	TC	TM
1591U...	1591RU...	mm	120	120	55	106	106	98	98	1591	1591
		ins	4.72	4.72	2.17	4.17	4.17	3.85	3.86	UC	UM
1591V...	1591RV...	mm	120	120	90	106	106	98	98	1591	1591
		ins	4.72	4.72	3.54	4.17	4.17	3.85	3.86	VC	VM

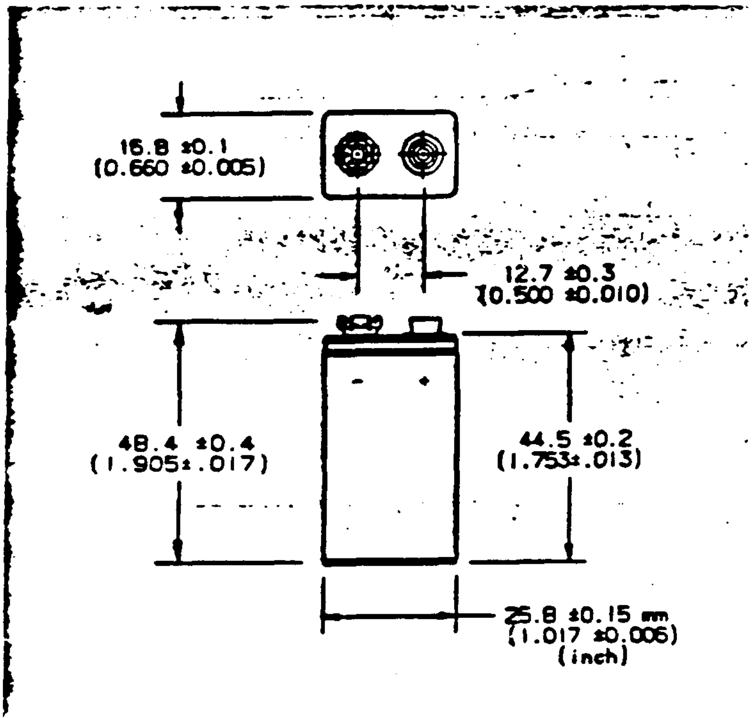
■ When ordering specify color with suffixes BK (black); BU (blue); GY (grey); or BG (beige). Replacement screws Cat. No. 1591MS100 (pkg. 100)

■ Clear plastic lids not EMI/RFI shielded

ULTRALIFE®
LITHIUM POWER CELL

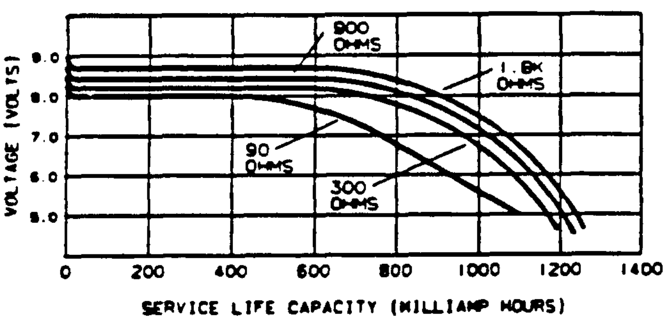
U9VL
9V-Size

Effective 11 Nov. 91

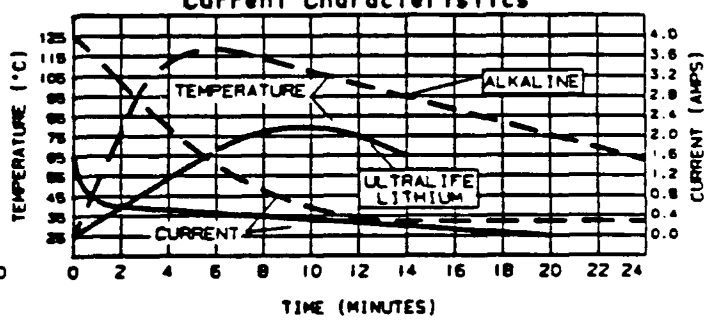


System:	Lithium/Manganese Dioxide, Li/MnO_2
Designation:	NEDA 1604LC
Nominal Voltage:	9.0 Volts
Rated Capacity:	1,200 mAh at 900 Ohms to 5.4 Volts
Maximum Discharge:	120 mA Continuous
Temperature Range:	-40°C to 70°C (-40°F to 158°F)
Weight:	34.4 grams
Volume:	22.18 cm³
Terminals:	Miniature Snap
Jacket:	Plastic Housing/Foil Label

Typical Continuous Discharge Capacity

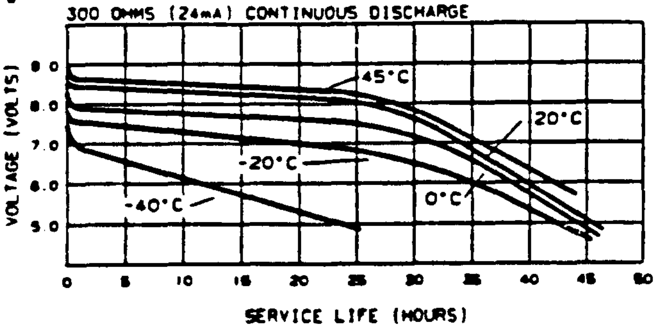


Typical Short Circuit Temperature & Current Characteristics



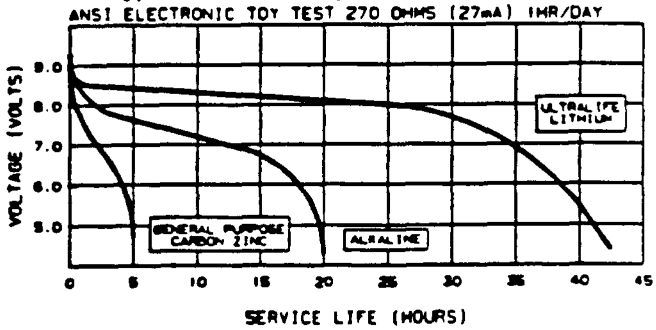
Typical Discharge Characteristics vs Temperature

300 OHMS (24mA) CONTINUOUS DISCHARGE

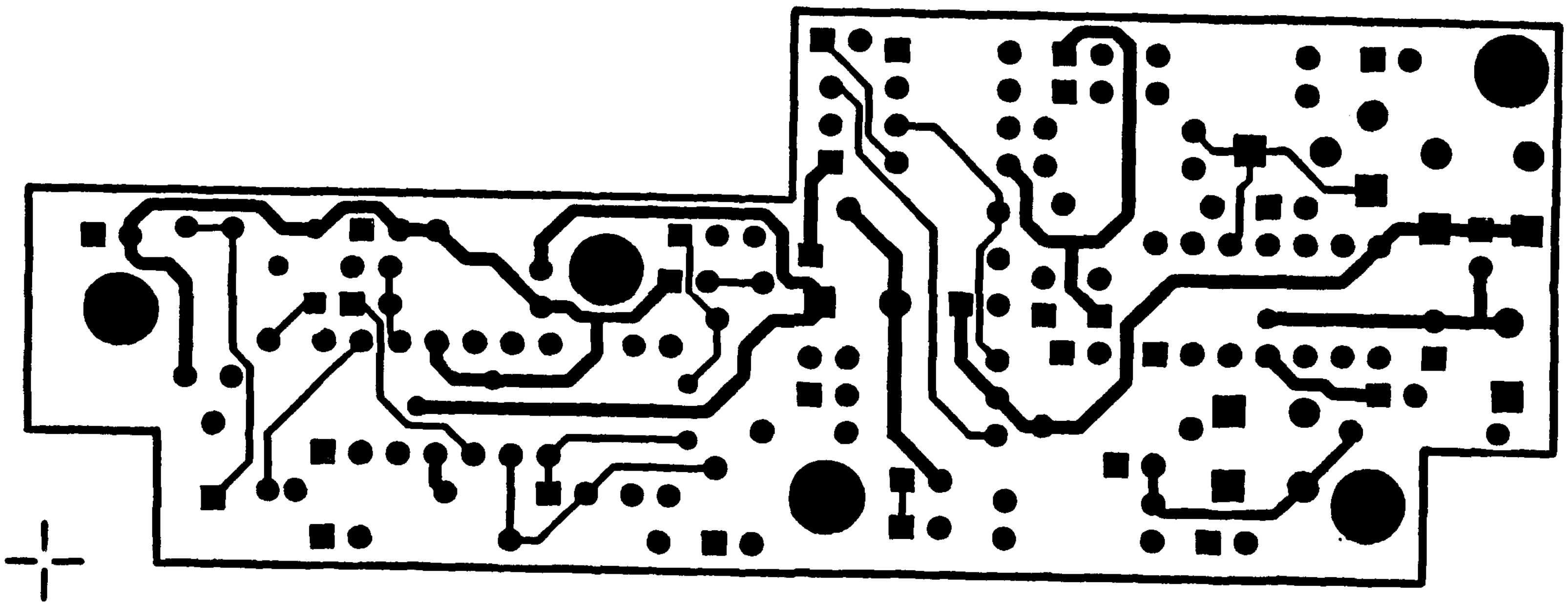


Typical Discharge Characteristics

ANSI ELECTRONIC TOY TEST 270 OHMS (27mA) 1HR/DAY

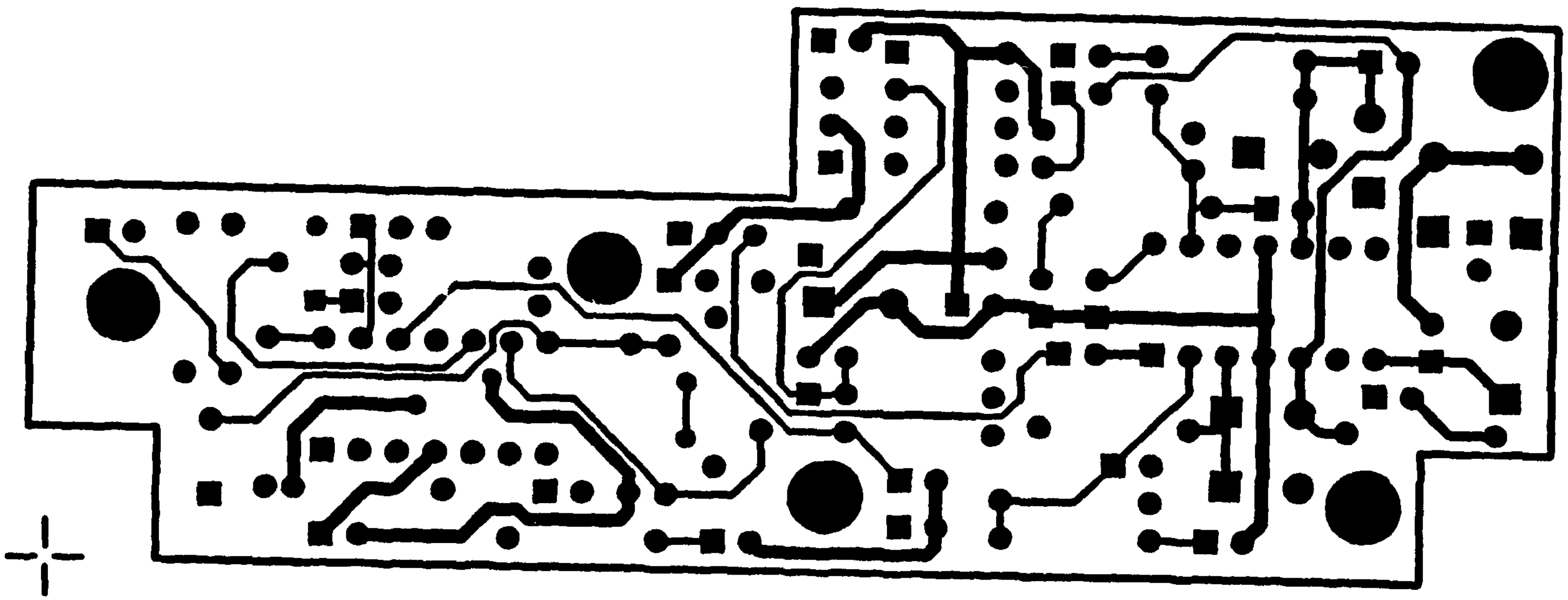


COMPONENT SIDE



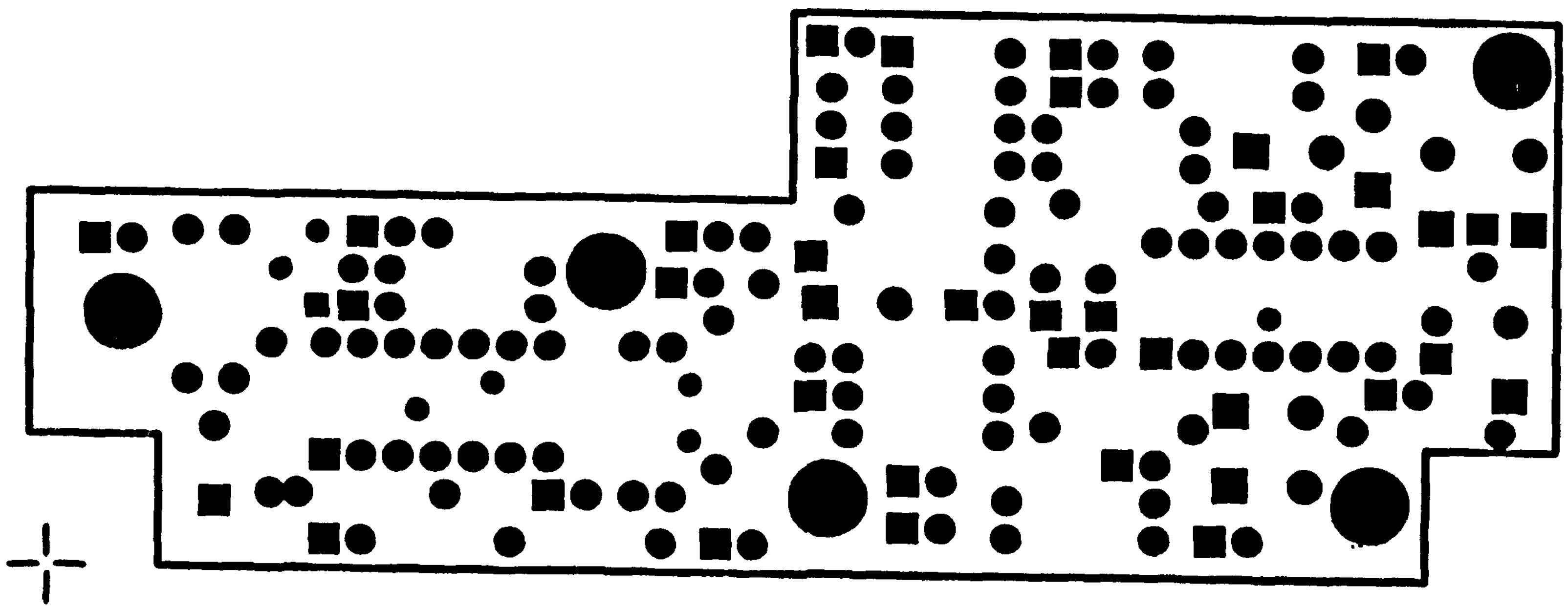
Communications Assist Circuit Printed Wiring Board

SOLDER SIDE

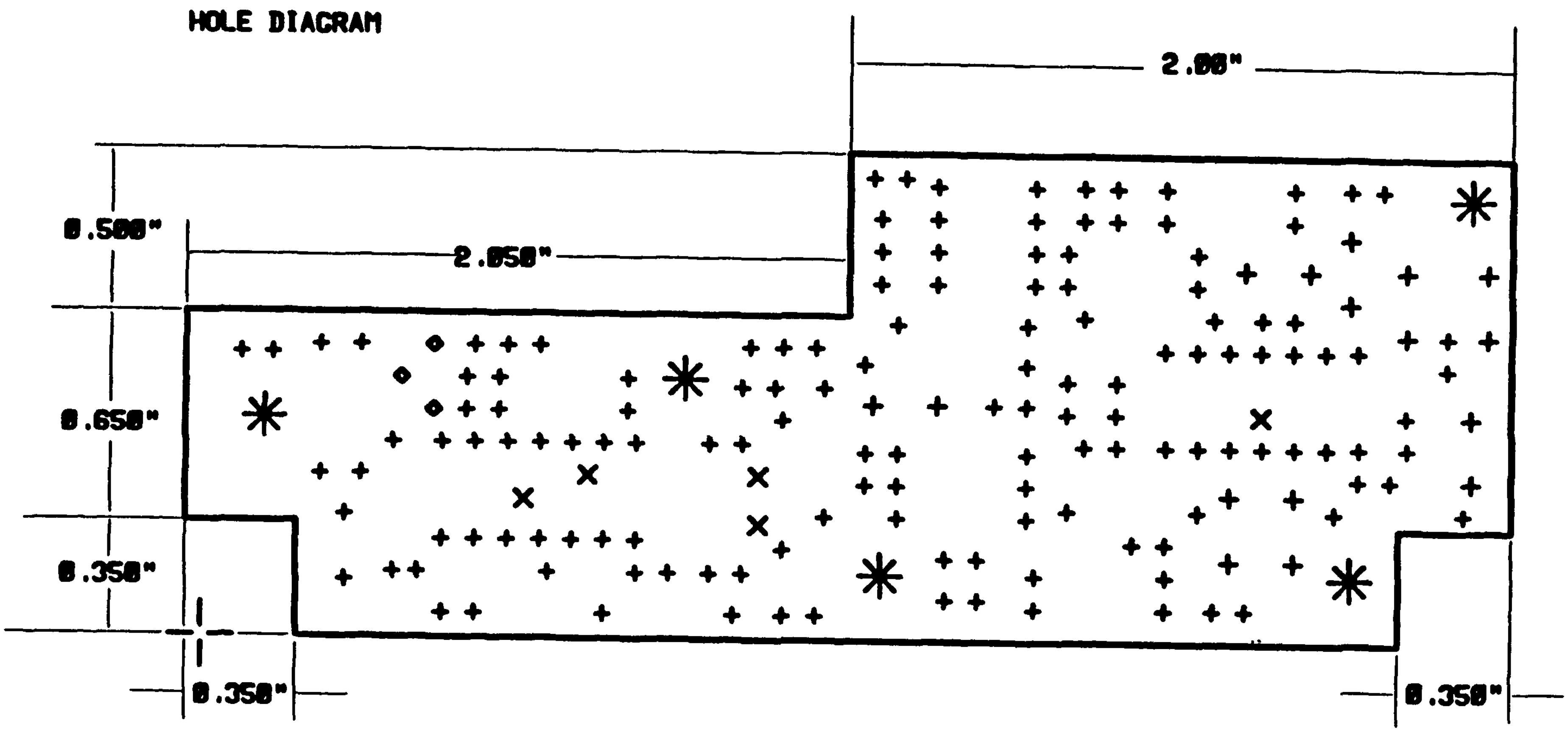


Communications Assist Circuit Printed Wiring Board

SOLDER MASK



Communications Assist Circuit Printed Wiring Board



Communications Assist Circuit Printed Wiring Board

MINIATURE FANS DC= Technical data

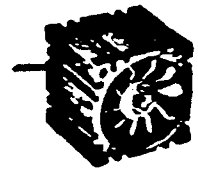
Notes: 1. Symbols ▶ Airflow direction
2. Std. leads are 7.5 inches long—24AWG

	V240	V300	V350	V360
Size:	.95×1.18 inch	1.18×1.42 inch	1.5×1.5×1.42 inch	1.42×1.77 inch
Voltage:	6/12 V=	6/12/24 V=	6/12/24 V=	6/12/24 V=
Housing:	cylindrical	cylindrical	square	cylindrical
Power:	0,3 W	0,84 W	1,2 W	1,2 W
Speed:	12500—14500 min⁻¹	13000—14000 min⁻¹	12000—13000 min⁻¹	12000—13000 min⁻¹
Air Vol.:	3.15 cfm	5.6 cfm	12.6 cfm	12.6 cfm
Air Pres.:	0,65—0,75 mbar	1,1—1,2 mbar	1,7 mbar max.	1,7 mbar max
Life:	1000 h CORRECTION ← 5000 h	1500 h CORRECTION ← 15000 h	1500 h CORRECTION ← 15000 h	1500 h CORRECTION ← 15000 h
Noise:	37—43 dB (A)	41 dB (A)	45—52 dB (A)	45—52 dB (A)
Temp:	−20 ...+65°C	−20 ...+65°C	−20 ...+65°C	−20 ...+65°C
Weight:	16 g	35 g	50 g	50 g
Bearing:	sleeve bearings	sleeve bearings	sleeve bearings	sleeve bearings

Screened area drawings are in mm.

V241K

V301L

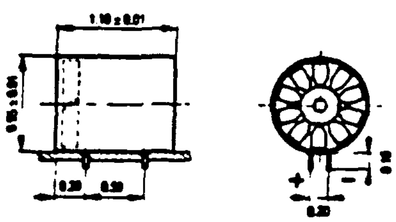


V351L

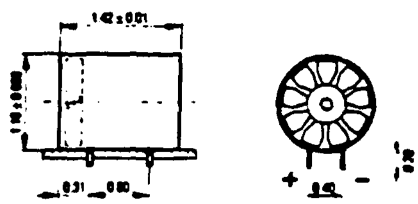
V361I

Direct current DC=

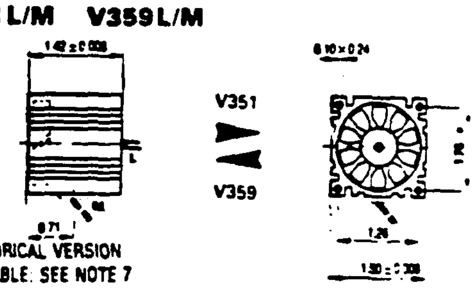
V241 K / V249 K
V241 ▶ V249 ◀



V301 K / V309 K
V301 ▶ V309 ◀

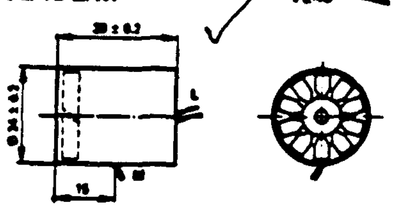


V351 L/M V359 L/M

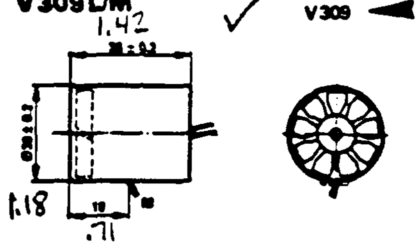


CYLINDRICAL VERSION AVAILABLE: SEE NOTE 7

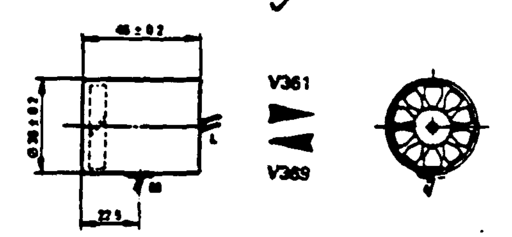
V241 L/M / V249 L/M
V241 ▶ V249 ◀



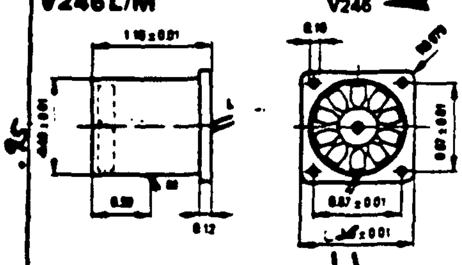
V301 L/M / V309 L/M
V301 ▶ V309 ◀



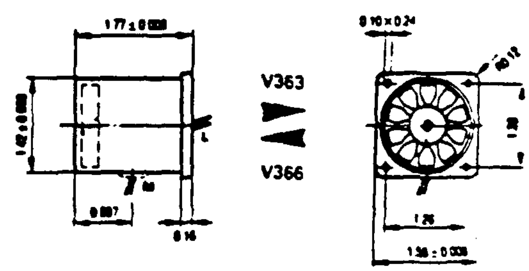
V361 L/M V369 L/M



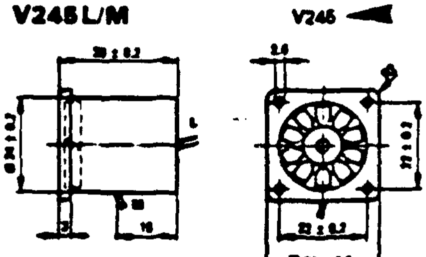
V243 L/M / V246 L/M
V243 ▶ V246 ◀



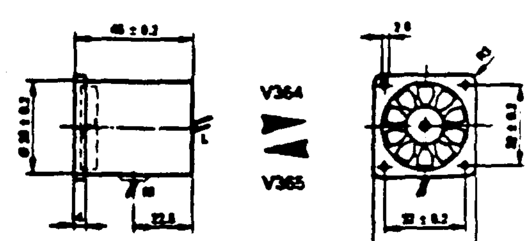
V363 L/M V366 L/M

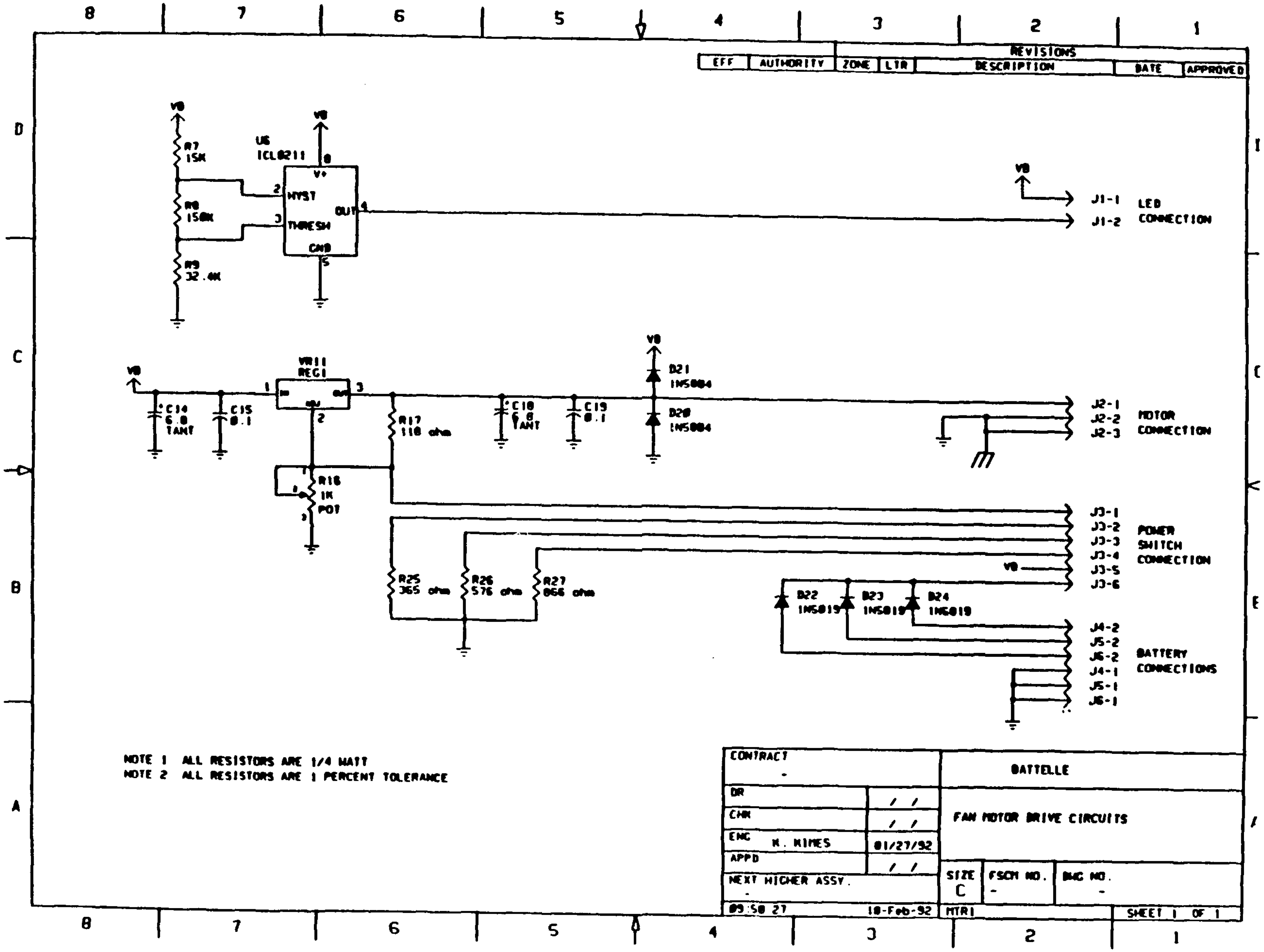


V244 L/M / V245 L/M
V244 ▶ V245 ◀

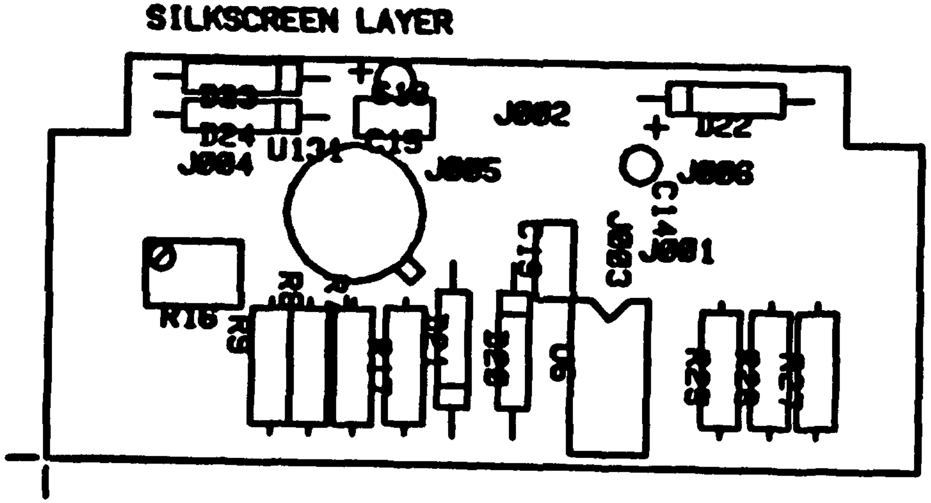


V364 L/M V365 L/M

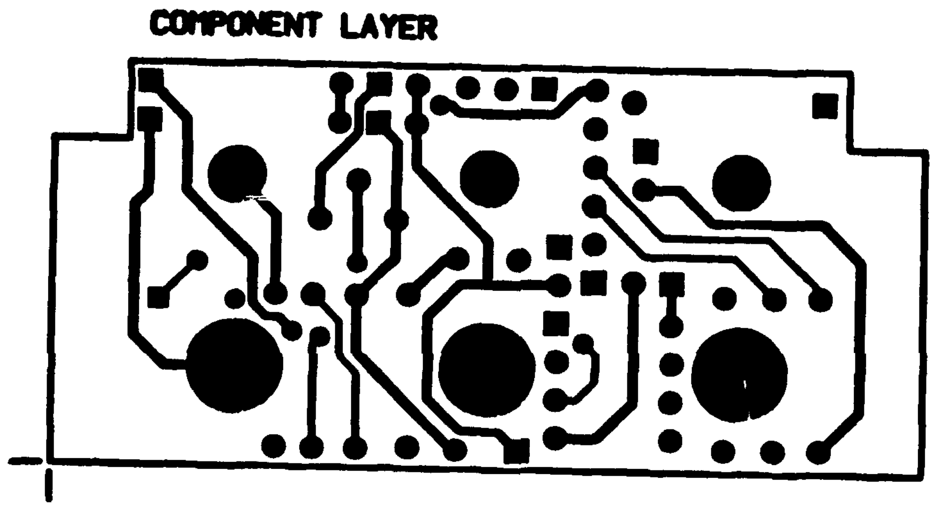




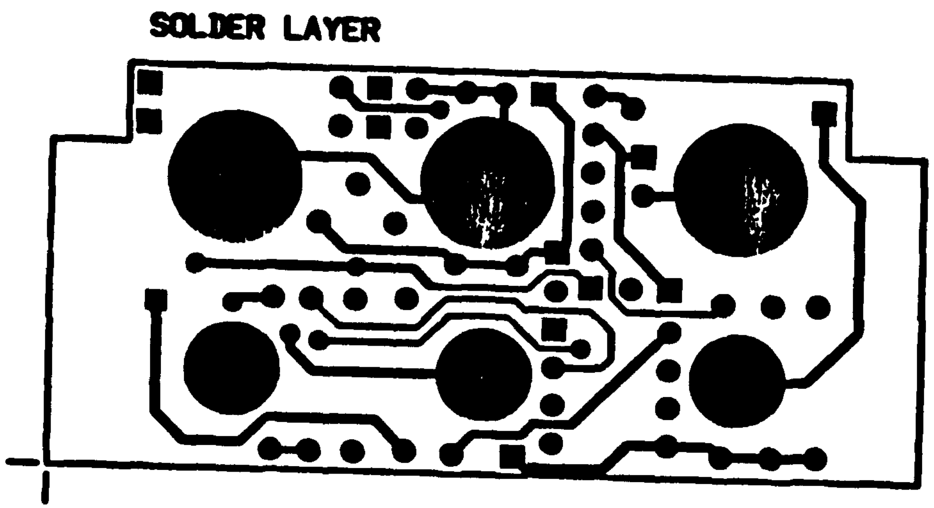
Fan Motor Drive Circuit Diagram



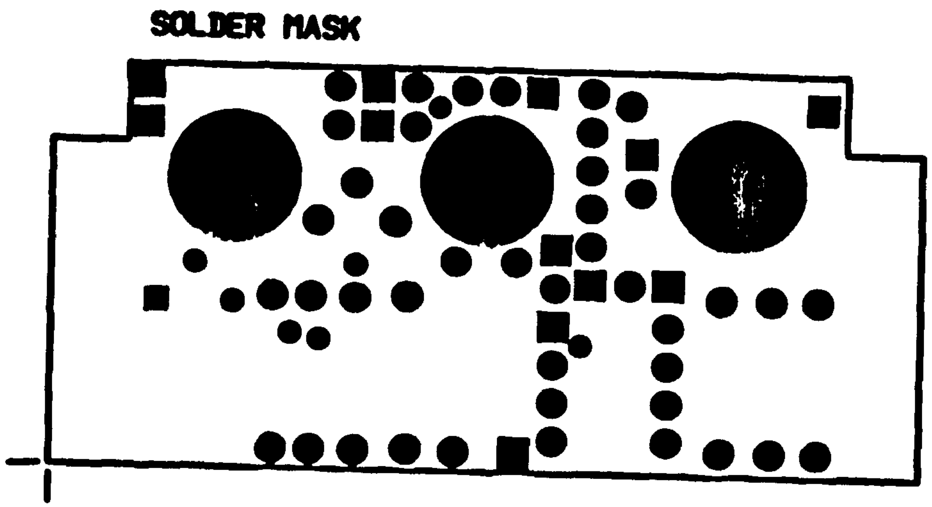
Fan Motor Drive Circuit Printed Wiring Board



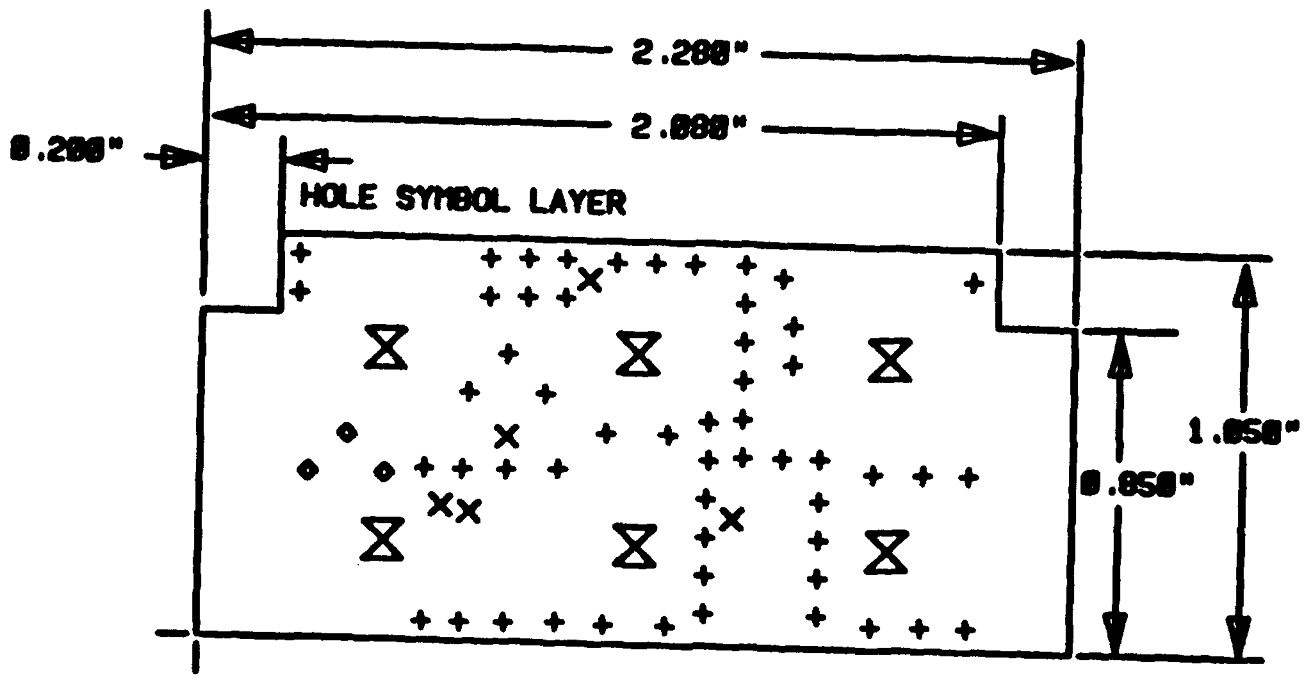
Fan Motor Drive Circuit Printed Wiring Board



Fan Motor Drive Circuit Printed Wiring Board

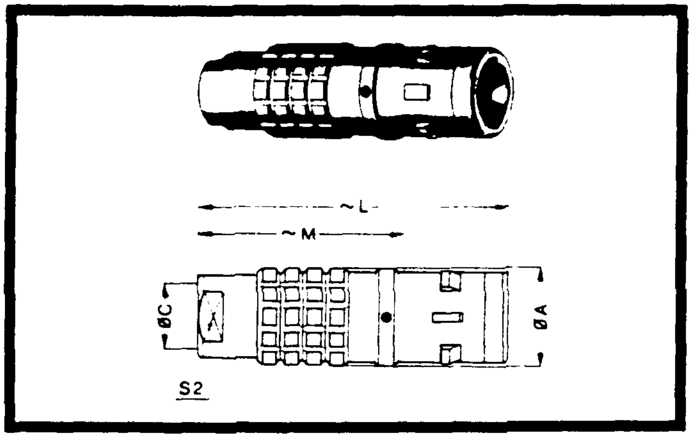


Fan Motor Drive Circuit Printed Wiring Board



Fan Motor Drive Circuit Printed Wiring Board

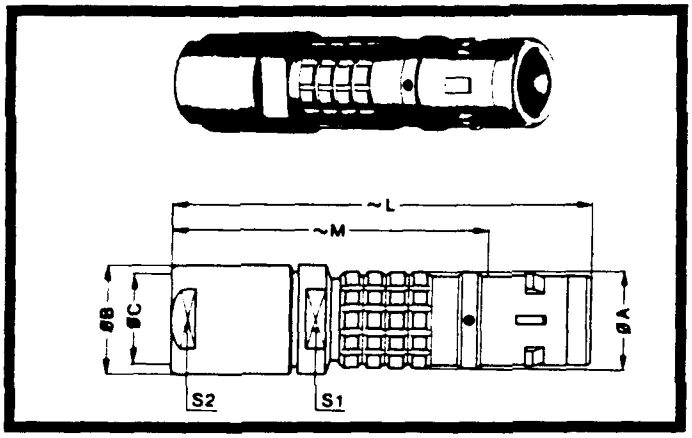
K Series–Plugs



FGG

Straight plug with cable collet

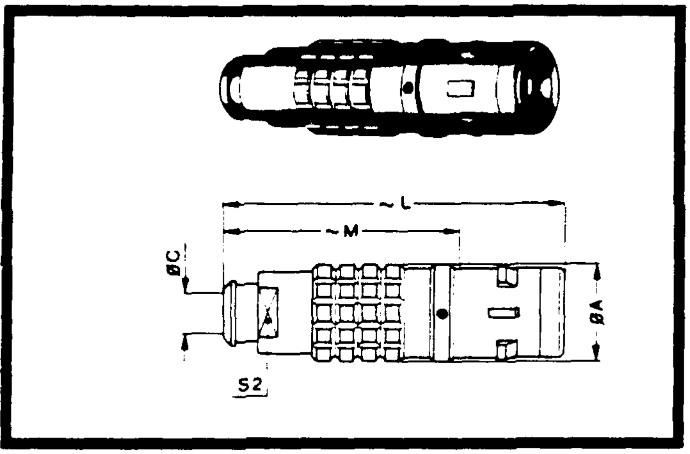
Series	Dimensions (mm)				
	A	C	L	M	S2
0K	11	6.2	34	23.0	7.9
1K	13	7.1	42	28.0	8.9
2K	16	9.2	52	36.0	11.9
3K	19	10.5	61	41.0	14.9
4K	25	14.0	71	50.5	18.9
5K	38	23.5	92	67.0	31.9



FGG

Straight plug with oversized collet nut

Series	Dimensions (mm)						
	A	B	C	L	M	S1	S2
1K	13	14.5	9.2	55	41	11.9	11.9
2K	16	17.0	10.5	65	49	14.9	14.9
3K	19	22.0	15.3	80	60	18.9	18.9
4K	25	136.0	23.5	105	84	30.0	31.9



FGG

Straight plug with cable collet and backnut to accommodate a strain relief

Series	Dimensions (mm)				
	A	C	L	M	S2
0K	11	5.2	37.0	26.0	7.0
1K	13	7.1	45.0	31.0	9.0
2K	16	8.7	49.0	33.0	11.9
3K	19	10.8	62.0	42.0	15.0
4K	25	15.3	78.5	50.5	18.9

Please see page 65 for strain reliefs.

LD-SERIES MINIATURE 2, 3 & 4 CONTACT CONNECTORS

Inner Cable Conductors: Solder or Crimp[1] to contacts

Cable Retention: Compression fitting

Moisture Resistance: Sealing Sleeves

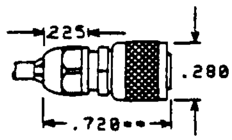
Coupling Type: Screw-On

Cable: AWG 30, Microtech MS-4 cable Max. jacket O.D. .150"

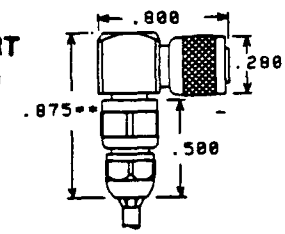
ALL Threads #1/4-28 NF
MOISTURE RESISTANT
COMPRESSION TYPE

PLUGS

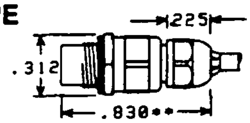
LDP-4S-1
Straight Plug



LDP-4S-1RT
Right Angle
Plug

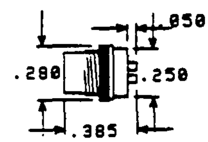


RECEPTACLES

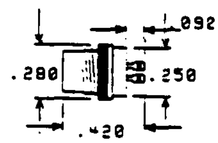


LDR-4S-3
Jack

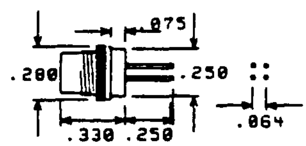
LDR-4S-3P
Panel Jack



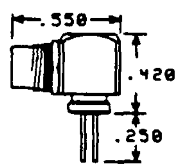
DR-4S-4
Solder Mount



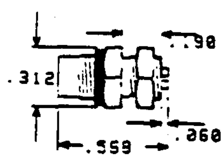
DR-4S-4H
Solder Mount
Hermetic Seal



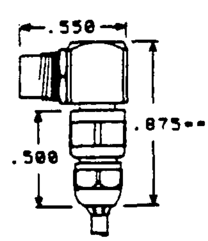
DR-4S-4PC [2]
Printed Circuit



DR-4S-4PC-RT
Right Angle P.C.



DR-4S-6
Threaded Mount



LDR-4S-3RT
Right Angle Jack

XX-2S-XX
2-CONTACTS

XX-3S-XX
3-CONTACTS

PLUGS*

LDP-2S-1
LDP-2S-1RT

RECEPTACLES

LDR-2S-3
LDR-2S-3P
DR-2S-4
DR-2S-4PC
DR-2S-4PC-RT
DR-2S-6
LDR-2S-3RT

PLUGS*

LDP-3S-1
LDP-3S-1RT

RECEPTACLES*

LDR-3S-3
LDR-3S-3P
DR-3S-4
DR-3S-4PC
DR-3S-4PC-RT
DR-3S-6
LDR-3S-3RT

* Use XX-2S-XX in part numbers for 2-contacts.
Use XX-3S-XX in part numbers for 3-contacts.
All shell sizes and dimensions are the same as shown above for the XX-4S-XX, 4 contact connectors.

[1] All LD-Series connectors are available with crimp type contacts. To order add C to model number.
XXCX-XX-XX

For .090" Min. to .150" Max. Cable O.D., AWG 28 to AWG 30

[2] Drill clearance holes for .018" leads

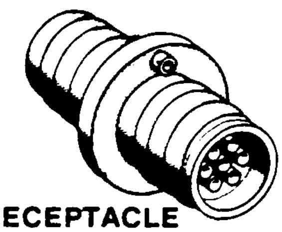
** Dependent on amount of clamping required

NANONICS® CORPORATION

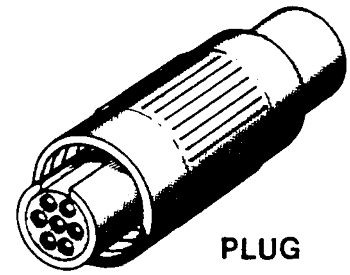
NANOMINIATURE CIRCULAR CONNECTORS (.025" CENTERS)

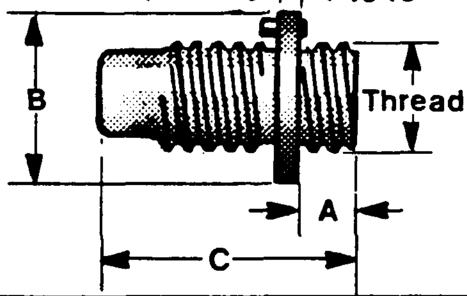
A NEW PRODUCT WITH ALL THE MATURE FEATURES!*

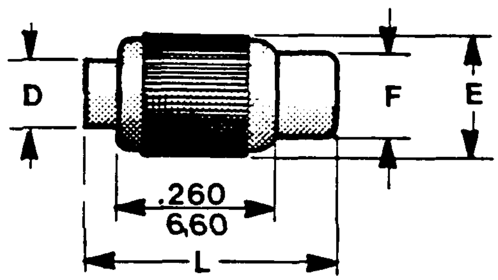
THE "C" SERIES



- Full perimeter RFI / EMI seal
  - RFI / EMI grounding surface environmentally sealed
  - Controlled deflection without rotation on the seal
  - Shell grounding avoids any rotating components
- pin or socket contacts in either plug or receptacle
- Environmentally sealed, mated or unmated
- Sheild termination on plug and receptacle
- Scoop proof mating protects contacts
- Plug to receptacle grounding
- Quick coupling with less than two (2) turns
- Straight or 90 degree terminations
- Stainless Steel, -55C to 200C temperature range
- Front or rear panel mount; lock pin (removable) or "loctite" bonding



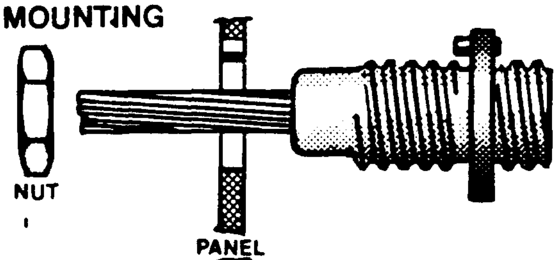


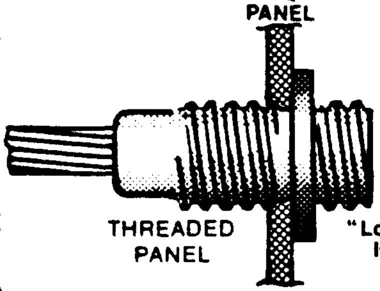


size	Thread	A (mm)	B (mm)	C (mm)	A (inch)	B (inch)	C (inch)
7	4.5 X.75	4.75	7.04	11.10	.187	.277	.437
19	6	5.41	8.53	11.77	.213	.336	.463
37	8X1	6.07	10.54	12.42	.239	.415	.489
61	10	6.73	12.55	13.08	.265	.494	.515

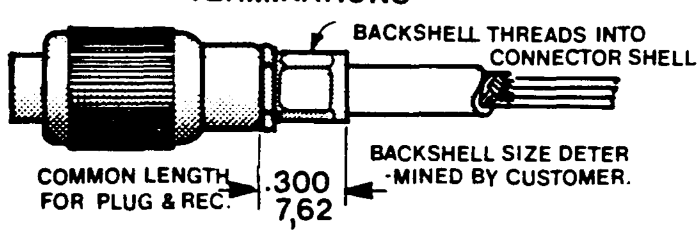
size	L (mm)	D (mm)	E (mm)	F (mm)	L (inch)	D (inch)	E (inch)	F (inch)
7	10.42	2.80	5.00	3.56	.410	.110	.197	.140
19	11.07	4.06	6.50	5.08	.436	.160	.256	.200
37	11.74	5.33	8.51	7.11	.462	.210	.335	.280
61	12.40	6.60	10.50	9.15	.488	.260	.413	.360

MOUNTING

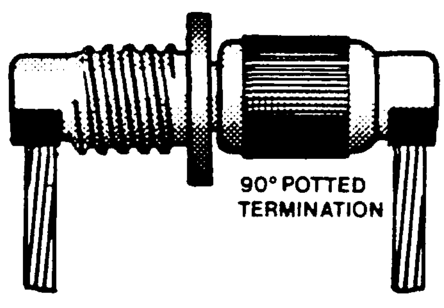




TERMINATIONS



ACTUAL SIZE
7 CONTACTS



REV 1.1

NANONICS® CORPORATION
204A E. EMERSON AVE., ORANGE, CA 92665
800-242-NANO 714-974-6246

LD-SERIES MINIATURE 2, 3 & 4 CONTACT CONNECTORS

Inner Cable Conductors: Solder or Crimp[1] to contacts

Cable Retention: Compression fitting

Moisture Resistance: Sealing Sleeves

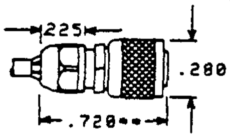
Coupling Type: Screw-On

Cable: AWG 30, Microtech MS-4 cable Max. jacket O.D. .150"

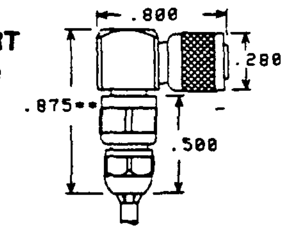
ALL Threads #1/4-28 NF
MOISTURE RESISTANT
COMPRESSION TYPE

PLUGS

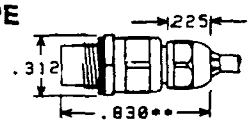
LDP-4S-1
Straight Plug



LDP-4S-1RT
Right Angle Plug

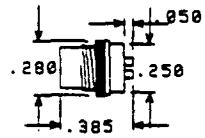


RECEPTACLES

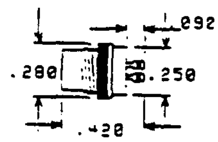


LDR-4S-3
Jack

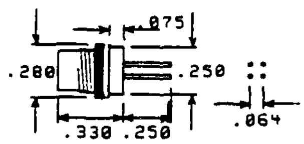
LDR-4S-3P
Panel Jack



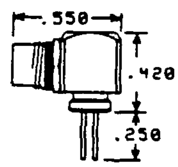
DR-4S-4
Solder Mount



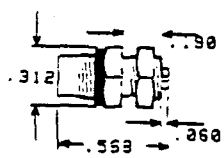
DR-4S-4H
Solder Mount
Hermetic Seal



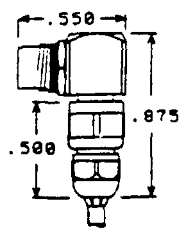
DR-4S-4PC [2]
Printed Circuit



DR-4S-4PC-RT
Right Angle P.C.



DR-4S-6
Threaded Mount



LDR-4S-3RT
Right Angle Jack

XX-2S-XX
2-CONTACTS

XX-3S-XX
3-CONTACTS

PLUGS*

LDP-2S-1
LDP-2S-1RT

RECEPTACLES

LDR-2S-3
LDR-2S-3P
DR-2S-4
DR-2S-4PC
DR-2S-4PC-RT
DR-2S-6
LDR-2S-3RT

PLUGS*

LDP-3S-1
LDP-3S-1RT

RECEPTACLES*

LDR-3S-3
LDR-3S-3P
DR-3S-4
DR-3S-4PC
DR-3S-4PC-RT
DR-3S-6
LDR-3S-3RT

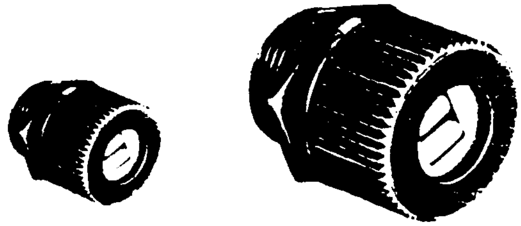
* Use XX-2S-XX in part numbers for 2-contacts.
Use XX-3S-XX in part numbers for 3-contacts.
All shell sizes and dimensions are the same as shown above for the XX-4S-XX, 4 contact connectors.

[1] All LD-Series connectors are available with crimp type contacts. To order add C to model number.
XXCX-XX-XX

For .090" Min. to .150" Max. Cable O.D., AWG 28 to AWG 30

[2] Drill clearance holes for .018" leads

** Dependent on amount of clamping required



Actual Size

LOW POWER (50 mw) BITE Indicators

Model MI 51LP
Qualified to MIL-I-83287/04

FEATURES
50 Milliwatt Sensitivity
Manual Reset Spring Return
Magnetic Latching
Positive Indication
Environmentally Sealed

This is a dual drum, magnetic latching indicator that requires only pulse power for fault indication. The main feature of this indicator is that it can be MANUALLY RESET. When a fault has occurred, the internal drums are positively held in a magnetic-locked position. Reset is accomplished manually by rotating the knurled ring clockwise 60 degrees. The knob returns to its normal position automatically.

This miniature indicator has a high latching capability, and it provides excellent positive indication under shock and vibration. It will provide fast response in any position and offers excellent visibility in a strong incident light.

ELECTRICAL SPECIFICATIONS
Standard Coil Voltages and Resistances

DC Coil Resistance in Ohms, ±10% @ 25°C	Nominal Voltage DC	Operating Voltage Min Required	Operating Voltage Max Allowed
45	1.5	1.2	1.8
180	3	2.4	3.6
500	5	4.0	6.0
720	6	4.8	7.2
2,880	12	9.6	14.4
11,500	24	19.2	30.0
15,700	28	22.4	35.0

Pulse Power: 50 mw. Nominal
Pulse Length: 25 milliseconds, minimum.
Dielectric Withstanding Voltage: 500 V RMS
Insulation Resistance: 1,000 megohms minimum at 500 VDC.
Electromagnetic Interference and Magnetic Susceptibility: Per MIL-I-83287. The MI 51LP will not malfunction or false transfer when subjected to a 20 ampere turn field at 400 Hertz.

MECHANICAL SPECIFICATIONS
Case: Black, anodized aluminum.
Mounting: Front panel mount (D hole or keyed washer)
Weight: 6.5 Grams
Display Colors: "NO FAULT" (reset) is black, "FAULT" (set) is white, as shown.
Terminations: Solder terminals (turret type), and wire leads standard per MIL-I-83287.
Solder loops also available. Designations are:

Turret Terminals	TT (Standard)
Wire Leads	WL (Standard)
Loop Terminals	LT (Special)

Reset: Unit is manually reset by rotating the knurled ring clockwise to stop, knob returns counter-clockwise to normal position. Reset knob is black anodized aluminum with sealed glass window.

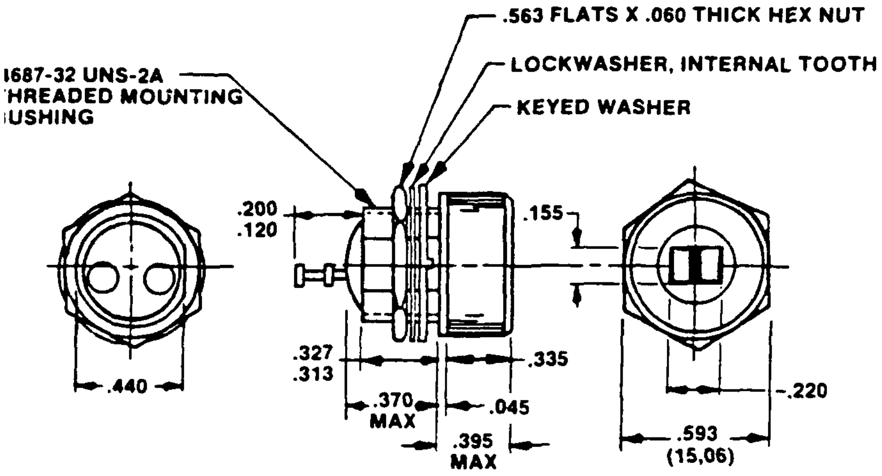
ENVIRONMENTAL SPECIFICATIONS
Operating Temperature Range: -65°C to +125°C.
*Vibration**: .06" D.A. or 15 G Peak, whichever is less, 10 Hz to 2 KHz per MIL STD 202, Method 204, Test Condition B.
Shock: 100 G's MIL STD 202, Method 213, Test Condition I.
Moisture Resistance: (Humidity): MIL STD 202, Method 106.
Altitude: 100,000 ft., MIL STD 202, Method 105, Test Condition D.
Thermal Shock: MIL STD 202, Method 107, Test Condition B.
Salt Spray: MIL STD 202, Method 101, Test Condition B.
Life: 10,000 cycles at cycling rate of 10 per minute.

*During vibration testing caution should be taken to shield the indicator from the strong magnetic field.

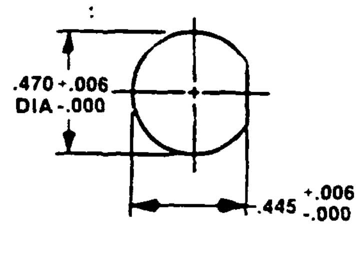
Patent No. 3,465,333

MINELCO INC. | Talley™ Industries
135 SOUTH MAIN ST. • THOMASTON, CT 06787-0459 • PHONE 203-283-8261 • TWX 710-475-1091 • FAX 203-283-6527

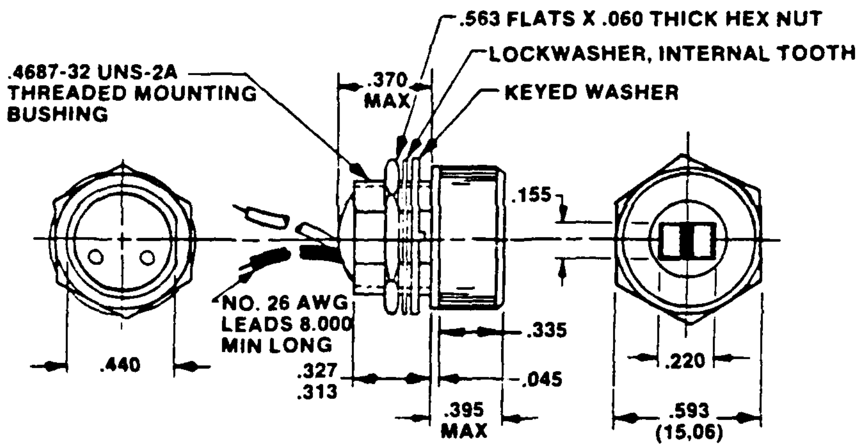
[I]ndicator Miniature BITE™ Model MI 51LP



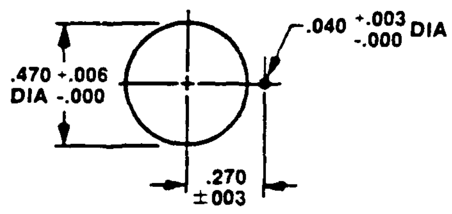
SOLDER TERMINALS



PANEL LAYOUT

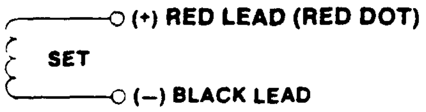


WIRE LEADS



OPTIONAL PANEL LAYOUT USING KEYED WASHER

Mounting Torque: 5-7 in-lbs.



SCHEMATIC

TOLERANCES
2 PLACE DECIMALS ±.010
3 PLACE DECIMALS ±.005

DIMENSIONS IN PARENTHESES ARE MM.

FOR MM CONVERSION: MULTIPLY BY 25.4

[O]RDERING INFORMATION

[Pa]rt may be ordered by utilizing the MIL designation [or] by the following designation:

Basic [M]odel [N]umber	Coil Voltage	Color Combination	Terminal Type	Factory Modification No. if Special
[M]I 51LP -(	)- (Set) / (Reset) -(	)-(	)	

[Ex]ample: Basic unit for 12 volts, standard colors, and [tu]rret terminals would be: [M]odel MI 51LP - 12 -W/BLK - TT.

The following specifications - where applicable - are applied to the production, packaging, and test procedures of these indicators: MIL-STD-202, MIL-STD-105, MIL-STD-129 MIL-STD-130, MIL-Q-9858, and MIL-I-83287.

This is just one of the many standard MINELCO miniature electronic components. We invite inquiries on other BITE indicators and our complete line of rotary selector switches, DIP switches and LED indicators.

[M]INELCO INC. | Talley™ Industries

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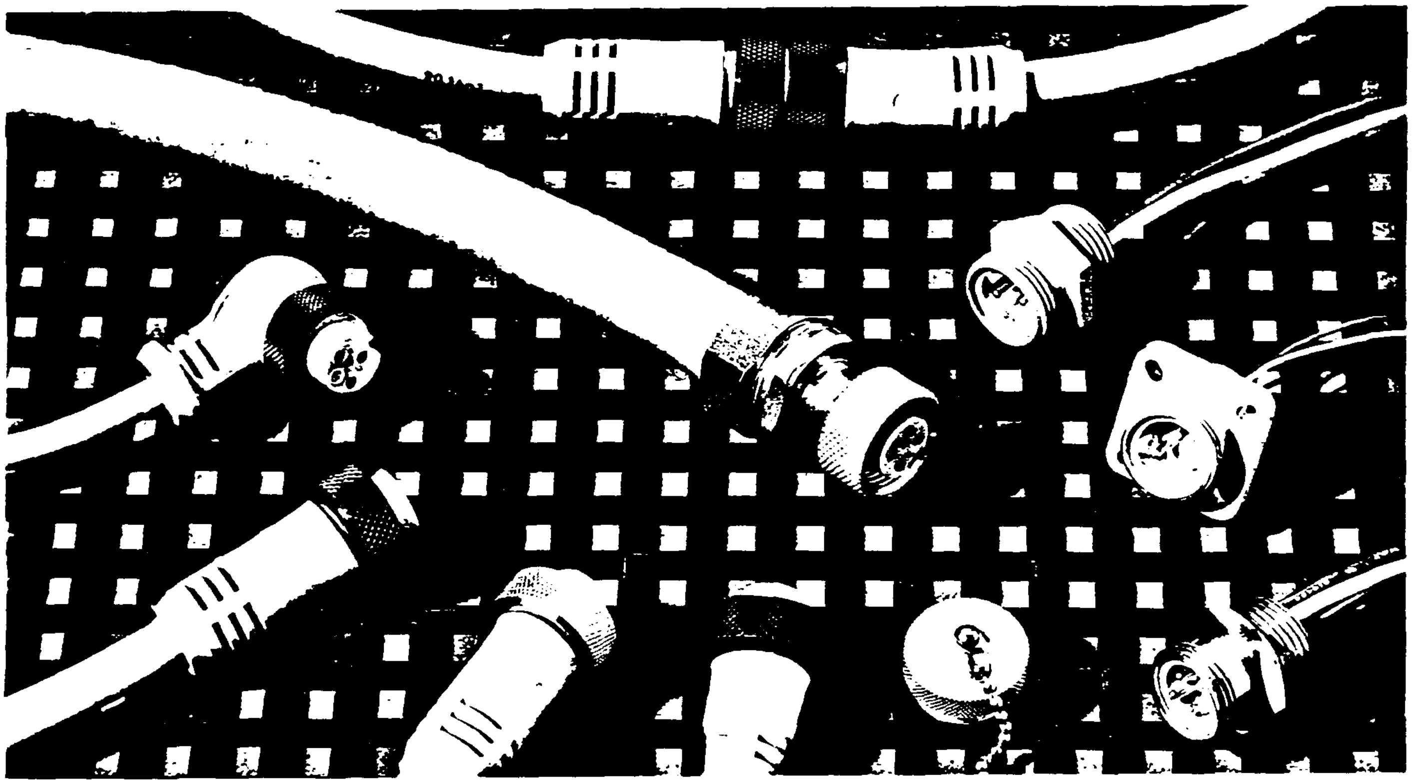
5K

Mini-Change® Molded Connectors



Brad Harrison Mini-Change® plugs and receptacles have set the design standard for rugged, long-lasting performance.

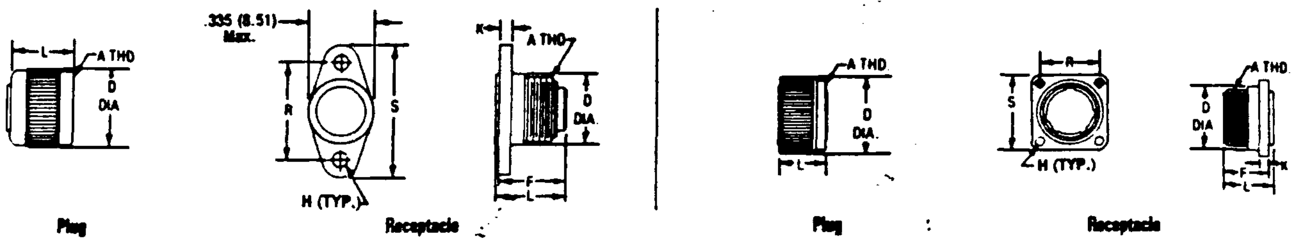
Mini-Change® Molded Connectors have been reducing downtime in a variety of industries and applications for twenty years. The extensive Mini-Change line features plugs and receptacles in 2 through 12-pole configurations, from 7 to 13 amps, all rated at 600 volts. Mini-Change connectors offer exclusive design attributes that ensure long-lasting performance under all sorts of harsh conditions:

- Seamless pins are machined from solid stock to prevent moisture from entering the connector through the contact.
- All mating parts are mechanically keyed to eliminate mismating of devices, thereby preventing damage to control equipment.
- A raised rubber collar around insert and receptacle pins forms a cork-in-bottle seal, which keeps moisture, oils, dirt and other contaminants away from contacts, reducing the risk of shorting.
- The unique contact design provides superior strain relief, reducing the risk of wire breakage while enhancing connection integrity.
- The connector head design features vents which "radiate" cable bend away from contact points, preventing wire breakage that can occur with excessive vibration.
- A brass retaining collar on female contacts applies constant pressure to prevent intermittent contact, significantly reducing costly trouble-shooting and downtime.

Mini-Change connectors are supplied with heavy-duty STO cable which resists the harmful effect of hydraulic fluids, cutting oils, and abrasion. Product options include 18 AWG female plugs, stainless steel or thermoplastic hardware, and custom-length cables.

Shell Dimensions (Continued)

MIKM (Rear Panel Mount Thickness .335 (8.51) max. – see Tabulation "T")



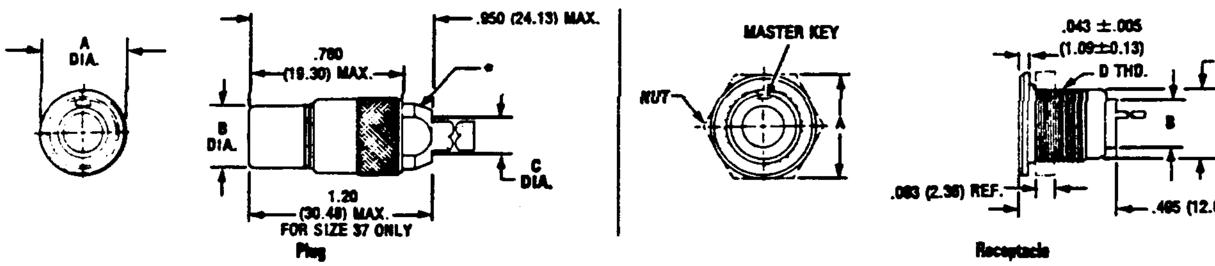
Plug

Part Number by Shell Size	A Thread	D Max.	L Max.	Avg. Weight oz. (gm.) ±5%
MIKM6-7P	5/16-24UNF-2A	.375 (9.52)	.315 (8.00)	.054 (1.54)
MIKM6-55P	5/8-24UNEF-2B	.755 (19.18)	.440 (11.18)	.333 (9.44)
MIKM6-85P	11/16-24UNEF-2B	.860 (21.84)	.460 (11.68)	.419 (11.88)

Receptacle

Part Number by Shell Size	A Thread	D	F Max.	H ±.003 (0.08)	K	L Max.	R ±.005 (0.13)	S Max.	T Max.	Avg. Weight oz. (gm.) ±5%
MIKM0-7S	5/16-24UNF-2A	.325 (8.26)	.320 (8.13)	.078 (1.98)	.062 (1.57)	.400 (10.16)	.460 (11.68)	.630 (16.00)	.032 (0.81)	.051 (1.45)
MIKM0-55S	5/8-24UNEF-2A	.625 (15.88)	.440 (11.18)	.091 (2.31)	.062 (1.57)	.490 (12.45)	.580 (14.73)	.760 (19.30)	.125 (3.18)	.269 (7.62)
MIKM0-85S	11/16-24UNEF-2A	.745 (18.92)	.440 (11.18)	.091 (2.31)	.062 (1.57)	.490 (12.45)	.674 (17.12)	.845 (21.46)	.125 (3.18)	.346 (9.80)

MIKQ (Front Panel Mounting Type Shown–.093 (2.36) Thickness)



Plug

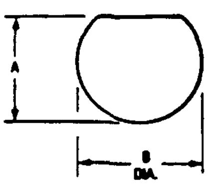
Part Number by Shell Size	A Max.	B Max.	C Ref.	Avg. Weight oz. (gm.) ±5%
MIKQ6- 7S	.385 (9.78)	.305 (7.75)	.180 (4.57)	.214 (6.08)
MIKQ6-19S	.515 (13.08)	.405 (10.29)	.260 (6.60)	.376 (10.70)
MIKQ6-37S	.760 (19.30)	.635 (16.13)	.350 (8.89)	.714 (20.23)

*Std. Conn. not supplied with Cable Nut & Grip. See Mod Codes. Lanyard Release is available. Consult factory.

Receptacle

Part Number by Shell Size	A Max.	B Max.	C Max.	D Thread	Avg. Weight oz. (gm.) ±5%
MIKQ7- 7P	.510 (12.95)	.245 (6.22)	.359 (9.12)	3/8-32UNEF-2A	.128 (3.63)
MIKQ7-19P	.575 (14.60)	.345 (8.76)	.470 (11.94)	1/2-28UNEF-2A	.214 (6.08)
MIKQ7-37P	.855 (21.71)	.520 (13.20)	.740 (18.80)	3/4-20UNEF-2A	.300 (8.52)

MIKQ Front Panel Mounting



Front Panel Mounting-MIKQ7

Shell Size	A ±.005 (0.13)	B Dia.
MIKQ7-7P	.364 (9.24)	.390 (9.91)
MIKQ7-19P	.475 (12.06)	.515 (13.08)
MIKQ7-37P	.740 (18.78)	.755 (19.17)

ITT Cannon

Dimensions are shown in inches (millimeters). Dimensions subject to change.

Microminiature Products • 666 E. Dyer Rd., P.O. Box 929, Santa Ana, CA 92702-0929 • (714) 557-4700 • FAX (714) 754-2142