Data Acquisition and Analysis System Based on a Lap-Top Computer

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Described in this paper is a data acquisition and analysis system based on a lap-top computer that is compatible with an IBM personal computer (PC). The hardware consists of a computer with a standard buss slot and analog-to-digital input/output card. The software permits acquiring up to eight analog signals of data, four of which can be plotted on the computer display screen as data are acquired. Data can be stored as standard ASCII files or in compact binary form to minimize file size and speed input/output. At the end of a data collection run, data can be scaled easily and plotted for review. Additional data reduction features permit data smoothing and crossplots between any pair of variables. The system replaces conventional tape recorders and strip chart recorders and stores data in a format convenient for further computer processing. The system can operate on 12-volt vehicle power and is compact and lightweight. The approach provides a convenient, lightweight, portable means to record and display vehicle motion and driver/rider response variables. Some data reduction can be accomplished online, and data can be easily processed and reviewed between runs to guide subsequent test conditions. Several popular lap-top computers with accessible PC busses are compatible with the approach. Some existing systems that could be used include the Datavue Snap 1+1 and the GRID Case Exp.

Data acquisition is a routine requirement in field testing vehicle response and driver/rider behavior. Acquisition systems must be able to monitor, condition, record, and review data. In the past, these requirements were met with combinations of electronics, tape recorders, and strip chart recorders (*1*). Where minimum weight was required, telemetry was used to permit off-board recording (*2*).

With the advent of microprocessor and microcomputer technology, a variety of data acquisition systems have been developed. These systems include both special purpose microprocessor-based systems (*3*) and systems that incorporate standard or ruggedized commercial microcomputers (*4,5*). Commercial microcomputers permit access to low-cost technologies, including disk storage, analog-to-digital converters, and software. This approach has been taken with the system discussed below.

SYSTEM DESCRIPTION

The data acquisition system is shown in Figure 1. It includes sensors, data conditioning electronics, and an acquisition and storage computer. The sensors consist of a variety of conventional elements that are specified for a given application, including potentiometers, tachometers, accelerometers, rate gyros, pressure transducers, thermocouples, and fuel flow meters. Transducer outputs are conditioned with conventional analog electronics to supply filtered voltage signals for analog-to-digital (A/D) conversion.

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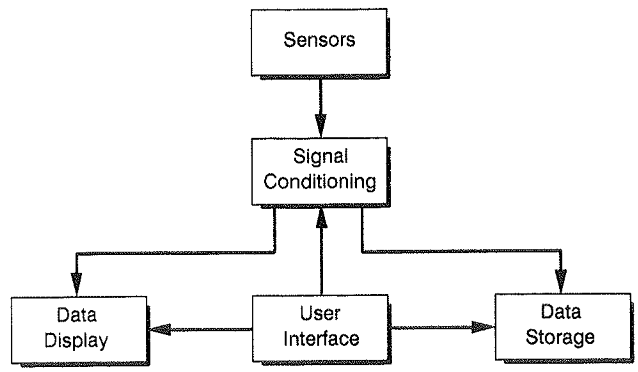
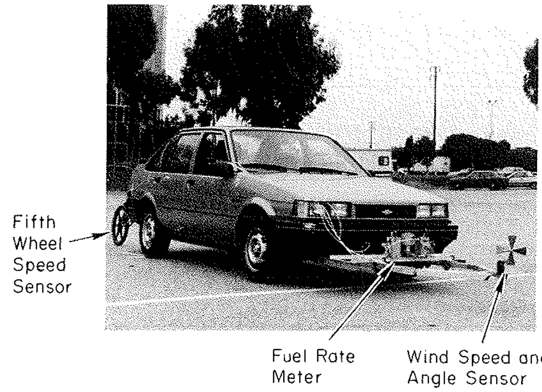


FIGURE 1 Typical data acquisition system elements.

Several A/D cards are available that will plug directly into microcomputer busses. The reason for configuring the current system was to obtain low-cost, lightweight hardware that could be configured conveniently with software. A variety of lightweight portable computers are available that are compatible with IBM personal computers (PCs) have accessible buss slots for installing expansion cards. A conventional portable computer, compatible with an IBM PC, was used for the prototype application, which involved automobile fuel economy tests. A Datavue Snap 1+1 lap-top computer was used for the second application, which involved lightweight, off-road vehicle testing. In both cases, a Metrobyte DAS-16 16-channel card with 12-bit resolution was used for A/D conversion.

The signal conditioning unit, shown in Figure 2, amplifies and filters sensor signals. Signals are amplified to give voltages within the range of 1 to 10 volts. The 12-bit resolution of the Metrobyte card then gives signal resolutions better than 0.5 percent. Filter break frequencies are set at least three times below the A/D sampling rate to avoid aliasing.

Software was developed to permit online sensor checkout and data monitoring, data recording and permanent storage, and data replay with limited data processing. The software allows the user to (a) specify signal scaling for up to eight recorded signals, (b) select up to four signals that can be monitored on the computer screen during data acquisition,



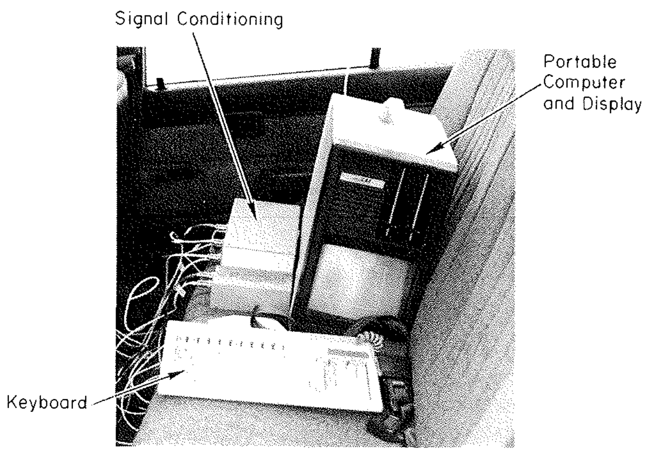


FIGURE 2 Vehicle instrumentation for fuel economy tests.

and (c) select all eight signals, four at a time, for post-run data review. The sampling rate can be specified up to 20 Hz for eight channels on a 4.7-MHz machine. This sampling capability is adequate for driver/rider behavior and most vehicle response variables. Higher sampling rates can be obtained with fewer signals and a faster processor clock rate (e.g., up to 500 Hz on a 16-MHz 80386 PC).

Run length varies up to the limit of memory, which is approximately 1.5 mins of data acquisition at 20 Hz for eight channels on a 640K byte machine. Run lengths can be increased by reducing the sampling rate and number of channels sampled. Extended memory can be added to expand data storage capability, which is provided by floppy disks. The current hardware configuration uses a machine with two 3½-in floppy disks that can store up to 720K bytes of data. Data input/output allows the user to write binary files as opposed to the standard ASCII file format. Binary files are 20 percent shorter than standard ASCII files and can be written and loaded five to seven times faster. The data files contain both raw data and scale factors, and file naming conventions can identify each file uniquely.

While the system is running, all data are stored in random access memory (RAM). When a test run is finished, data are written onto floppy disks. At the start of the next run, the program clears all of the previously used RAM memory. Although the data are written onto a disk after each run, the disk should be removed during test runs to prevent damage and possible loss of data.

APPLICATIONS

The computer data acquisition system has been applied in two different field tests. The first application concerned fuel economy testing and vehicle performance was the only issue. This application had a low sample rate requirement (e.g., 1 to 2 samples per sec) and involved a prototype of the current data acquisition system. The second application involved off-road vehicle testing, both vehicle and driver behavior were of concern, and high sampling rates were important (e.g., 20 samples per sec).

Fuel Economy

The fuel economy application required measurement of fuel flow, vehicle speed and distance traveled, and aerodynamic influences on the vehicle (wind velocity and direction). The vehicle was instrumented as illustrated in Figure 2. Vehicle forward motion was sensed with a magnetic pickup on the rear-mounted fifth wheel. Speed was derived from the time differential between pulses from the magnetic pickup. Distance traveled was obtained by counting pulses. Wind velocity and direction were sensed with a wind vane mounted on the front of the vehicle. Wind vane angle was sensed with a potentiometer and a tachometer measured propeller speed, which is proportional to wind speed. Fuel flow and total fuel consumed were sensed with a Maxmeter model 213 Flowmeter, which is designed to accurately measure small liquid volume displacements (i.e., produced 111 digital pulses per cc of fuel). Actual fuel usage must be measured in terms of weight, so fuel temperature was also measured with a thermocouple and an SAE formula was used to convert volume and temperature to mass flow.

The sensor signals were conditioned and filtered, consistent with a 2-Hz sample rate. In this prototype application, data were acquired using a conventional portable computer, compatible with an IBM PC, mounted on the seat of the test vehicle so it could be easily controlled by the driver. Fuel economy runs were conducted on various stretches of rural roads to determine the influence of pavement condition on fuel usage. The driver conducted several minute runs in both directions on given road segments to cancel out grade effects. Data files were stored in the field on standard floppy disks. Data review and analysis were conducted using a standard spread sheet program (i.e., Lotus 1-2-3). Data from a typical run are shown in Figure 3.

Driver/Vehicle Response

The prototype approach was adapted to meet lightweight off-road vehicle applications. Instrumentation weight was the overriding concern in these applications, which suggested the use of a lap-top computer. The hardware arrangement on an instrumented vehicle is shown in Figure 4. The instrumented signals included vehicle speed, steering angle, yaw rate, and lateral and longitudinal acceleration. A string potentiometer was also configured to monitor rider lateral position, which could be shifted to affect vehicle motion.

Because of the extreme environmental conditions in the off-road application, a simple flexible plastic material enclo-

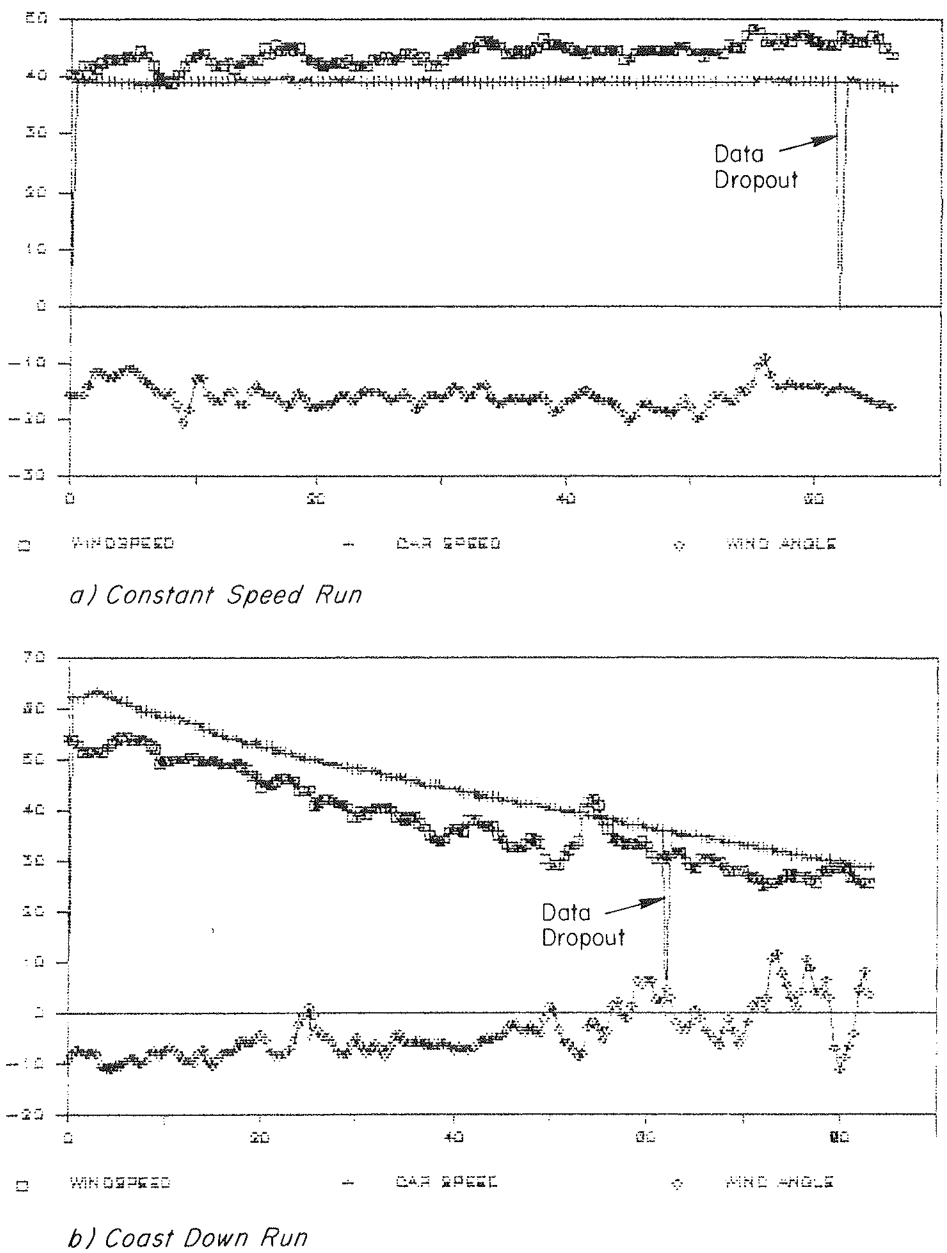
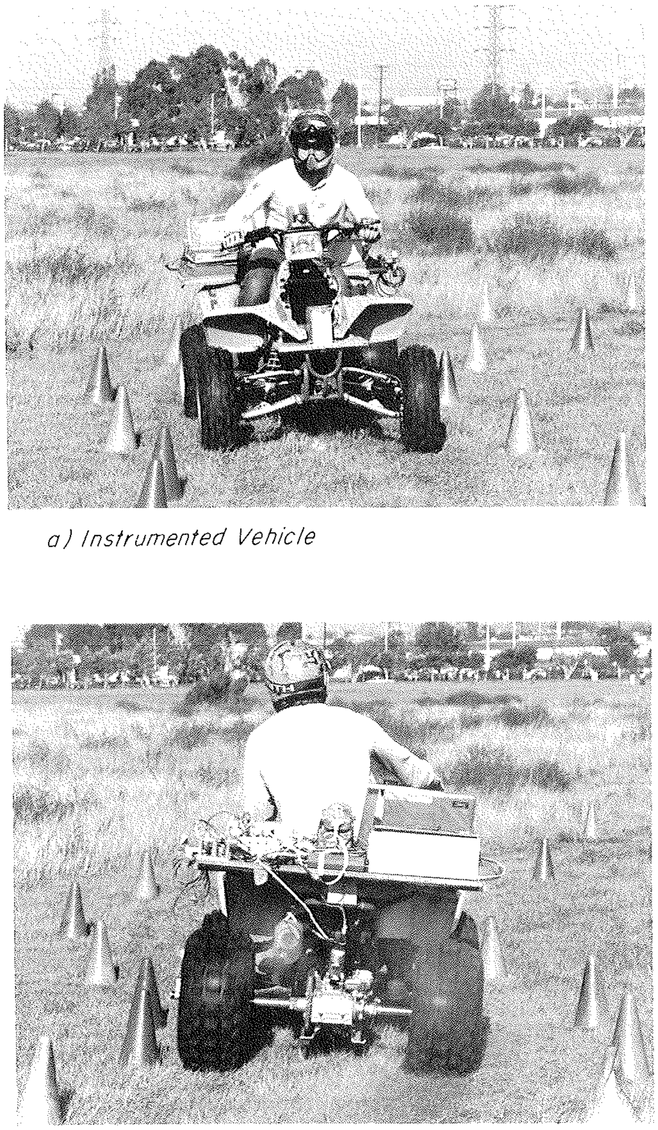


FIGURE 3 Example fuel economy test data.



a) Instrumented Vehicle

b) Rear Mounted Laptop Computer

FIGURE 4 Instrumented off-road vehicle.

sure was prepared for the computer. The unit was mounted in a foam-lined fixture, as shown in Figure 4. Data acquisition, display, and storage could then be conducted reliably despite relatively hot, dusty, and vibratory conditions.

The objective of the off-road vehicle tests was to measure vehicle steering control characteristics and rider behavior during standard maneuvers and obstacle avoidance tests. Test data were routinely monitored on the lap-top computer screen to verify proper sensor operation and test conditions. Figure 5 shows the format for online data presentation during acquisition. Variable names assigned by the user are displayed on the left-hand side of the data plot, along with scale factors. Data are written to the screen by a cursor that moves from left to right and writes over data from the previous pass.

When a data collection run has been completed, the user can elect to replot the complete run and store the data as either a binary or ASCII file on floppy disk. Figure 6 shows the data plotting format for raw recorded data from a typical obstacle avoidance maneuver. The user can also request a full-scale plot of any one variable at a time, as illustrated in Figure 6. Further data processing can be carried out, including the data smoothing technique shown in Figure 7, and *X-Y* plots, as illustrated in Figure 8 for the two previously smoothed variables.

CONCLUDING REMARKS

The current lap-top configuration of the instrumentation system is a very compact, economical, lightweight and rugged package for acquiring, displaying, and storing vehicle and driver/rider response data. The computer and A/D card weigh approximately 15 lbs. The primary data acquisition and display program is written in compiled QuickBASIC with math coprocessor (i.e., 8087) support. Application-specific processing needs can be easily added to the primary program or stored data files can be read into general purpose processing software such as spread sheet or relational data base programs.

A variety of lightweight lap-top computers with processor speeds up to 16 MHz are available and compatible with the

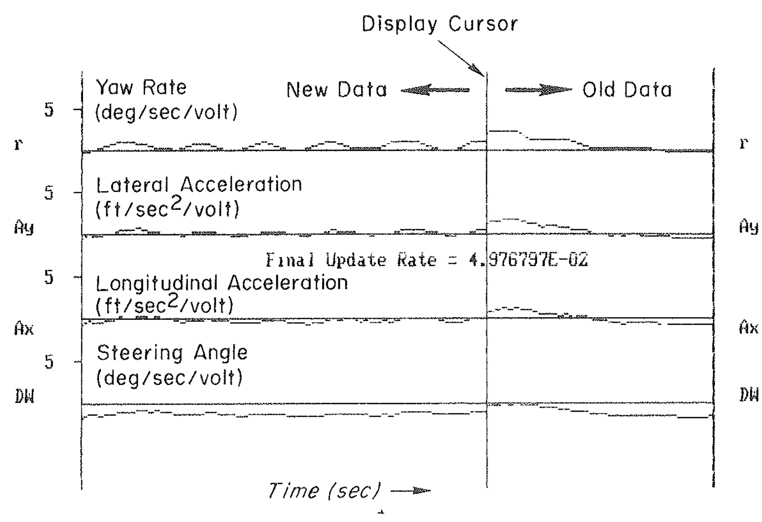
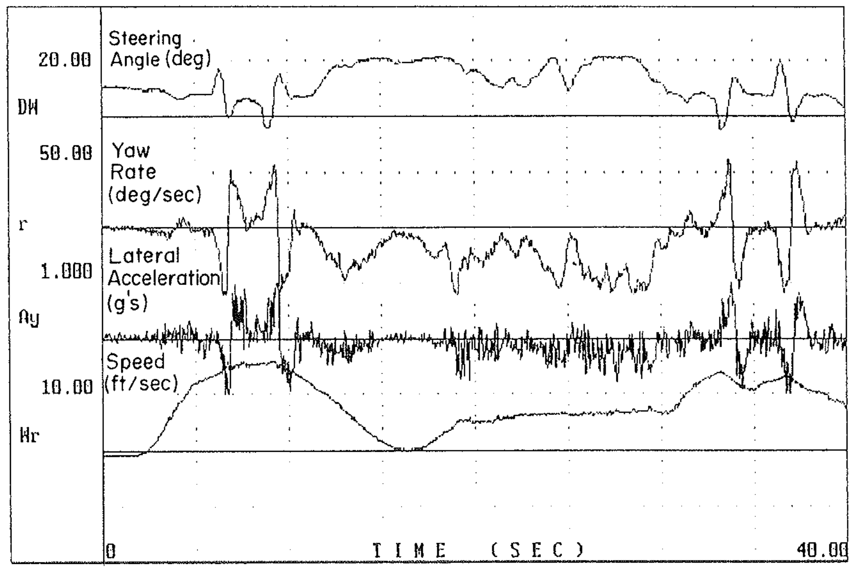
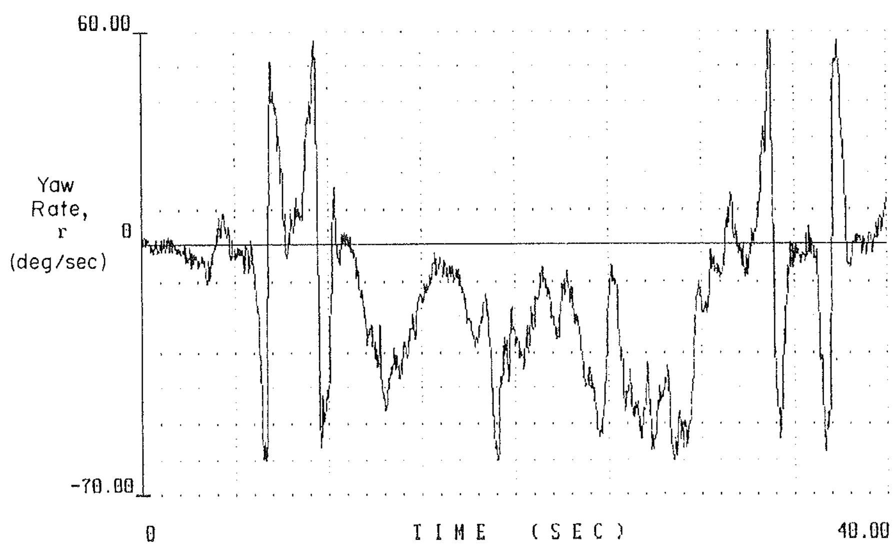


FIGURE 5 Online data acquisition display.



a) Four Signal Format



b) Single Signal Expansion

FIGURE 6 Post-run raw data plotting formats.

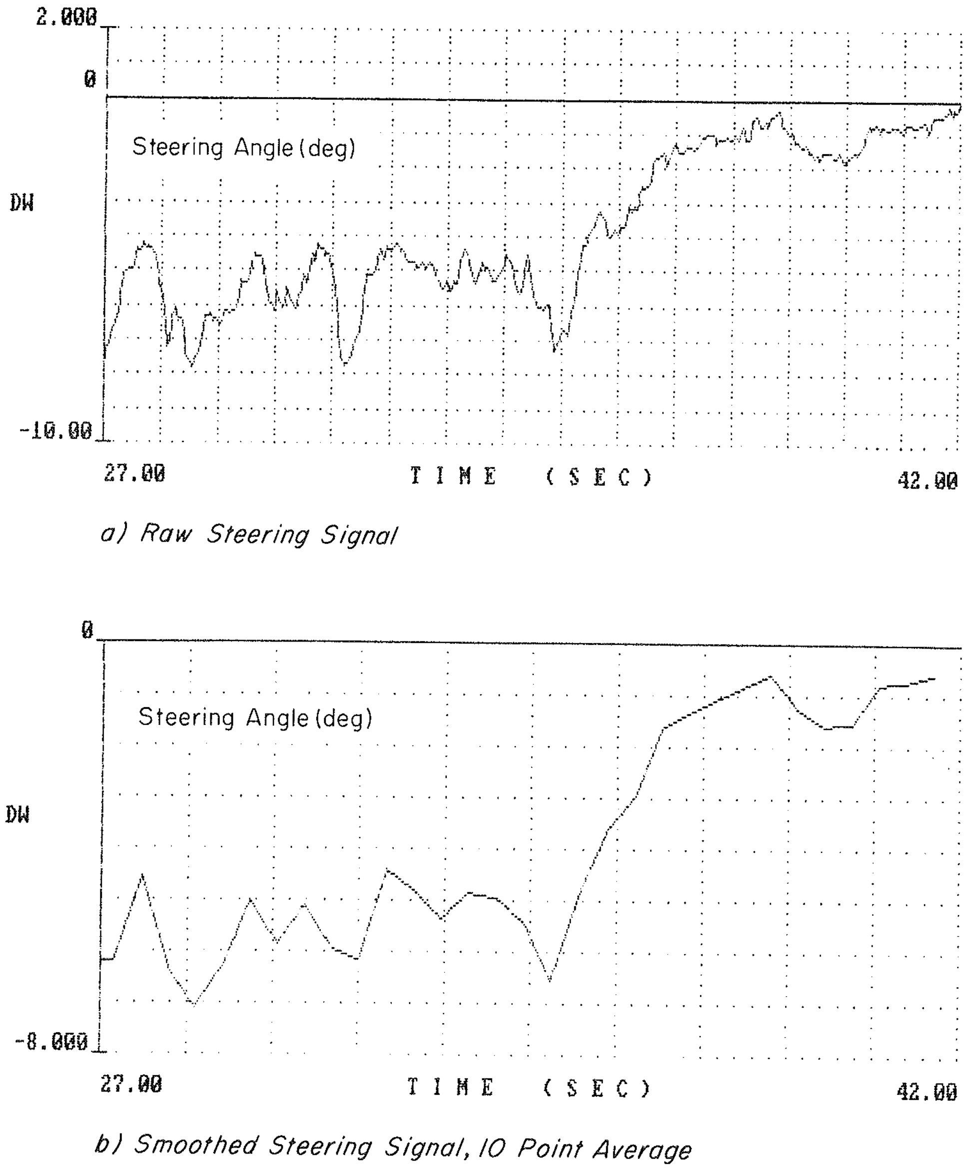
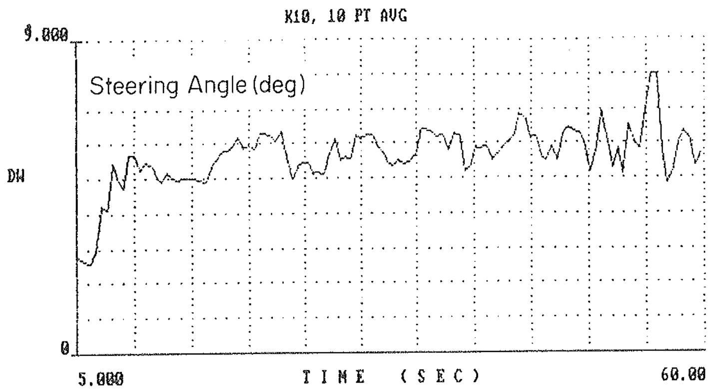
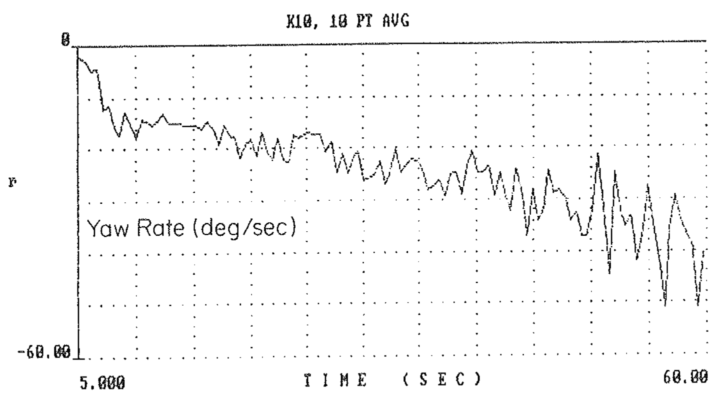


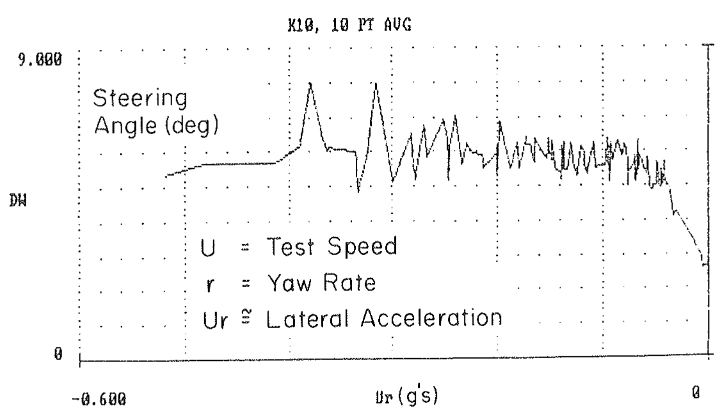
FIGURE 7 Signal smoothing using a zero phase lag window average.



a) Smoothed Steering Data



b) Smoothed Yaw Rate Data



c) Steering vs. Derived Lateral Acceleration

FIGURE 8 ***X-Y*** **data plot format for off-road vehicle test.**

approach discussed here. Benchmarks suggest that the new high-speed processors (i.e., 80286 and 80386) will permit significant performance improvements, including combinations of higher data rates (e.g., 500 Hz for each of eight signals), additional online processing, and more complex display formats. Higher-resolution screens will also permit richer data display formats.

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