# ANALYSIS OF TRANSIENT DATA USING HYBRID TECHNIQUES

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## ABSTRACT

This paper describes a data analysis and reduction program for transient data obtained from an instrumented locomotive-freight car combination as it made cross-country runs. The data consisted of fourteen channels of information recorded on analog FM tape.

The program utilizes a hybrid computer for its computational requirements. The analog processor is used to condition the data, to determine when the data is to be analyzed, and to reduce the data into a predetermined form during the period of interest. The digital processor accepts the reduced data from the analog processor, formats it to a standard form, and outputs the resultant on digital tape.

The program was successfully run at a speedup analysis of sixteen. Thus an eight hour run was analyzed in thirty minutes.

## INTRODUCTION

The data analysis and reduction program described herein enables the evaluation of transient data obtained from an instrumented locomotive-freight car combination. The data was obtained during cross-country runs from the West Coast to St. Louis, Missouri and was recorded on analog FM tapes. Each tape contained 14 channels of information for an eight hour period.

Much of the data recorded reflected normal track-train conditions. There was no interest in the analysis of this data. However, during periods of abnormal conditions (i.e., bad track, high speed on a curve, etc.) the recorded data became of interest. The objective then was to be able to selectively analyze sections of the data. It was this requirement that made the use of a hybrid computer attractive.

## PROBLEM DESCRIPTION

The primary purpose in instrumenting a locomotive-freight car combination is to obtain transient data regarding its behavior during cross-country runs on operating track. The principal objectives in evaluating this data is to:

- o Establish what correlations might exist in the data when certain conditions occur.
- o Geographically locate where these conditions occur.

To this end, the locomotive-freight car combination was instrumented to measure and record on analog FM tape certain accelerations, displacements, angles, forces, speed and location.

The instrumentation recorded the lateral acceleration and the vertical acceleration on each side of both the locomotive and the freight car. Also recorded were two rail profiles, the drawbar force, the coupler angle, and the velocity of the train. In addition, mile post indications were superimposed on the velocity signal. Figure 1 illustrates a typical section of the recorded data.

Four conditions were used to establish when certain conditions had occurred. Specifically, whenever the ratio of lateral acceleration to vertical acceleration on either side of the locomotive or the freight car exceeded a given value, a period of interest was initiated. The time length of each interest period was variable with the train speed. The period of interest following each initiation generally covered about five cycles of data.

Thus a window look at the data was taken whenever an interrupt from any one of four l/v's occurred. The window was left open for a time inversely proportional to the train speed. During these periods of interest the fourteen channels of data were analyzed per a specific format. Figure 2 shows the specific analysis made on the data.

## COMPUTATIONAL APPROACH

In order to obtain the necessary reduced data information, a number of computational tasks were required. Figure 3 is a functional schmatic illustrating some of the tasks. As shown, the data on the analog FM tapes needed base line correction and filtering of high frequency noise. The specific type of output analysis required peak to peak amplitude, peak to base amplitude, maximum value, root mean squared, and time averages. Figure 4 represents the analog circuitry necessary to perform one of the analysis paths shown in Figure 3. It consists of a base line correction, a filter, an absolute value, a peak to peak detector, and a time average of the peak-peak signal during the "window" period.

In this application the analog processor was used to:

- o Condition the data
- o Determine the window of interest
- o Perform specific analysis of data

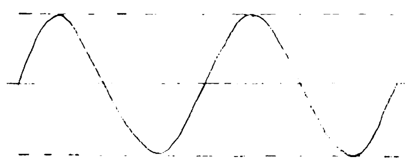
The digital processor was used to:

- o Accept the reduced data from the analog
- o Format the reduced data
- o Output the formatted data on digital tape

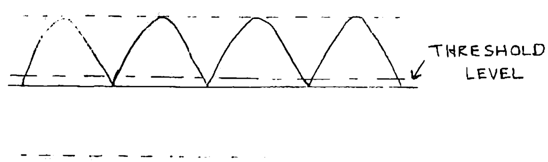
The resultant digital tape was then used as input to an existing correlation program on a large digital computer for final analysis.

The use of the parallel logic on the analog processor was an important factor in the success of this program. This can be illustrated by the analysis of the peak-peak detector circuit. Figure 5 shows the functional operation of that circuit. A high speed integrator was used as the temporary storage element for the peak value. Upon transferring of the value to an appropriate track/store unit, the integrator was reset and made ready for the next peak of the signal.

The following description should serve to explain the operation of the circuitry. Consider a sine wave of any amplitude and frequency as sketched:



When rectified, it becomes:




In climbing up a peak, comparator I is used to control the mode of the integrator. If the comparator output is high, it puts the integrator into the "IC" state and the integrator tracks the input signal. When the comparator is low, the integrator is put into the "Hold" state. When climbing a peak the integrator follows the input signal in a stairstep manner. After the peak has occurred, the integrator remains in the "hold" state until the signal to reset occurs. The signal to transfer the peak value from the integrator to the track/store device occurs when the input signal drops below the threshold level on comparator 2. Upon completion of this transfer, the integrator is "reset" via the operate mode to the threshold level and is ready for the next peak detection. This initialization is accomplsihed through the logic signal from AND gate I controlling the "OP" state and will take on the value of the threshold level as inputted by POT I. Flip-Flop 1 is used to alternate the track/store units as the storage element for the peak value.

## CONCLUSIONS

The hybrid program could analyze tapes at a speedup of sixteen. The speedup factor was limited by the playback recorder maximum speed. A factor of thirty-two speedup was feasible with the analog processor.

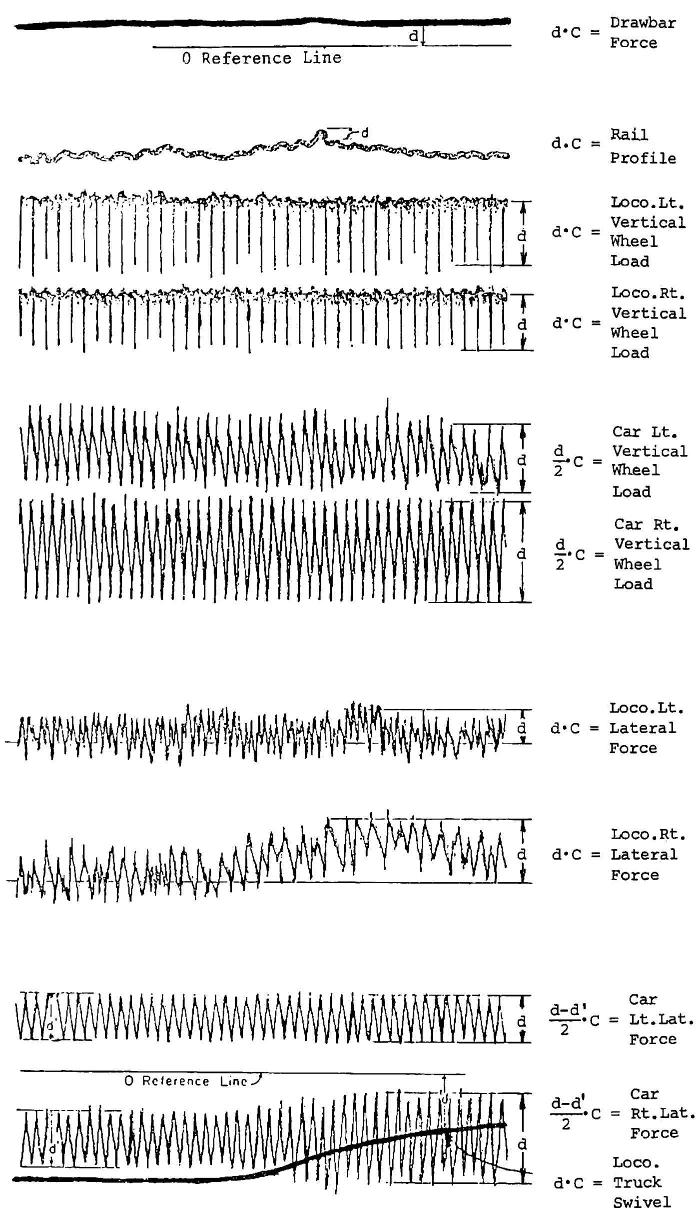
In the specific example cited in this paper, the hybrid computer was the only way to accomplish the task. The cost and storage requirements of an all-digital approach were prohibitive. An all-analog approach could not produce the necessary output for the further correlation analysis.

The use of a hybrid computer in the analysis of transient data is very effective when:

- o Data to be analyzed does not comprise the entire data collected.
- o Data collected is in analog form.
- o Multiple parallel channels of data are to be analyzed.

## ACKNOWLEDGEMENT


The author wishes to thank Mr. Ed Lind, Southern Pacific, San Francisco, California, for presentation of the problem and Mr. Jim Dolence for assistance in debugging the program.


C = Calibration Factor

Figure 1 - Typical Data

1. Analog Reel Number
2. Mile Post Indication
3. Relative Position Between Mile Posts
4. Time Average of Peak-Peak Signal of Rail Profile (Lt. Side)
5. Time Average of Peak-Peak Signal of Rail Profile (Rt. Side)
6. Maximum Peak Value of Drawbar Force
7. Maximum Peak Value of Coupler Angle
8. Time Average of Peak Signal of Locomotive Vertical (Lt. Side)
9. Time Average of Peak Signal of Locomotive Vertical (Rt. Side)
10. Time Average of Peak-Peak Signal of Freight Car Vertical (Lt. Side)
11. Time Average of Peak-Peak Signal of Freight Car Vertical (Rt. Side)
12. Locomotive Lateral Steady State Force (Lt. Side)
13. Locomotive Lateral Steady State Force (Rt. Side)
14. RMS Average of Locomotive Lateral Force (Lt. Side)
15. RMS Average of Locomotive Lateral Force (Rt. Side)
16. Time Average of Peak-Peak Signal of Freight Car (Lt. Side)
17. Time Average of Peak-Peak Signal of Freight Car (Rt. Side)
18. Train Speed

Figure 2 - Identification of Digital Output

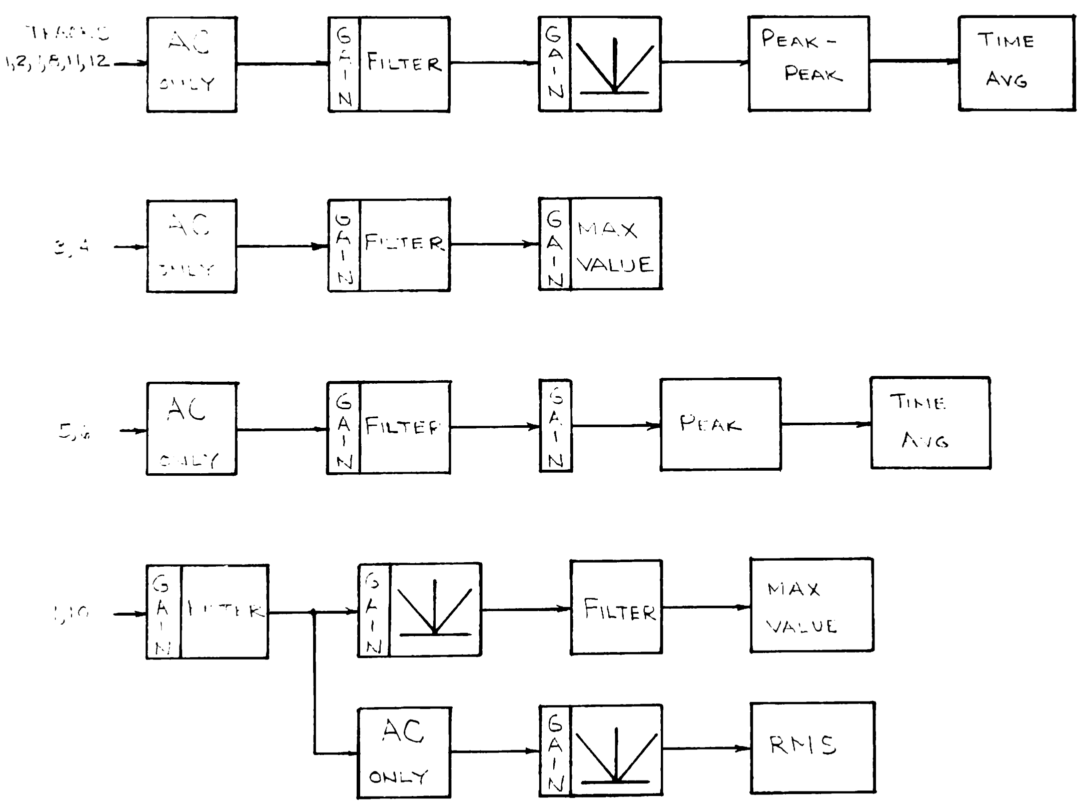



Figure 3 - Functional Schmatic of Data Analysis

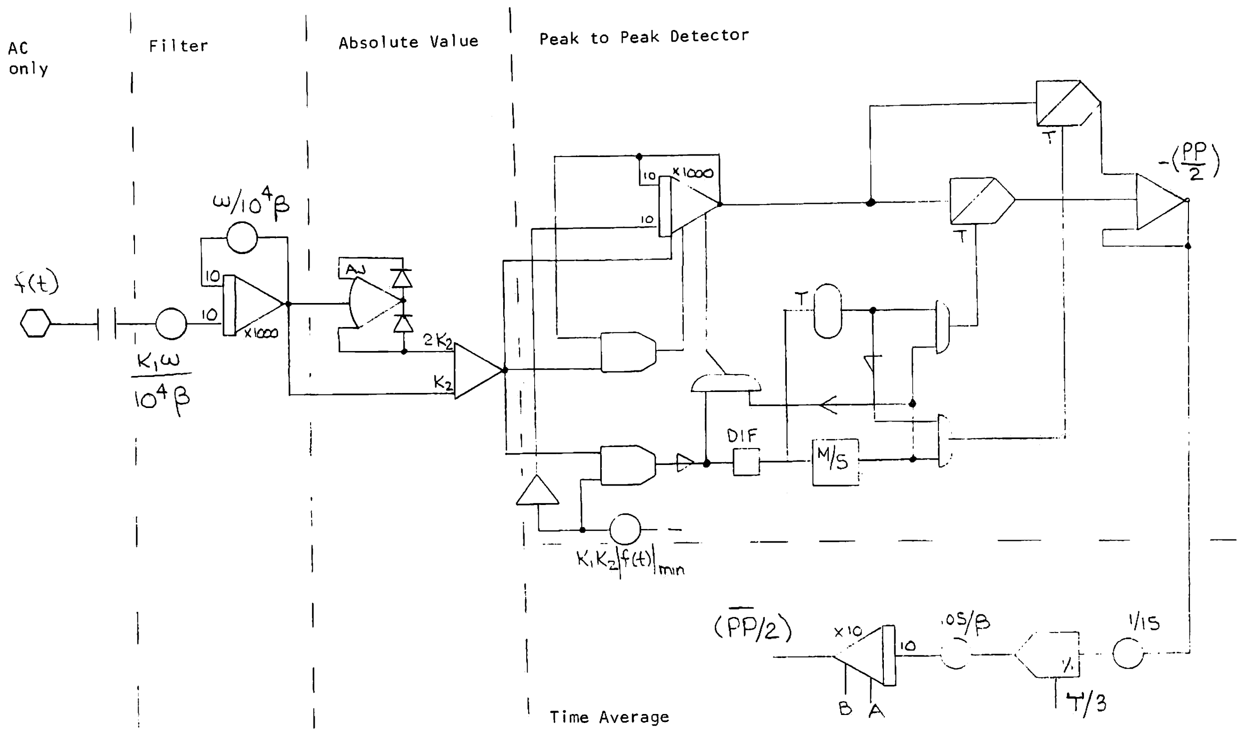



Figure 4 - Typical Analog Circuitry

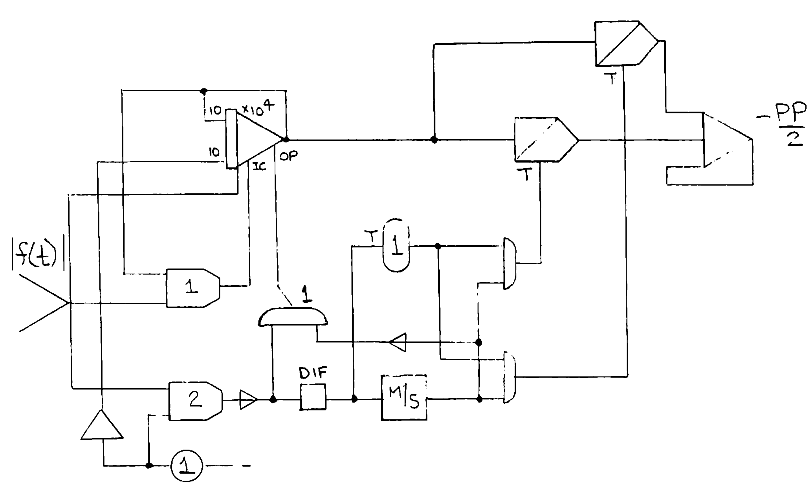



Figure 5 - Peak to Peak Detector