Lane Departure Warning System –VEHICLE END-OF-LINE ROLLS TEST MACHINES TOWARDS LDWS STATIC CALIBRATION AND DYNAMIC TESTING
HTTPS://WWW.LANEDEPARTUREWARNING.ORG/

Vehicle End-Of-Line Rolls Test Machines towards LDWS Static Calibration and Dynamic Testing

Christopher A. Warner
Department of Electrical and Systems Engineering
Oakland University, Rochester, Michigan USA.

Abstract

This paper chronicles information potentially related to End-Of-Line (EOL) rolls test machines. It includes (but is not limited to) aspects of both hardware and software design and development associated with these pieces of equipment. The hardware experience includes (but is not limited to) that related to microprocessor-based processing and control subsystems, backplane-based subsystems, rolls test stands, PLC-5 processors and those subsystems interfaced to by these processors, electrical and electronic hardware, and vehicle subsystems. The software experience includes (but is not limited to) that related to all high-level application software and low-level drivers along with Allen Bradley 6200 ladder logic programs. In addition, potential vehicle EOL rolls testing processes are considered. This testing process includes possible sequencing of events during a rolls test along with potential required human interactions with the system.

TABLE OF CONTENTS

1. Introduction to dynamometers stands used in vehicle rolls test machines

The purpose of using dynamometer stands in End-Of-Line (EOL) testers is to allow vehicles to be tested for various functionality and performance after a vehicle has gone through the assembly process. After a vehicle had gone through the assembly process, certain systems and subsystems had to be efficiently and effectively tested using dynamometer stands at the end of the assembly line (EOL). The primary system within a vehicle being tested by these EOL testers is the braking system and in particular, the anti-lock braking system (ABS). However, since engine and transmission systems may be directly involved in the testing process, they are typically incorporated into the testing procedure. Examples include checking an engine controller for fault codes before beginning a test or monitoring the electronic automatic transmission gear (PRNDL). Dynamometers provide a dynamic environment for testing these (and other) vehicular systems. The vehicle may be accelerated or decelerated, simulating commonly occurring driving activities experienced out on the road.

End-of-line testing via dynamometers provides a means of verifying that certain systems are meeting certain functional and performance criterion before being sold to the customer. End-of-line means just that, that the assembly process has reached the end of the line and is completed. However, if the vehicle does not successfully pass through the EOL rolls tester, the source of the failure must be identified and corrected before being shipped.

The focus of this paper will not be on the various types of dynamometers, the theory of dynamometers, or the mechanical/electrical specifics of the actual apparatus that the vehicle sits atop during the rolls test process. There are many papers and texts that may be viewed on dynamometer theory and applications should the reader desire. What will be touched upon includes:

1) Hardware and software for processing and control in vehicle EOL rolls test machines.
2) Systems architectures for vehicle EOL rolls test machines.
3) Some added detail to hardware and software for processing and control used in vehicle EOL rolls test machines.
4) The testing procedure possibly used in vehicle EOL rolls test machines.
5) The hardware and software update process plus support of vehicle EOL rolls test machines.

2. Introduction to hardware for processing and control used in vehicle rolls test machines

The hardware for processing and control in vehicle EOL rolls test machines consisted of those units with processing capabilities (central processing units), those units interfacing to the processing systems, and those components housing or in some other way supporting the processing systems. These units could be ordered from vendors advertising in catalogs or engineering magazines. The following portions of this paper detail some of the hardware components for processing and control used in vehicle EOL rolls test machines.

2.1 Intel 486 microprocessor based Industrial Computers

Special industrial grade computers were purchased to offer expanded quality and reliability in the harsh assembly plant environment. These systems typically operate in temperatures above and beyond that of typical desktop PC's and are tested for increased vibration and shock performance characteristics. These systems are rack mounted in a fashion similar to figure one below. Although it is not shown in the figure, a key to unlock the 'can' is typically required to gain access to the monitor and keyboards. These systems are passive backplane systems in which the microprocessor based 'daughter' cards are plugged into the system backplane. One particular benefit of the passive backplane system is the ease and quickness in which cards may be 'swapped out' should the need arise. These 486 based computers formed the 'backbone' of the EOL rolls test system. One of their primary goals was to provide the interface to the vehicle bus called the Vehicle Communications Interface (VCI). Another purpose was to enable asynchronous communication with many other components of the system including the roll speed interface and the PLC processor, the subject of the next section of this paper.

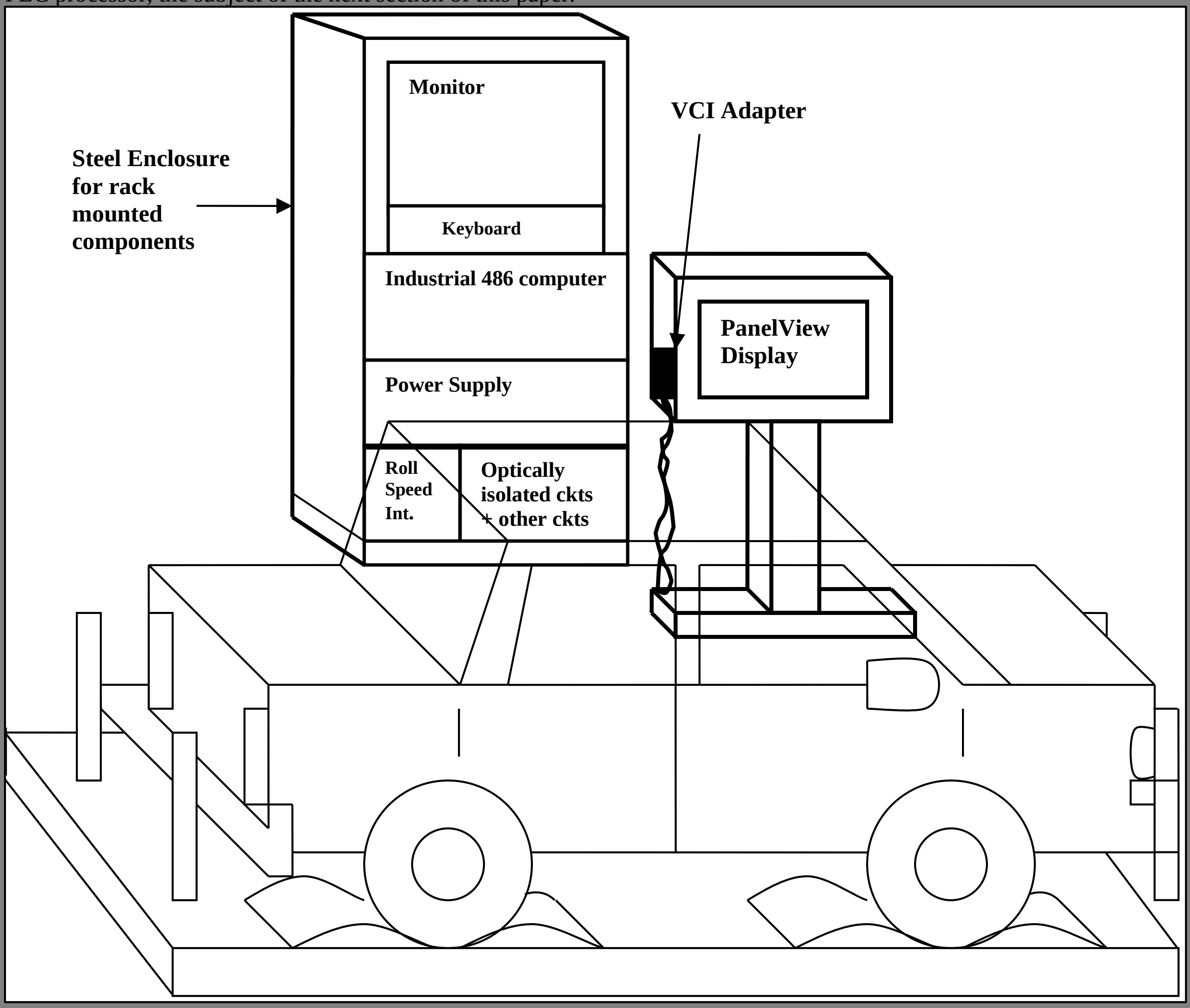

Figure One. Example of possible rack mounted system layout and PanelView used in vehicle EOL rolls test machines

2.2 Programmable Logic Controller's (PLC's) from Allen Bradley

The programmable logic controllers used in the roll test machines were typically PLC-5 processors mounted in an Allen-Bradley 1771 I/O chassis. Each system had its own power supply that also mounted in the I/O chassis along with any other modules (input/output, analog input, +) that were being used by the test system. The PLC communicated information to and from the 486 based test system before, during and after the test. Information was typically communicated in large bit streams that needed to be encoded before transmission or decoded after transmission. The ladder logic programs used in the EOL rolls test machines were typically written in AB 6200 ladder logic and were not too complicated nor long. Because much of the complex controls during the test were performed by the 486 based portion of the test system, the ladder logic was primarily used for tasks such as engaging/disengaging the safety stops, coupling/decoupling the rolls, serving as the interface to the PanelView display for vehicle input, test initiation, etc., and monitoring and controlling some of the other high-power devices of the rolls test system.

The I/O devices are used to interface high power plant systems to low power electronic systems. The high-power plant input components (typically 115V ac) are connected to the PLC processor in the form of limit switches, proximity switches, photo eyes and other similar components. For example, when a particular switch is closed (conducting), meaning that the 115V ac is reaching the termination strip of the I/O Rack, a '1' will appear in the input image table of the Allen Bradley 6200 software for that particular address. Conversely, when a switch is open (creating an open circuit), a '0' will appear in the input image table of the AB software for that particular address. The high-power output components (typically 115 V ac) are connected to the PLC processor in the form of valves, motors, drives and other similar components. This overall system of inputs and outputs is then controlled via the ladder logic program residing in the processor memory.

The PLC system played an important role in the vehicle EOL rolls tester mechanical and electrical components function and operation. For more information on Allen-Bradley PLC hardware refer to [3]. It served as the primary interface to the overall apparatus that the vehicle sat upon during the rolls test procedure. However, the primary control of information from the actual rollers that the vehicle drove on during testing was performed via the roll speed interface housed within an Octagon System Micro PC and processed using a 5025/486 control card.

2.3 Octagon Systems Micro PC 5025/486 control card

There are several important features to the Octagon Systems Micro PC 5025/486 control card including ROM-DOS operating system, watchdog timer, solid-state disk options, speaker and keyboard port, plus many others [1]. Many of these features played a very important role in the EOL rolls testers and will be described in the following portions of this paper.

Two important features are the ROM-DOS operating system and the watchdog timer. The ROM-DOS was stored in SSD0 (solid state disk 0) and contained both the Basic Input Output System (BIOS) and DOS v 5.0. However, the rolls test application code for the RSI could be stored in SSD1 which typically used 256K flash EPROMs that were reprogrammed through the serial port. The software that was used to facilitate communications with the serial port was called PC SmartLINK and designed specifically by Octagon systems for use with the 5025 control card. This software played a fundamental role in establishing communications and allowing reprogramming of the flash EPROM using the serial port during any software updates process. There are two com ports available and these are designated as COM 1 and COM 2. COM 1 can be configured as console I/O or as RS-232 I/O while COM 2 may be configured as RS-422/485. A watchdog timer is also available in the system to prevent unintended program operation. This timer will typically need to be reset in order to prevent unintended program operation. In the Micro PC system, the watchdog timer could be reprogrammed to reset every 0.15 seconds, 0.6 seconds, or 1.2 seconds. While the 486 control card performed processing and control for the roll speed interface, the actual interfacing to the rolls encoders was performed by the 5300 Counter-Timer Board from Octagon Systems.

2.4 Octagon Systems Micro PC 5300 Counter-Timer Board

One configuration that may be used with the Counter-Timer Board for vehicle EOL rolls test machines is shown in the figure below.

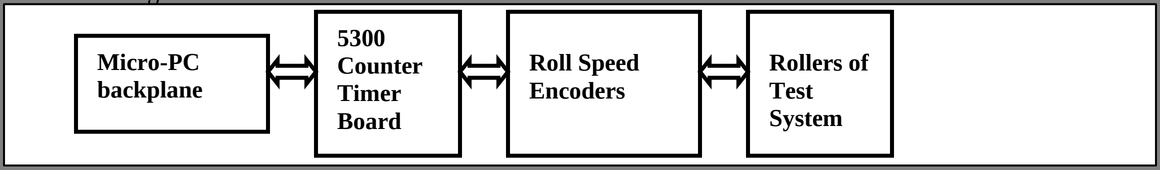

Figure Two. Potential sample interfacing for 5300 Counter Timer board used in vehicle EOL rolls test machines

The primary function of the 5300 Counter Timer Board is to count pulses from the 1000 count encoders. This particular board may be used to serve many other purposes from precision timing to pulse width modulation. One important feature of the counters used in the system is that they are capable of a count rate greater than 1 MHz. The reason that this is important is that the maximum counting rate must be considered when dealing with an encoder mounted on a roller of a particular radius rotating at a high rate of speed as it relates to the total number of revolutions per second. The rate of change of the encoder count number may then be used to determine the change in revolution speed of the roller.

The roll speed marquee is a device that is used to visually display the velocity that the vehicle is traveling on the rolls. This speed is also displayed on the PanelView during the testing sequence, but under certain circumstances viewing one might be chosen over viewing the other. The vehicle speed is transmitted to the marquee by converting the floating-point value into a character string and then transmitting it out the serial port of the system. While the counter-timer board did contain some digital I/O lines, a separate 5600 Digital I/O board needed to be used to interface to other digitally controlled lines of the vehicle EOL rolls test system.

2.5 Octagon Systems Micro PC 5600 Digital I/O board

A potential architecture using a digital I/O board in the vehicle EOL rolls test machines is shown in figure three below.

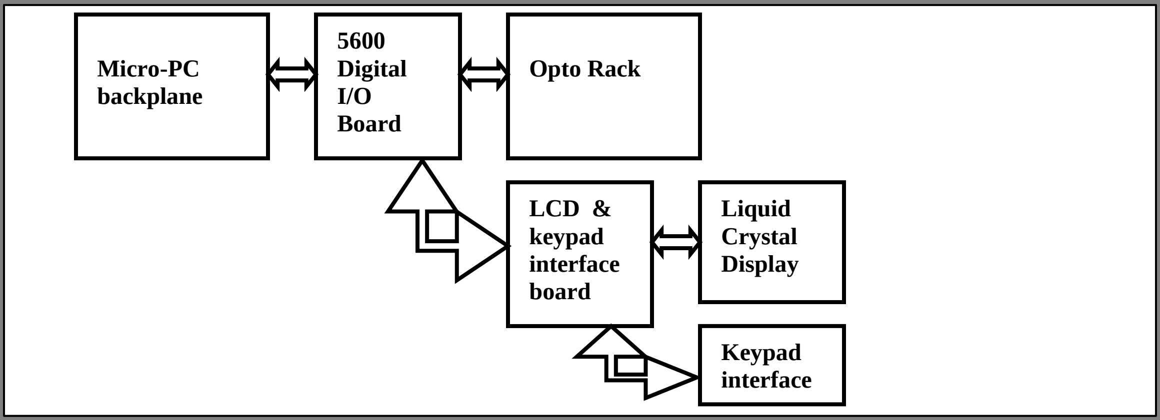

Figure Three. Potential sample interfacing for 5600 Digital I/O board used in vehicle EOL rolls test machines

The optical isolation board is a means of providing electrical isolation between circuits that operate at different voltage levels and provides a means for signal conversion, noise isolation and eliminating ground loops. It also provides protection when circuits conducting high currents interface to circuits conducting small amounts of current. The liquid crystal display (LCD) and keypads have related uses.

The 5600 board uses the 82C55A chip from Intel which contains 24 programmable I/O pins which are TTL compatible and capable of driving 2.5 milliAmps DC on all port outputs. For further information on this Intel chip refer to the Intel Peripheral Data Book [2]. Since the 486 PC based test system had only two serial ports with one being dedicated to the VCI with several other serial devices needing to be interfaced to, a serial expansion board needed to be added to the system.

2.6 Advanced Communication Link II+ (ACL) serial expansion boards

The ACL boards provide a means for expanding the number of serial lines available to the system as shown in figure four below.

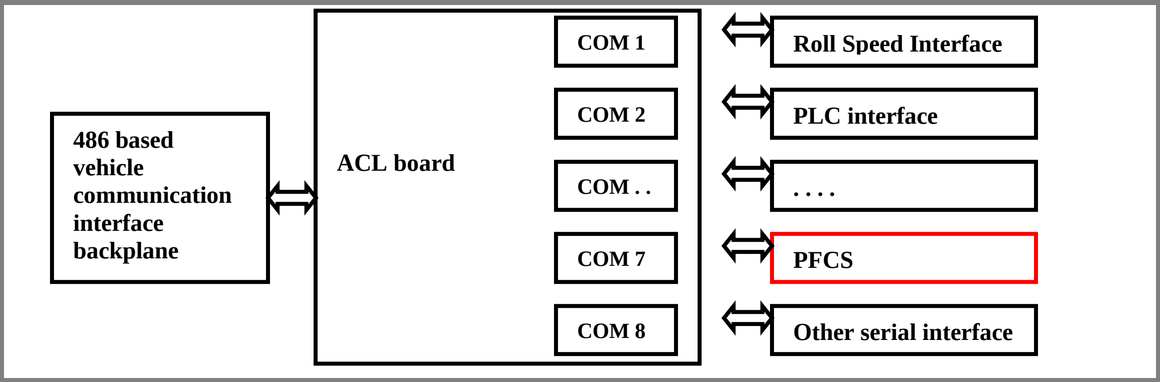

Figure Four. Potential sample interfacing for ACL board used in vehicle EOL rolls test machines

Up to eight EIA-232 or EIA-422/EIA-485 devices may be configured depending on the required system architecture. Each port (interface) must have a unique I/O address and the system may be configured to use dual port memory in the extended memory space. Additionally, there is a user selectable dual-inline package (DIP) switch which allows the choice between polled or interrupt-based modes of operation. For more information on the ACL and ACLII+ boards from Industrial Computer Source, refer to [5]. Up to this portion of the paper, there has been very little said about the devices that may be used to interface with the system.

2.7 PanelView displays for potential operator and plug-in vehicle communication interface

The PanelView display is the first thing that the vehicle test operator potentially comes in contact with upon driving the vehicle onto the rolls. The vehicle communication interface adapter (the connector that plugs into the under-dash vehicle bus interface) will typically be hanging on the left side of the PanelView (when facing it from the vehicle) and the operator may grab it, plug it into the in-vehicle connector and begin the test. However, some vehicle information may also need to be entered into the PanelView display through the user interface in order to uniquely identify the vehicle to the system through its Vehicle Identification Number (VIN). This vehicle information, along with a host of other vehicle information including vehicle options, may be contained within a small piece of paper that might typically found attached to the vehicle. After the test is initiated, a sequence of instructions for performing the test was dictated through the PanelView. There are sometimes other visual cues available to aid in performing the test (in addition to the PanelView and the marquee).

There are also screens within the PanelView program that allow the manual cycling of the hardware devices being controlled by the PLC. This method of engaging or disengaging certain hardware components is done in a manual mode of operation (independent of the automatic test mode) and is used at various times in the machinery's lifecycle. Each button in a PanelView display maps to a certain area of the PLC memory and thus facilitates control of the rolls test process because a portion of the ladder logic program is specifically dedicated to the processing of PanelView information screens, whether it is for accepting input or guiding screen output.

At the completion of the test, the operator will know whether or not the vehicle has passed and will proceed accordingly. They will then hang the VCI connector back on the PanelView and continue on according to their normal routine.

3. System architecture for vehicle rolls test machines

It is beyond the scope of this paper to get into an in-depth discussion of the implementation specific details of the vehicle EOL rolls test systems. However, what will be expounded on is an overall system architecture incorporating the VCI and RSI along with other portions of the rolls test system.

3.1 Vehicle Communications Interface (VCI)

As shown in figure one, the plug-in connector for interfacing to the vehicle bus could be mounted on the left side of the PanelView. A potential block diagram of the vehicle communication interface is shown below.

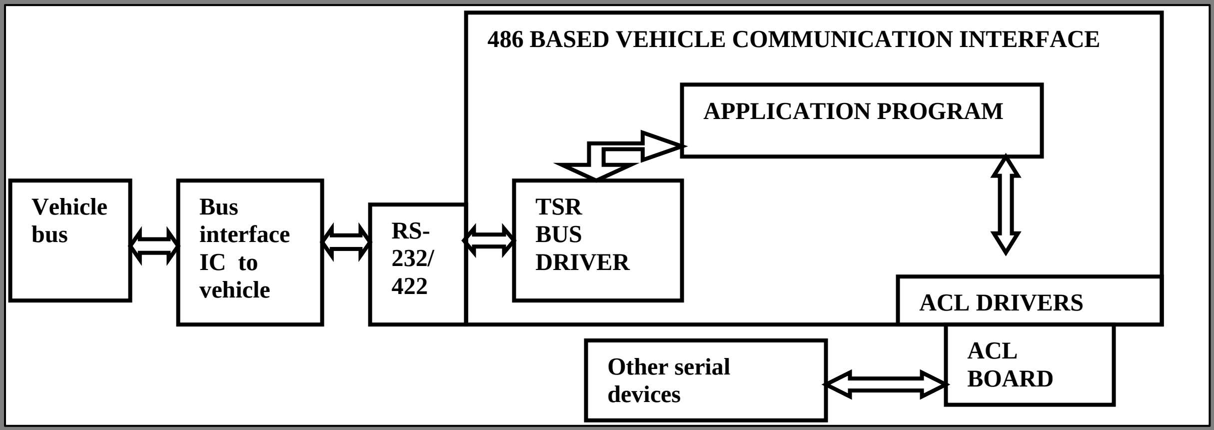

Figure Five. Potential block diagram of Vehicle Communication interface of EOL rolls test machine

There was an enormous amount of processing going on within the vehicle communication interface during the vehicle EOL rolls test process. Communication with the vehicle bus involved constructing bus messages, transmitting them onto bus and then constructing a received message (if any) as a response from the module being communicated with via the bus. The specific messages for communicating with the various controllers including the engine controller, electronic automatic transaxle controller and ABS controller needed to be constructed before transmission and reconstructed after being received. Once the 'start test' button on the PanelView was depressed and this information was communicated from the PLC to the PC, there were memory checks that need to be performed, control sequences that need to be followed and continuous communications that needed to be performed until the test was completed. Because each message that was received from the bus was in the form of a hexadecimal byte, careful bit manipulations had to be performed (including masking) to check individual bits of information within the hexadecimal bytes.

However, the source code files in the VCI also performed the serial communications through the Advanced Communications Link (ACL) board. This coding was substantially more complex because an RS-485 communication scheme with four signal lines (T+, T-, R+, R-) connected between 1 master and 3 slaves must be controlled using handshaking and arbitration.

There is one last portion of communications that needed to reside within the VCI system. PFCS system updates necessitated creating an interface to the rolls test machines via Ethernet cards using Transmission Control Protocol (TCP). Meetings with Management Information Systems (MIS) manufacturing personnel were conducted to establish precisely how the systems would be implemented along with other important details of the design and implementation process.

3.2 Roll Speed Interface (RSI)

The roll speed interface contained three cards that might be mounted in a micro PC chassis. These three cards are shown in figure six below.

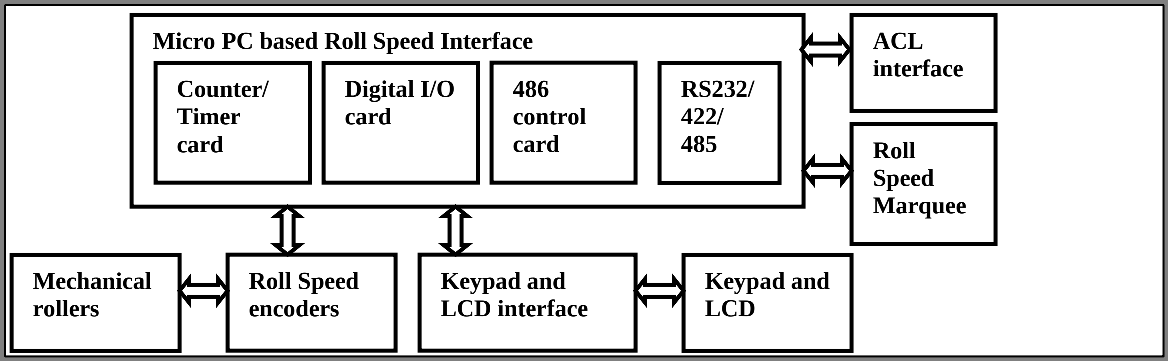

Figure Six. Potential block diagram of rolls speed interface of vehicle EOL rolls test machine

The 1000 count encoders were mounted on the rollers that the vehicle would sit upon and provide 1000 counts per revolution. The reasons for having a separate roll speed interface are apparent when one considers the importance of having very accurate readings coming from the rolls. Since the encoder readings were directly used to calculate the brake force generated by the vehicle braking system, and since the brake force being generated was one principal quantity being tested for in the rolls test system, the roll speed controls had to dedicate their processing power during the testing towards the task at hand. Another reason is that (in early rolls test machines), the vehicle communications interface and rolls speed interfaces were written in different languages. There are numerous other reasons that support the use of a separately dedicated processing system. The digital I/O card provided additional I/O lines to those already available in the counter/timer card and the 486 control card provided the system with a microprocessor, on-board memory, two serial ports, and various other peripherals. More information on the actual calculations is provided in a subsequent portion of this paper.

The keypad and LCD shown in figure six were mounted on the front door of the enclosure shown in figure one. Specific information stored by the system could be accessed via this system.

3.3 Overall test system architecture and interfacing

Figure seven below shows a potential overall high-level generalized system architecture for the vehicle EOL rolls test machines including the VCI, the RSI, and other processing and control subsystems.

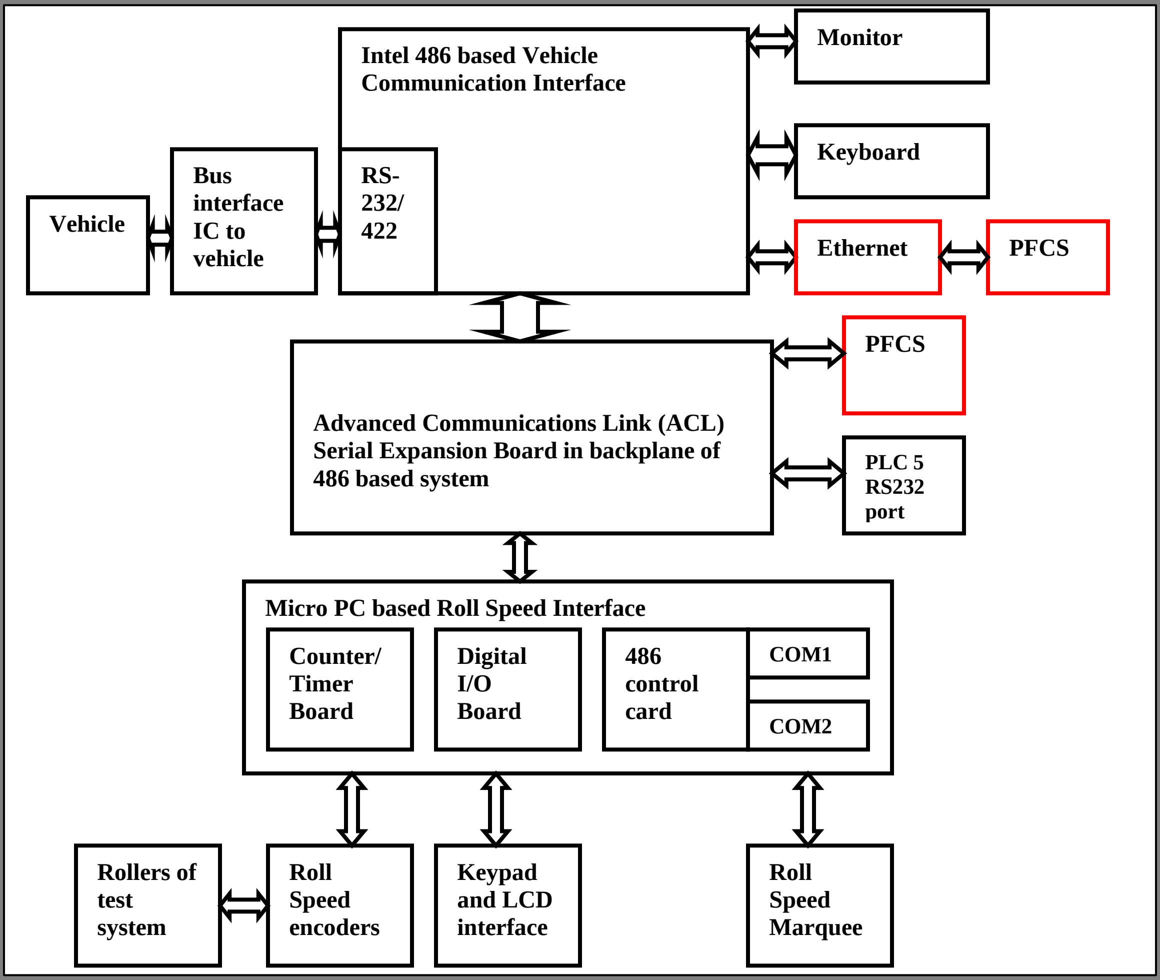

Figure Seven. Possible general system architecture to vehicle EOL rolls test machine

As can be seen in figure seven, there are a number of subsystems that interface and a great deal of serial communications being performed at any one time during the rolls test process. Note also that in figure seven, the two indicators of the PFCS reflect two different implementations of the system itself. The next section of this paper gets into more hardware specifics of the vehicle EOL rolls test machines.

4. Hardware specifics of vehicle EOL rolls test machines

Previous portions of this paper have given some general information regarding the hardware processing and control systems used in vehicle EOL rolls test machines. Some of the major units were covered along with functional descriptions. This portion of the paper will add a layer of detail to both the plant floor layout of the vehicle EOL rolls test machines as well as to the hardware architecture for processing and control used in these test systems.

4.1 Proposed floor layout of vehicle EOL rolls test machines

Figure one at the beginning of this paper gave a very general idea as to where the processing and control hardware, PanelView and vehicle could be collocated in a vehicle EOL rolls test station. Figure eight below gives a different perspective (top view) showing with more detail how the vehicle could be positioned with respect to the remainder of the EOL rolls test hardware.

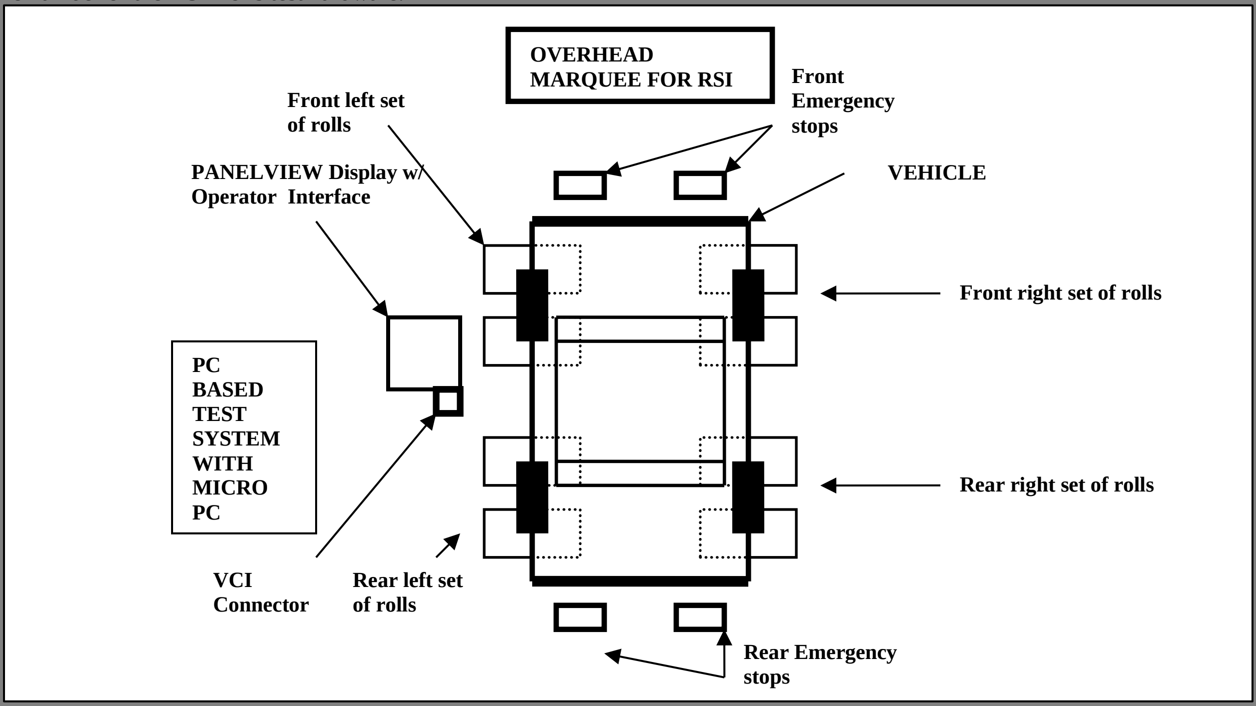

Figure Eight. Potential top view (general layout) of single vehicle EOL rolls test station

5. Software specifics of vehicle EOL rolls test machines

Previous portions of this paper have included some general information regarding the software used in EOL rolls test machines. The compilers used and the frequent use of file I/O during the rolls test process has been touched upon. This portion of the paper will attempt to add some detail to the actual processing and control within the software that occurs within the vehicle EOL rolls test machines.

5.1 Asynchronous communications and RS232/422/485

A very common asynchronous information communication interface in use today is the RS-232 standard. If the data circuits are communicating in each direction, then the circuit is in full-duplex operation. If however the circuits are communicating in only one direction (at a time), the circuit is in half-duplex operation. The RS-232-C standard (and its comparable counterpart EIA-232-D) include mechanical, electrical, functional, and procedural specifications [4]. The details of these specifications are beyond the scope of this paper. However, the use of the RS-232-C family and its electrically improved RS-422 play a major factor in the vehicle EOL rolls test machines. The following table gives a brief summary of the three standards.

Table One: General differences in asynchronous transfer methods

RS-232-C	**Asynchronous Transfer (no clock signal)**
RS-422	**Asynchronous Transfer using balanced transmission**
RS-485	**Multidrop configuration of asynchronous transfer incorporating ‘multiple nodes’**

One of the reasons that using balanced transmission is so important is due to the fact that it is less susceptible and produces less electrical noise than the unbalanced transmission line. When considering the electrically noisy environment of the automotive assembly plant, information carrying lines of any substantial length must be RS-422. When considering the layout of the rolls test stations, it becomes apparent why a balanced transmission line is so important. An automotive assembly plant is filled with machinery from end to end and the vehicles are transported throughout the plant in a carefully designed maze aimed at being as efficient and effective as possible. It is not uncommon for multiple pieces of associated machinery to be spaced apart due to limitations in the plant floor layout. Consider again the layout of figures eight and nine. From figure eight, it is apparent that the PanelView display (with VCI adapter) is located in close proximity to both the vehicle being tested and the enclosure with the VCI controller, RSI controller, etc. However, note where the roll speed marquee is located in figure eight and where the PLC-5 processing and control enclosure is located in figure nine. Clearly, there can be a substantial distance between processing stations in these rolls test systems and thus the most electrically robust communication architecture must be used.

The PLC-5 processors from Allen Bradley have a built-in on-board RS232 port on the front panel of the processor itself. This port may be used to transmit asynchronous message to or receive messages from other serial devices. The vehicle EOL rolls test machines used this port to communicate information to the PC based test system.

5.2 Construction of messages for PC to PLC communications

Before, during, and after the rolls test sequence, there was a great deal of information being communicated between the various processors within the system. The communication between the 486 based test system and the vehicle and roll speed interface has already been discussed at length. However, the communication of information between the 486 based test system and the PLC has not yet been covered. Construction and transmission of messages between the PC and PLC might consist of huge bit streams being encoded and decoded during the testing process. This was performed over a serial communications link and consisted of test status information for test sequencing and other pertinent information. Although it might not seem feasible for the PLC to perform binary message encoding and decoding, there are some bit manipulation instructions within the AB6200 PLC software language including the logical AND, NOT, OR, and XOR instructions. There are also other instructions that may be manipulated to produce bit tests and checks. This is not the only way in which information may be communicated in the EOL rolls test machines. Direct electrical interconnects, called interlocks, are a common way for PLC processors to communicate various ‘digital’ states occurring within a test system. It might also be feasible to have hardwired interlocks between the PLC processor and the 486 based test system.

PLC-5 processors have special interconnection interfaces called Data Highway connections via the ‘infamous’ blue hose which allows them to be uniquely identified within a plant from other PLC processors. However, while it is possible to access these processors over the data highway and view the programs they have stored (along with other possibilities), it is the plant floor communications system which allows systems within the assembly plant to communicate information between nodes within the networks.

5.3 Plant Floor Communications System and TCP

The Plant Floor Communications System (PFCS) may be considered as the primary information communication facilitator within a plant. Information about the vehicle production process may be both transmitted and received through a complex network to most (communications capable) machinery stations in the plant. It will typically originate from a centralized location where plant supervisory personnel are also monitoring the production process with the intent of manufacturing their required number of vehicles in the smoothest fashion possible. The PFCS itself may take many forms depending on the age and technological capabilities of the plant including plant broadcasts to TCP based networks for individual sets of machines on a local or wide area network.

Early versions of the rolls test machine possibly used a version of RS422 called RS485, a multi-drop version of RS 422. Figure nine below shows how a number of rolls test stations may be configured in a multi-drop network.

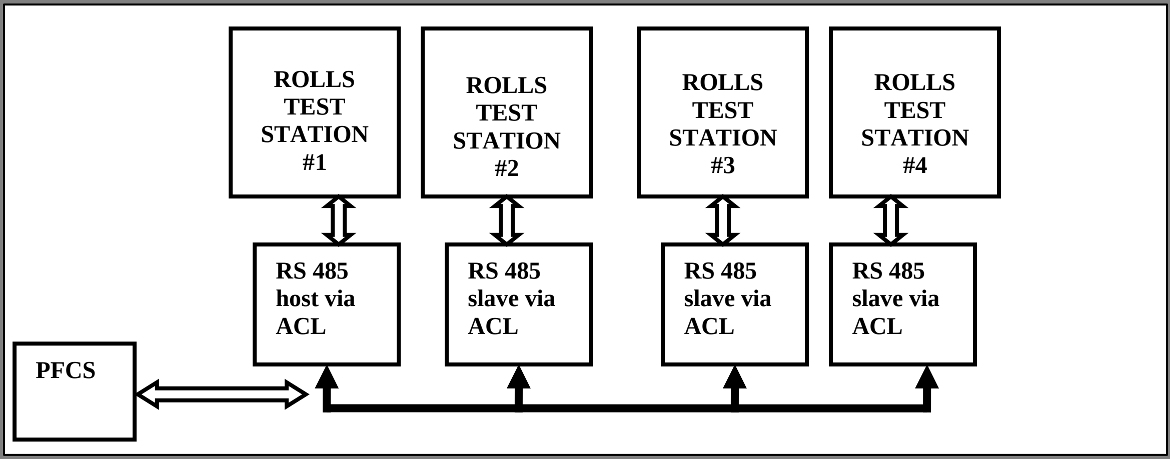

Figure Nine. Potential Multi-drop connected network for early vehicle EOL rolls test machines

There are two primary methods for controlling which node on the network is allowed to transmit its information, namely interrupt mode and polled mode. One of the keys to enabling multi-drop communications is to make sure that the signal wires (transmit positive 'T+', transmit negative 'T-', receive positive 'R+', receive negative 'R-', and ground 'GND') are connected properly.

Later versions of the rolls test machines potentially incorporated a PFCS based on the Ethernet network using TCP protocol, shown in figure ten below.

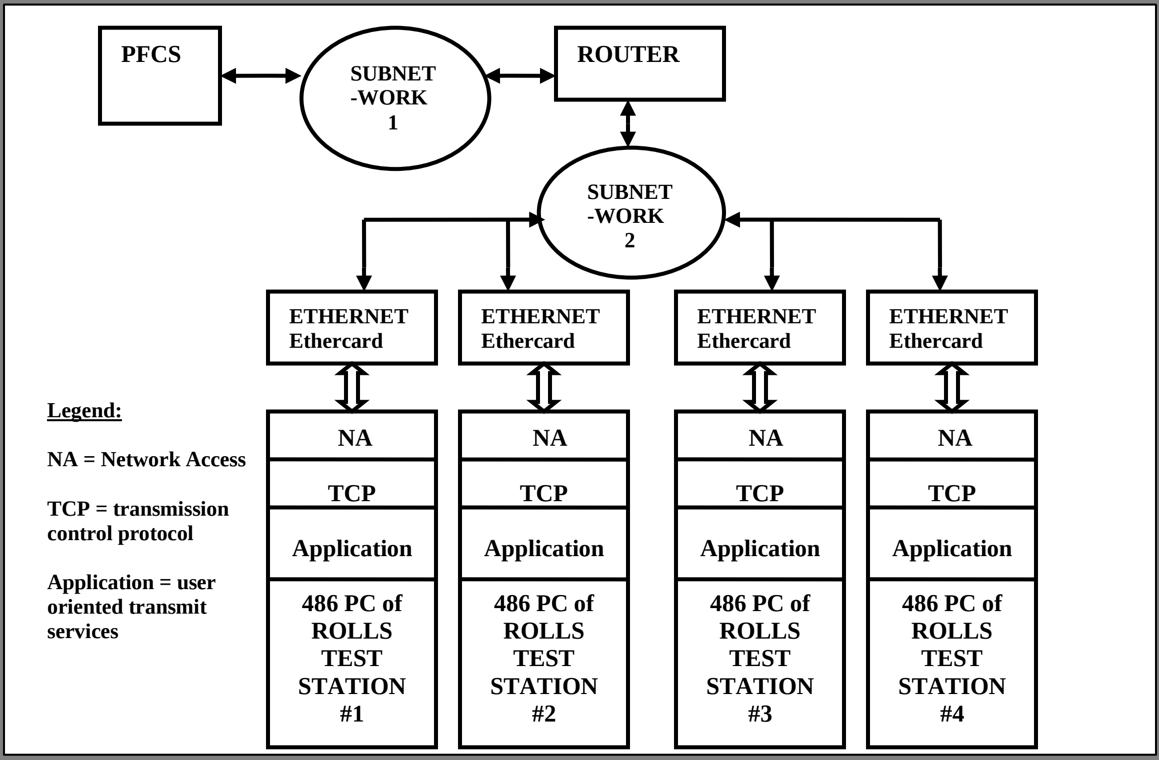

Figure Ten. Possible vehicle EOL rolls test machines connected to PFCS over Ethernet using TCP protocol

Some primary areas of focus should likely be on the process/application and host/host layers being used within the test environment. However, discussions should also touch on both network procedures and network communication protocols. One other point should be made about ten above. The router serves to join the two networks and chooses the best path (path control) for networks having multiple paths between them. Thus it should be apparent that the router shown will also be connected to plant machinery throughout the plant which will provide many potential paths for the messages to travel. Note also that the router will not (generally) perform protocol conversion between two dissimilar networks.

The details of the applications code for communication over the TCP network are beyond the scope of this paper. However, in a client-server environment, there are certain fundamental components to the communications that may be elaborated on. For the following discussion, take the client as the particular EOL rolls test station and the server to be the plant floor communication system. On the client side, a TCP socket must be created and then a connection must be established with the server. After establishing the connection, the client will send a request to the server and wait for a response. The response is then read by the client and the connection is closed by the server. Synchronization may be performed through the use of 'acknowledgements' or 'not acknowledgements' to assist in maintaining the integrity in the transmission process. Should 'not acknowledgements' be sent at any point in the synchronization process, message portions may be retransmitted until the proper response has been received by the server. It is important to note that the address and port number of the server must be used in establishing the communications with the server.

5.4 Some specifics on software modules used in the vehicle EOL rolls test machines

REMOVED

Up to now, there has been quite a bit of information given regarding the software and hardware used in processing and control for vehicle EOL rolls test machines. The possible sequencing of events in the testing process will be covered in the next portion of this paper.

6. Testing procedure potentially used in vehicle EOL rolls test machines

The following table gives a general idea as to the possible sequencing of events during an EOL rolls speed test.

Table Two. Potential sequence of Events for EOL rolls speed test

Generalized Sequence of Events for EOL rolls speed test	
1	Calibration (pre-test)
2	Initialization
3	Memory Checks
4	Electronic Transmission Gear (PRNDL) checks
5	Low-speed tests
6	High-speed test including
6a	Acceleration to high velocity
6b	Decouple rolls
6c	Switch gear to neutral
6d	Measure rolling resistance
6e	Apply brakes and wait for proper force at each brake
6f	Test completed when vehicle achieves zero velocity and test has been passed

The calibration stage (or pre-test) involves making plots of the indicated load versus the applied load to verify the relationships between the two. The memory checks serve to check certain control units for any stored fault codes. To perform the electronic automatic transmission PRNDL check, the vehicle operator could put his foot on the brake and shift the transmission shifter through the complete sequence of gears and then back to the park position. However, during the testing sequence, there is a great deal of communication with the modules within the automobile.

6.1 Communication with various vehicle electronic control units

Communication with engine controllers could primarily be used for reading of existing fault codes and storing of any fault codes that might have arisen during the testing sequence. The electronic automatic transmission controller needed to be communicated with for tests having to do with checking the PRNDL position as well as special transmission features. Most of the communication likely needed to be done with the brake controller in calculating the build and decay forces being generated by the braking system.

After modules such as the engine controller and electronic automatic transaxle controller had been communicated with during their particular portion of the testing sequence, it was time to begin the actual low speed and high-speed testing portions of the vehicle EOL rolls tester.

6.2 Low-speed and High-speed portions of EOL rolls test

In the low-speed tests, the vehicle might be accelerated up to a very low rate of speed (less than fifteen miles per hour) and then decelerated to zero miles per hour with a 'mild' brake application. Preliminary low speed checks are performed during this test as a precursor to the high-speed test along with having other purposes.

In the high-speed rolls test, there are two potential modes of operation: constant speed and inertial. In the constant speed mode the two sets of rolls are driven at a surface speed of over 55 miles/hour. Once the vehicle operator achieves the required velocity, the rolls are decoupled and the vehicle brakes will need to work against the inertia of the rolls and the motors to decelerate the vehicle. After decoupling the rolls the vehicle needs to be switched to neutral to eliminate most sources of powertrain drag contributing to the total deceleration. The machine measures the rolls speeds and by differentiating this signal with respect to time, gives the signal proportional to the instantaneous force being applied at the roll surface. The sequencing of the four individual brake checks between the individual components of the front and rear brakes was specifically chosen according to engineering specifications provided by vehicle and the brake system manufacturers. The brake force might be calculated in the following fashion.

$$\text{Brake force} = \text{deceleration} / \text{radius of roller}. \quad (4)$$

Deceleration was calculated in the following fashion:

$$\text{Deceleration} = (\text{present revolutions} - \text{previous revolutions}) * \text{inertia of roller}. \quad (5)$$

The present revolution was calculated in the following fashion:

$$\text{Present revolution} = \text{present speed} / \text{encoder counts}. \quad (6)$$

There are some important parameters that play fundamental roles in the calculations being performed by the software and several of them are shown below in table three. Note that current draw on the motors will also play an important role in the testing process.

Table Three. Possible parameters used in EOL rolls test machines

SOME IMPORTANT PARAMETERS FOR ROLL SPEED CALCULATIONS	
Roller size (radius)	**15.75 inches**
Rear inertia weight	**280 lbs.**
Front inertia weight	**550 lbs.**
Encoder resolution	**1000 counts/revolution**

At the conclusion of the high-speed test, the vehicle will receive a passing or failing performance evaluation from the test system. There are two courses of action at this point. Either the vehicle will go to the final inspection area (upon passing) or it will be need to be reevaluated after a careful diagnosis of the problem that caused the rolls test failure. There are screens within the rolls testing software which could indicate what portion of the test the vehicle failed along with other pertinent diagnostic information. One of these screens allows the viewing of build/decay plots, the subject of the next portion of this paper.

6.3 Viewing results (build/decay plots) after test completion

After the completion of a test, it was possible to view the build/decay brake forces generated by the braking system. Due to limitations in the technology of the time including lower bus speeds, using file I/O during testing, combined with the sampling rate of the data acquisition system, there was might not be an enormous amount of detail in the plots that were viewable for the build/decay brake forces. However, enough accurate information was available to identify if and why a test had failed, which of the four brake components had failed, and what the corresponding build/decay brake forces were.

7. Support of vehicle rolls test machines

REMOVED

7.1 The hardware and software update process and support of vehicle EOL rolls test machines

REMOVED

8. EOL for ABS to LDWS

What was my reasoning for including this draft document on this website which has been (pretty much) dedicated to technologies surrounding advanced safety systems and specifically lane departure related technology? What was my reasoning for taking a paper that I wrote over twenty years ago, based on professional engineering experience I had gained over ten years prior to that, and attempting to integrate a new aspect of modern automotive safety into what I am sharing? The first reason is that end-of-line testing systems are essentially the final check before the brand-new vehicle gets taken to the distribution location and I happen to have significant professional engineering experience with EOL assembly plant systems. The second is that a camera-based lane departure warning system, whether using a front front-facing camera and/or a rear-view camera, should at least be checked for correct calibration and likely given a basic test for correct performance before using it out on the road. Thirdly, backup and parking assist systems may potentially be checked at EOL test stations. The fourth is that static LDWS calibration can be performed with a relatively straightforward test rig. The fifth is that the EOL dynamometer rolls tester has many capabilities that might be applied to LDWS dynamic testing. The sixth is that I have just recently (7/2025) added some professional experience/employment pursuits to this website and this technology is one that I have considerable (and much more detailed) experience with. Please see the email address in the professional experience portion of this site. The following figure shows a portion of figure one from above combined with image portions from other advanced safety/LDWS draft documents on this site into a possible framework for a static/dynamic LDWS calibration/testing system.

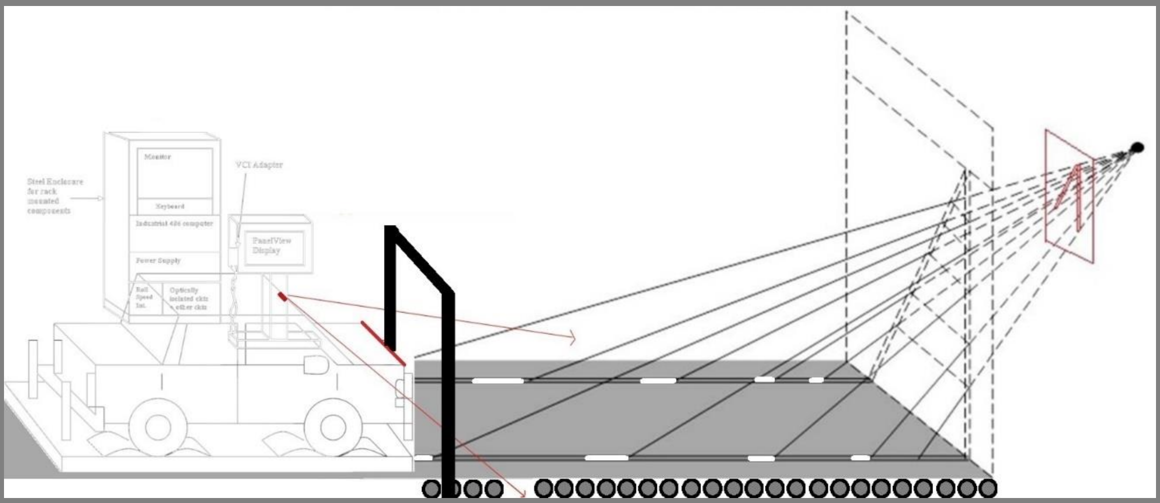

Figure Eleven. Vehicle EOL rolls test machines towards ‘visualized’ LDWS static calibration and dynamic testing

This draft document was originally written more as a ‘refresher’ for job interviewing over a decade before I published this website. I have covered a wide range of technologies associated with distinct EOL rolls tester systems, but in this paper, I have sort-of ‘melded’ them into a document which might lead one to believe that the whole discussion is about one single EOL type tester in only one location when it is more of a ‘topic cohesive’ paper.

Finally, it should be noted that different auto manufacturers sometimes use different technologies within their EOL dynamometer rolls test systems. While this paper focuses primarily on using technologies surrounding Micro PC based serial expanded communications for interfacing various test system components, I also have significant experience with an EOL rolls test system based on VME bus-based technologies. The manufacturer of the VME bus-based system used in those EOL testers was XYCOM.

DISCLAIMER: It is now about thirty years since I worked in this specific engineering field and much of what I am including in this preliminary draft is to the ‘best of my recollection and knowledge’, without me forcing myself to review each and every engineering specific associated with the EOL rolls test systems. Most of the technology covered in this draft is likely relatively outdated, except for many of the enduring engineering principles. I believe it is also important to understand the history of where the current technology might have evolved from. Please be aware that there are additional resources available with further information on end-of-line rolls test systems, lane departure warning system calibration/testing, and related. Commercial systems do likely exist as well. Consider **[7]**, **[8]**, **[9]**, **[10]**, **[11]**, **[12]**, **[13]**, **[14]**, **[15]**, **[16]** and **[17]** for additional background/historical perspective. Please also consider my more comprehensive https://www.lanedeparturewarning.org/Related_Sources.html for additional resources. This document does not in any way constitute a specification.

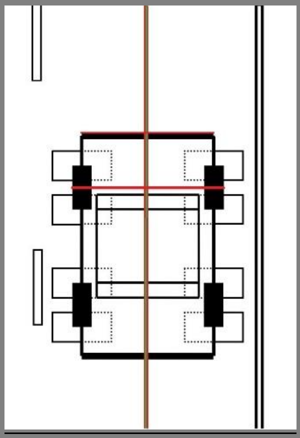

Figure Twelve. EOL rolls test machine base with potentially associated centerlines and widths

8.1 For further thought

Imagine if there was both the coupling between the vehicle and the rollers as well as a coupling between the vehicle dynamometer test stand and the longitudinal lane markings/boundaries in the field of view? Consider a coupling between a stationary vehicle and a set of lane markings in the field of view that moved towards (simulating forward motion of) the vehicle using (possibly) a set of rollers to ‘feed the roadway’ at various velocities? What about if the longitudinal lane boundaries not only approached the vehicle but also moved laterally back and forth simulating the lateral change of position of the vehicle ‘within’ the lane? How might the lateral velocity of the vehicle towards a boundary be accurately monitored, considering that the vehicle might tend to shift in position on the rolls (at least slightly) during testing? Consider how a slight shift of a vehicle’s position on the rolls tester might affect an estimate of lane departure based on the front tire distance to the boundary?

How might different vehicles, say with different wheel bases and front-end geometries, be tested at the EOL testers? How might this affect an estimate for the time to lane boundary crossing and/or the actual determination of a departure? How might basic properties of longitudinal lane boundaries (dimension, color characteristics, gap/segment ratio, etc.) be preliminarily checked for at this EOL dynamometer test system? How might inherent differences between lower speed LDWS systems and the higher speed testing of ABS systems be dealt with during the same EOL test?

What is the significance of potentially using a vehicle turn signal, throttle position, and/or brake pedal signal as part of the actual testing? What about how steering wheel angle, torque sensing and/or yaw rate potentially factor in? What other modules on which vehicle network bus might be included as part of the calibration/testing? How does a forward/rearward facing camera system, as part of a discrete or integrated assembly, get incorporated? How do naturalistic driving studies contribute to best practices (potentially) for this type of testing? How might illumination conditions be altered as part of the calibration and/or testing? How do navigation system and/or GPS system dependencies potentially get addressed?

References

[1] MICRO PC 5025/5025-486 User's Manual from Octagon Systems Corporation, Westminster, CO 80030, 1994.

[2] Intel Peripheral Data book, Intel Corporation.

[3] https://www.rockwellautomation.com/en-us/products/hardware/allen-bradley.html

[4] Stallings, William, Data and Computer Communications 4th, Macmillan Publishing, 1994.

[5] ACL II+ Users Guide, manual part number: 007930097-02A from Industrial Computer Source.

[6] "Measurement Systems: Analysis and Design", Fourth edition, Doebelin, Ernest O., McGraw-Hill Inc., 1990.

[7] Report No. DOT HS 811 405, "Advanced Crash Avoidance Technologies (ACAT) Program – Final Report of the Volvo-Ford-UMTRI Project: Safety Impact Methodology for Lane Departure Warning – Method Development and Estimation of Benefits", Gordon, T., Sardar, H., Blower, D., Ljung Aust, M., Bareket, Z., Barnes, M., Blankespoor, A., Isaksson-Hellman, I., Ivarsson, J., Juhas, B., Nobukawa, K., and Theander, H., NHTSA 2010.

[8] Report No. DOT HS 811 416, "Integrated Vehicle-Based Safety Systems, Light-Vehicle Field Operational Test Key Findings Report", Sayer, James R., Bogard, Scott E., Buonarosa, Mary Lynn, LeBlanc, David J., Funkhouser, Dillon S., Bao, Shan, Blankespoor, Adam D., and Winkler, Christopher B., USDOT/Research and Innovative Technology Administration ITS Joint Program Office 2011.

[9] Project number FP6-2004-IST-4_026912, "D1.3 eSafety Recommendation Note (December 2008)", Carrotta, Alessandro, Blervaque, Vincent, European Commission DG INFSO/ERTICO-ITS Europe 2009.

[10] Report No. DOT HS 811 362, "Integrated Vehicle-Based Safety Systems, Heavy-Truck Field Operational Test Key Findings Report", Sayer, James R., Bogard, Scott E., Funkhouser, Dillon, LeBlanc, David J., Bao, Shan, Blankespoor, Adam D., Buonarosa, Mary Lynn, and Winkler, Christopher B., USDOT/Research and Innovative Technology Administration ITS Joint Program Office 2010.

[11] ISO 17361:2007 "Intelligent transport systems – Lane departure warning systems – Performance requirements and test procedures", International Organization for Standardization, February 2007.

[12] Report No. GAO-09-56, "HIGHWAY SAFETY Foresight Issues Challenge DOT's Efforts to Assess and Respond to New Technology-Based Trends", Government Accountability Office Report to the Chairman, Committee on Commerce, Science, and Transportation, U.S. Senate, 2008.

[13] Report No. PPR 374, "Study on lane departure warning and lane change assistant systems FINAL REPORT", Visvikis, C., Smith, T. L., Pitcher, M., and Smith, R., Transportation Research Laboratory, 2008.

[14] Report No. FHWA-SA-07-002, "Low-Cost Treatments for Horizontal Curve Safety", McGee, Hugh W., Hanscom, Fred R., USDOT/Federal Highway Administration Office of Safety, 2006.

[15] Report No. FMCSA-MCRR-05-005, "Concept of Operations and Voluntary Operational Requirements for Lane Departure Warning System (LDWS) On-board Commercial Motor Vehicles", Houser, Amy, Pierowicz, John, Fuglewicz, Dan, Federal Motor Carrier Safety Administration Office of Research and Analysis, 2005.

[16] Report No. UMTRI-2006-9-1, "Road Departure Crash Warning System Field Operational Test: Methodology and Results", LeBlanc, D., Sayer, J., Winkler, C., Ervin, R., Bogard, S., Devonshire, J., Mefford, M., Hagan, M., Bareket, Z., Goodsell, R., and Gordon, T., Sponsored by USDOT/NHTSA performed by The University of Michigan Transportation Research Institute, 2006.

[17] Report No. DOT HS 810 829, "Final Report: Objective Test Procedures for Road Departure Crash Warning Systems (RDCWS)", Szabo, Sandor, Norcross, Richard, USDOT/National Highway Traffic Safety Administration, 2006.