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SAFETY BRIEF

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Triodyne Inc.
Consulting Engineers & Scientists – Safety Philosophy & Technology
666 Dundee Road, Suite 103, Northbrook, IL 60062-2702
(847) 677-4730 FAX: (847) 647-2047
e-mail: infoserv@triodyne.com
www.triodyne.com

Driver Fatigue/Inattention Monitoring Device – An Integrated System for Heavy Trucks

By Christopher W. Ferrone* and Charles Sinkovits**

ABSTRACT

The National Transportation Safety Board has reported statistics which indicate that 31% of all fatal-to-the-truck driver accidents occur due to fatigue/inattention (Ref.1) and 58% of all single-vehicle large truck crashes were also fatigue related (Ref. 2). If these numbers can be reduced, many lives can be saved.

A Driver Fatigue Monitoring System has been designed and built to monitor whether a driver is sleeping or inattentive. This integrated system monitors the steering input behavior of the driver during a specified period of time. If the number of steering inputs is below the expected predetermined threshold, the system activates an audible alarm and light in the cab, waking the driver. Furthermore, this system can deactivate cruise control as well as activate various other preprogrammed truck systems or components to further aid in the control of the truck and to alert nearby motorists.

INTRODUCTION

Commercial drivers drive long hours each day and up to 70 hours per week. Driving occurs throughout the day: daylight, dusk and night.

Fatigue has long been a problem for commercial drivers. Fatigue is cumulative (Ref.3); without proper rest periods (off duty cycles), fatigue will "accumulate" in the human body and eventually create moments when the driver has to struggle to stay awake. Once this occurs, the overall performance of the driver is greatly compromised.

The Department of Transportation, the National Transportation Safety Board as well as the National Highway Traffic Safety Administration have all invested millions of dollars in researching driver fatigue. Statistics show that over two decades, 30% to 40% of all serious accidents involving heavy trucks are in some way related to fatigue or inattention. Since driver fatigue can only be controlled to an extent, the next logical step would be to detect when the driver is falling asleep or becomes inattentive.

During alert driving, drivers "micro-steer." They make small steering movements which correct the course of the vehicle. Research indicates that as drivers begin to become inattentive or fall asleep, the amount of physical steering they do diminishes (Ref.4). If drivers stop micro-steering, they drift or change lanes. Therefore, there is a direct correlation between micro-steering behavior and driver wakefulness.

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* Senior Mechanical Engineer, Triodyne Inc., Northbrook , IL
** Senior Vehicle Service and Systems Specialist, Triodyne Inc., Northbrook , IL

No Charge

SYSTEM DESCRIPTION

A Driver Fatigue Monitoring System has been designed and built to monitor whether a driver is sleeping or inattentive. This integrated system monitors the steering input behavior of the driver during a specified period of time. If the number of steering inputs is below the expected predetermined threshold, the system activates an audible alarm and light in the cab, waking the driver. Furthermore, this system can deactivate cruise control and activate various other preprogrammed truck systems or components, like brake lights or hazard lights, to further aid in the control of the truck and to alert nearby motorists. This proof of concept system was assembled and installed on a 1996 Peterbilt 379 tractor (photo 1 - See Appendix 1).

Photo 1 - Truck / Tractor Used for Prototype Upfit

FAILURE MODES AND EFFECTS

The system has a self-check function which initiates at vehicle start-up. If system faults are detected at startup or during driving, the "check steering" light illuminates notifying the driver that the system has malfunctioned.

In addition to the failure signal light, the system reverts to "typical" cruise control function and all other preprogrammed truck system options "fail to safety," that is they go back to their normal way of operating as if the new monitoring system was not in place.

Advantages of the system are that a sleeping driver is detected within seconds of sleep onset and the driver is awakened. This saves lives, community property, and cargo.

As designed, the system does not have any disadvantages.

FEASIBILITY STUDY

When proposing any alternative design, one must analyze practicality, cost, engineering issues, maintainability, market acceptance, prevention of accident(s) and reduction/elimination of injury. This system has been evaluated against these criteria.

There are a number of practical aspects of this design. Standard off-the-shelf automotive components were used for motion detection and off-the-shelf electronics (programmable logic controllers) were used. This leads to high reliability and makes the design, manufacturing and maintenance costs low as no special parts must be developed or fabricated. Low cost, easy maintenance, and high reliability usually lead to market acceptance. As for safety, waking a sleeping driver will prevent accidents or allow the driver opportunity to mitigate them.

TECHNICAL SYSTEM DISCUSSION

Design Solution 1 - Cruise Control Deactivation

This system is comprised of common automotive components: A.B.S. tone-ring, A.B.S. sensor, wiring and a networked I/O module. The module features universal input-output ranges and a micro-controller to provide monitoring and control capabilities. This module monitors discreet levels of various devices and/or provides on/off control capabilities. Its functional capability is control of on/off, high/low, open/close switching along with activation of audible and visual alarms (Ref.5).

The tone-ring (Fig. 1) is mounted on the steering shaft (engine compartment) of the vehicle by way of a self-

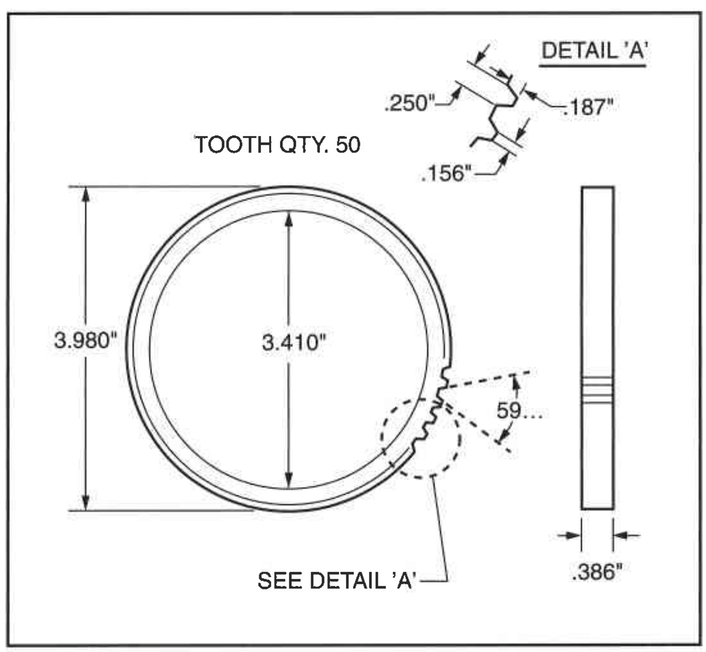

Figure 1 - Tone Ring

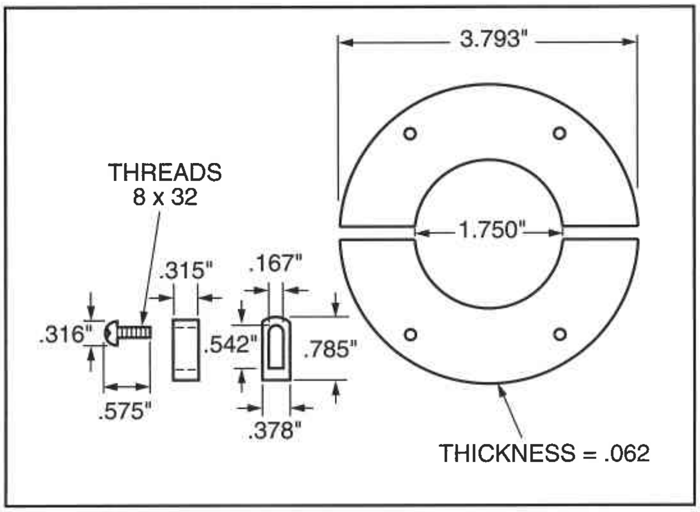

Figure 2 - Self Centering Clamp (Tone Ring to Steering Shaft)

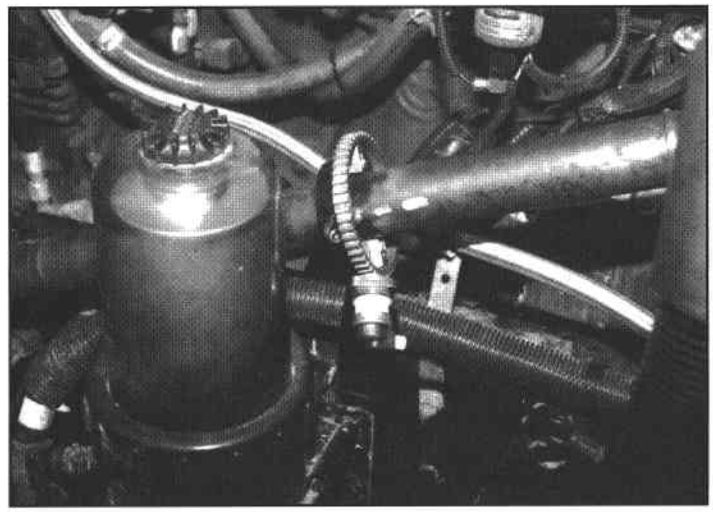

Photo 2 - Tone Ring and Sensor (Solution 1)

centering clamp (Fig. 2). This allows the ring to mount to the shaft concentrically. The sensor (photo 2) is mounted to the left frame rail with a bracket that allows for positioning and adjustment. The sensor is then wired into the cab to the module (photo 3). The module utilizes the millivolt AC signal from the sensor to determine steering input activity. The module is programmed via proprietary software supplied with it through a laptop computer (photo 4). Steering input counts along with time duration are adjustable through the laptop. The steering input counts are converted to millivolts which are then analyzed by the module.

As long as the module detects a signal greater than 40 millivolts in 5.4 seconds, no action is taken by the module. If the signal drops below 40 millivolts in 5.4 seconds, a predetermined set of contacts close in the module. Once these contacts close, the system begins to activate. Alarm configuration (1) disables the cruise control (normally closed contacts), and alarm configuration (2) activates the in-cab alarm and light (normally open contacts). Once this occurs, the system will remain "on" disallowing future cruise mode and continuing the alarm and light. This may only be deactivated by cycling the cruise on/off switch. Once that is done, the system can be reactivated.

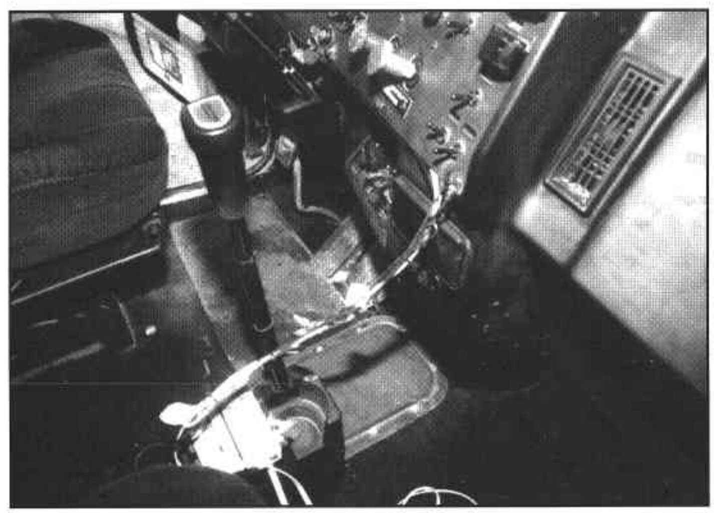

Photo 3 - Alarm Module

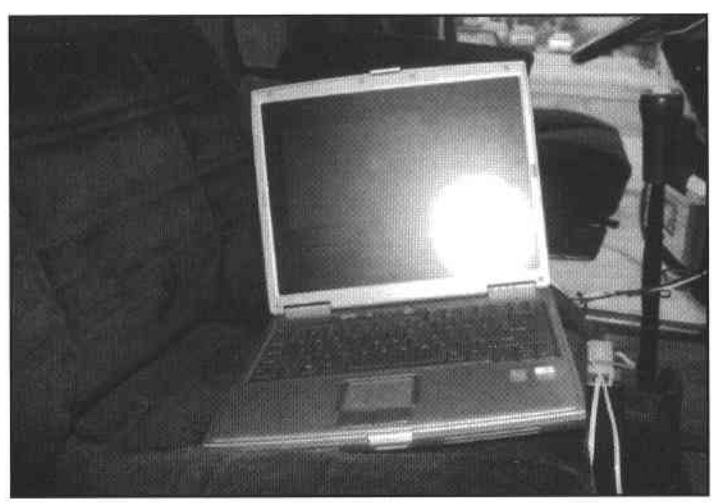

Photo 4 - Laptop Computer

Design Solution 2 - Cruise Control Deactivation

This system is comprised of non-automotive components with the exception of the already mentioned tone ring. An industrial proximity sensor was used in place of the A.B.S. sensor. This has the ability to actually detect a discreet number of tooth counts from the tone ring (photo 5).

The tone ring and proximity sensor work the same way as the ones in System (1). However, the signal generated from the proximity sensor is fed into a programmable logic controller (P.L.C., Photo 6). The P.L.C. uses ladder logic to evaluate the steering input and the subsequent output actions. The P.L.C. is programmed originally through a laptop but can be reprogrammed through the touch pad on its face. As long as the P.L.C. detects a signal (3 pulses in 6 seconds), no action is taken.

If the signal drops below 3 pulses in 6 seconds, the output logic begins to function and deactivates the cruise control and activates an audible alarm and in-cab light. Once this has occurred, the system will remain "on" disallowing future cruise mode and continuing the alarm and light. These may only be deactivated by cycling the cruise on/off switch. Once that is done, the system can be reactivated.

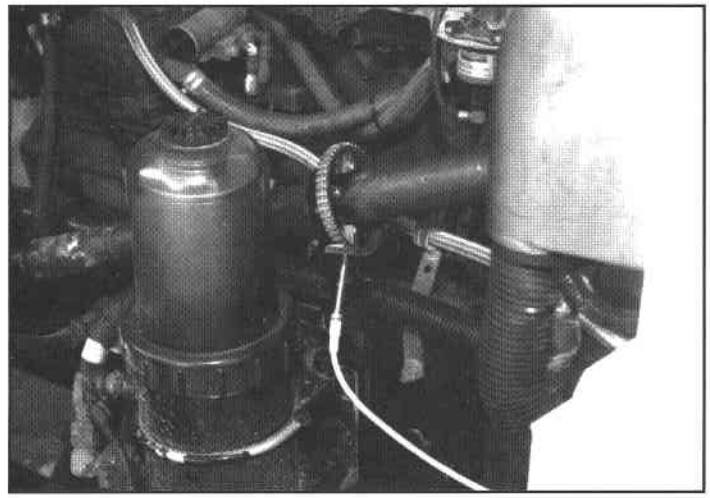

Photo 5 - Tone Ring and Sensor (Solution 2)

CRUISE CONTROL DEACTIVATION LOGIC

The cruise control is deactivated the same way for both Design Solutions 1 and 2. Specifically, the module (Solution 1) and the P.L.C. (Solution 2) eliminate the electrical ground source at the cruise on/off dash switch location (Photo 7). Once the switch ground has been interrupted, the cruise control drops out and will no longer function until the system re-initiates.

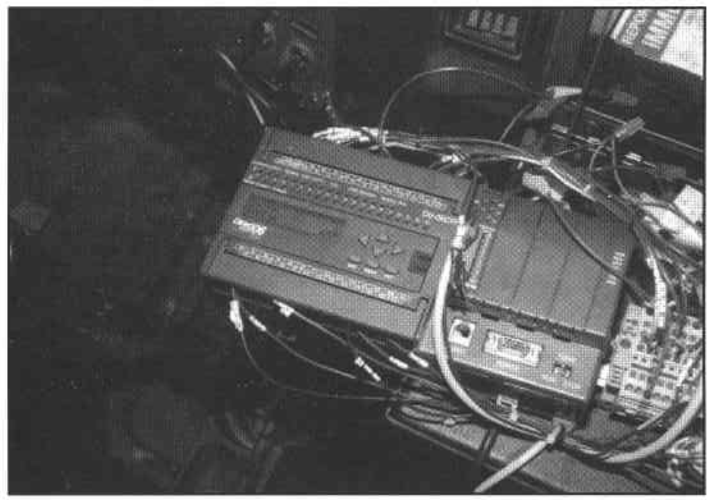

Photo 6 - Programmable Logic Controller (Solution 2)

FUTURE APPLICATIONS

The driver fatigue/inattention monitoring device has many future applications; automobiles, SUVs, buses and a variety of trucks can benefit from this technology. The system's primary function is to detect sleeping or inattentive drivers. The system can be expanded to control other vehicle system controls based on the vehicle, driver, community and vehicle operational profile. Expansion possibilities include:

- System will record an "event" if sleep is detected, which can be logged on the P.L.C. for later extraction and analysis. It can include time, date, speed(s).
- If the vehicle utilizes satellite navigation (heavy trucks), an "event" can be time stamped with longitude, latitude, and speed, and can automatically send an emergency message.
- A cruise control termination strategy would eventually preclude the use of cruise control after repeated activations of the sleep detection system. Only after a prescribed "lockout" time has been met would the cruise be reactivated. To force the driver to stop driving and rest, an engine derating schedule similar to engine protection logic (already in place) can be utilized. This would begin to reduce engine performance sequentially (75%, 50%, 25% power) after multiple triggerings, if the driver refused to stop driving and rest.

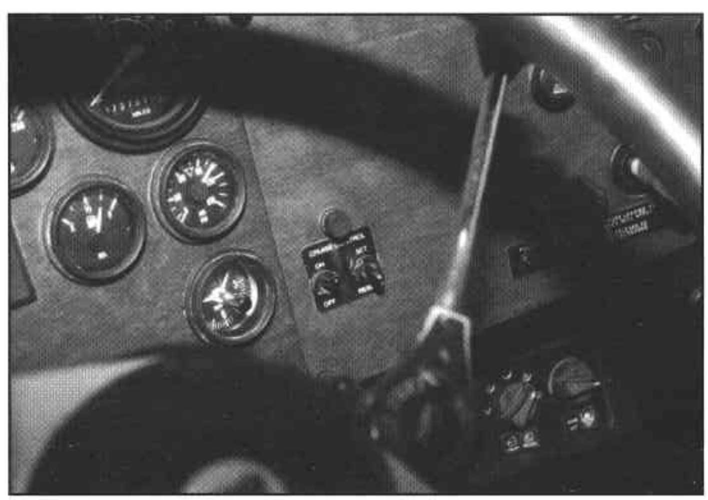

Photo 7 - Dash Mounted Cruise Control Switches

CONCLUSION

1. The proposed fatigue monitoring system uses standard off-the-shelf components with the concomitant reliability.

2. The fatigue monitoring system has not been incorporated into production.

3. The fatigue monitoring system subjects a sleeping or inattentive driver to an in-cab alarm and light.

4. The fatigue monitoring system can deactivate the cruise control and then activate various other truck systems or components such as:

    - Engine Brake
    - Stop lights
    - Hazard Lights

DISCUSSION

Numerous questions arise from the inclusion of this system in commercial vehicles:

- Are road vibrations causing false steering inputs?

- If road vibrations are creating false steering inputs, is it feasible to include a triaxial accelerometer to record road vibrations and then have them subtracted from the count; or is it possible to mount the tone-ring and sensor to a portion of the steering shaft in the cab?

- Should the system be adjustable for time duration and steering input counts?

- If adjustments are desired, who should make them and how? Only authorized maintenance personnel with personal identification numbers (PINS) should make these adjustments. Time stamping the adjustment along with other critical chronology data will assist with accountability.

- Should the system use adaptive learning similar to fuel trim control or shift scheduling in some automatic transmissions? This approach will allow for specific driving habits to be recognized and learned by the system. Once accomplished, the system knows the driver's normal behavior and can more accurately distinguish sleeping.

- Is "bump steer"due to jouncing a factor in creating false steering input?

- Does "road steer" due to roadway crown and other grooves and bumps create false steering input?

- If "road steer" is a concern, is it feasible to include additional steering input sensors on the vehicle to detect if the road or the driver has initiated the most recent steering motion?

- Should there be a mechanism to recognize steering box wear from aging and mileage that necessitates more active steering by the driver to maintain guidance of the vehicle? This could be part of the system adjustment process proposed above.

- Should steering "center" be considered to account for vehicle turning as with a gradual lane change or perhaps misalignment?

- Will drivers skip needed rest stops, depending on the alarm to wake them up?

ACKNOWLEDGMENTS

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APPENDIX 1

Penske No.	194329
VIN:	1XP5DR8X9VN428254
Model:	379 Peterbuilt
Year:	7/96
Miles:	0,737,5902
Engine:	Series 60 (DDC)12.7L
HP:	430/470 HP
Rated:	1800 RPM
Peak Torque:	1550 ft/lbs @ 1200 RPM
Idle:	600 RPM
Axle Ratio:	3.90
Total (top) O.D.:	0.73
Rev/Mile:	499
Pulse/MI:	31136
Cruise & Engine Brake Min:	3 mph
Max Cruise:	70 mph
Min Cruise:	20 mph
Max Road Speed:	70 mph
Software:	1989-93 (1.10ver) DDECIII
Engine Model:	6067GK60
S/N:	06R0305951
ECM S/N:	SE600 VCW
Software Level:	5.05
E.P.A. Cert:	530

APPENDIX 2

System #1	
Alarm Module:	Acromag
Model:	801A-0200
S/N:	067668G
System #2	
PLC Module:	Koyo
Model:	DO-06DR (Direct Logic)
S/N:	N/A
In-Cab Alarm:	Federal Signal
Model:	252
Level:	dBA 97
V:	12V - 49V
In-Cab Warning Light:	Tri-Light Inc.
Model:	MV-2-MAG
V:	12V DC
Color:	Red
Tone Ring:	Motorcraft (Ford)
Model:	F587-2C182B
Sensor System #1:	Motorcraft (Ford)
Model:	F587-2C204-BA
Sensor System #2	Automation Direct
Model:	AE1-AN-SF

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