OVERVIEW OF AUTOMOTIVE APPLICATIONS

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INTRODUCTION

The purpose of this Application Note is to provide a top-level overview of current and future applications of Liquid Crystal Displays in the automotive industry. Key focus areas are current LCD applications, such as digital meters and gauges, and future multi-information system applications, such as navigation. The scope of the paper will be limited to providing systems level descriptions and architectures rather than focusing on display requirements which will vary basedon specific market demands. A special emphasis will be made to provide an understanding of Navigation System design by providing descriptions of direction sensors, dead reckoning, map-matching, GPS, and route guidance.

DIGITAL METERS

Conventional methods for displaying information such as vehicle speed, engine RPM, fuel level, and mileage consist of mechanical pointers and scrolling numerical displays. The rapid development of practical LCD materials, however, has provided an inexpensive alternative. Digital LCD gauges provide benefits such as low power consumption and improved form factor over mechanical gauges.

Speedometer/Odometer

The basic operating principles for odometers and trip meters are based on counting signals generated from rotational transducers. These analog pulsed inputs are A/D converted counted and stored in a rewritable battery backed or non-volatile memory. A systems configuration of a speedometer is shown in Figure 1.

The basic method of calculating vehicle speed uses a Magneto-Resistive Element (MRE) at the drive shaft to create electrical pulses that are proportional to the vehicles speed. The speed is based on counting the number of pulses output by the vehicle sensor during a fixed period of time. When the sampling period ends, a comparator relates to the microcontroller whether the vehicle speed has changed by more than one mile per hour and updates the display value. To enhance the accuracy of the speed sensing, a minimum of twenty pulses are created per single wheel revolution.

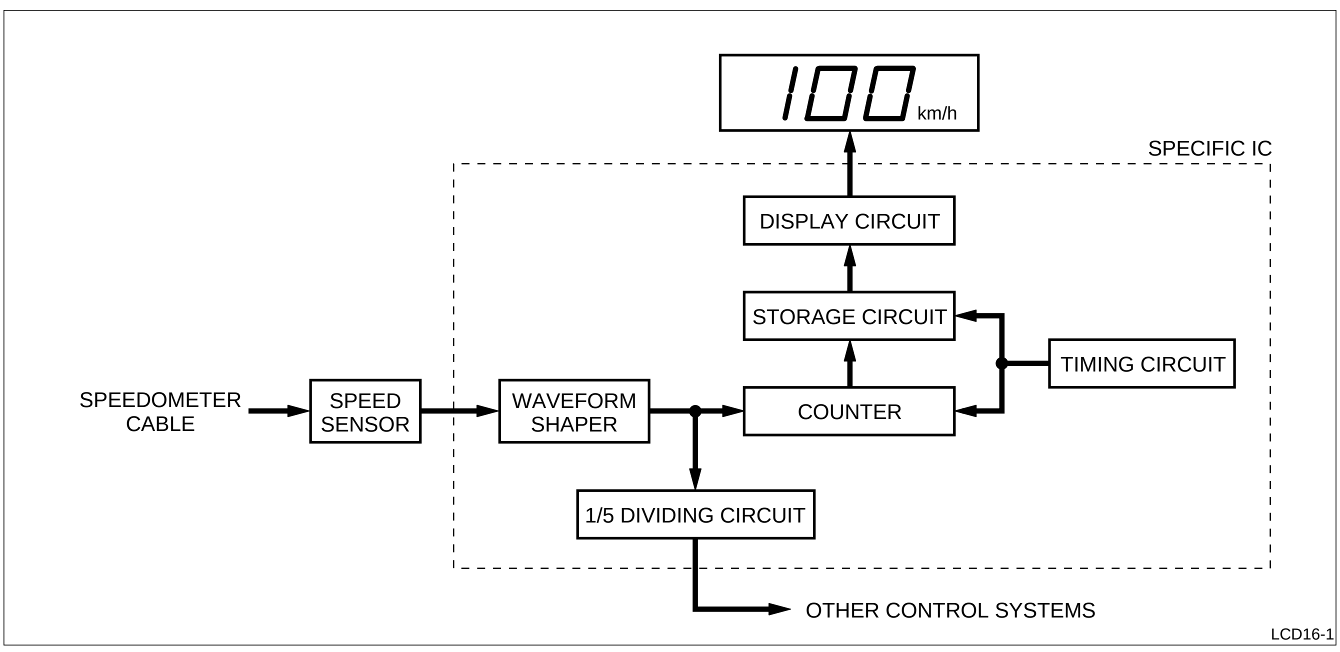

Figure 1. Systems Layout of a Typical Speedometer

Figure 2 shows a cut-out of an MRE-based vehicle speed sensor. The system includes a multipolar ring magnet attached to the drive shaft and an MRE sensing element with the associated support circuitry. As the shaft rotates, the resistance of the MRE on the IC chip changes in relation to the magnetic flux. The resistance changes are picked up by the bridge circuit and converted to pulse signals which are then digitized and processed by the microcomputer. The basic operating principles of the MRE are illustrated in Figure 3. The MRE resistance is maximized when the current flowing through it is parallel with the direction of the magnetic flux lines. Conversely, when the current and the line of magneticforce are at right angles to one another, the resistance is minimum.

Tachometer

A tachometer inputs the source signal from the primary side pulse of the ignition coil. The inverse of the period of this signal is proportional to the engine speed. An interrupt driven routine is then used by the microcontroller to average the period of several engine cycles and determine the engine RPM. Display update times are staggered according to the pulse time period and shorten in proportion to the engine speed, thus providing an intuitive feel to the meter. Figure 4 shows the basic principles and architecture for a tachometer system.

Fuel Gauge

The most widely used fuel sender gauge consists of a float, which rises and falls according to the fuel level, a mechanical linkage system, and a resistance transducer. The body of the gauge is fixed to the wall of the fuel tank and the float rises and falls, causing the contact plate to slide over the printed resistors, changing the resistance value. The relative resistance is then sensed by a voltage divider circuit, converted by an A/D and processed by a microcontroller. The appropriate display segment is illuminated in accordance to this value. In order to dampen the response of the system and prevent display flicker during sudden maneuvers, time averaging is used to determine the actual fuel level and display updates are limited to only one segment at a time. Figure 5 shows both the mechanical construction of the fuel sender structure and a systems layout of the fuel gauge.

MULTI-INFORMATION SYSTEM (MIS)

The basic concept of a Multi-Information System is to allow the driver access to a centralized user interface for basic vehicle functions such as:

1. Trip information: Information on the distance from the beginning of the trip, elapsed time, the amount of fuel consumed, and range based on current fuel consumption rate.
2. Climate control: Displays cab temperature, as well as fan settings, for both the heater and air conditioner functions.
3. Radio functions: Displays station settings, tape player functions, CD player functions, and graphic equalizer bar graphs.
4. Calendar/Organizer: Calendar with daily schedule information can be stored by the driver.

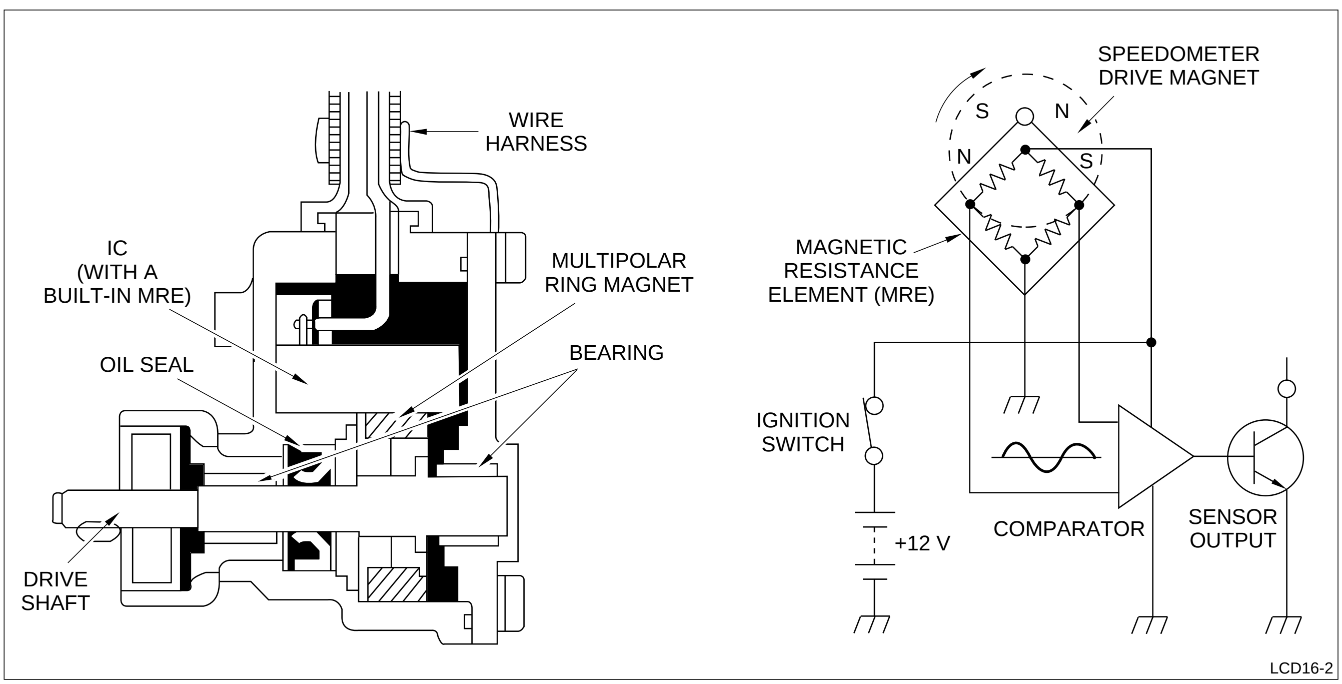

Figure 2. MRE Vehicle Speed Sensor and Supporting Circuitry (Toyota)

And advanced features such as:

1. Map information: Road maps are scrolled at various scales relative to vehicle movements, thus tracking the current position. Additional benefits include route guidance and traffic information.
2. Entertainment features: Displays video signals from either broadcast sources or prerecorded tapes.
3. Maintenance information: Displays updates on regular engine maintenance requirements, including built-in fault diagnostics.
4. Rear-view camera: Integrates video input from a rear-mounted CCD camera.

Navigation

Navigation represents the best near term application of graphical displays in automobiles and will be the focus of the rest of this report. Navigation technology is comprised of dead reckoning, map matching, and GPS functions. Dead reckoning obtains the relative position of the vehicle from information on distance and direction obtained from the built-in compass and wheel sensors. Map matching compares the travel path determined from dead reckoning and fixes the vehicle's position on a map grid. In addition, GPS can provide an improvement in positioning accuracy by providing satellite-derived latitude and longitude data. Figure 6 illustrates a Navigation System's typical configuration.

Direction Sensor

There are two commonly used input sensors for transducing the vehicle's direction: the compass sensor and the wheel sensor.

The compass sensor determines the vehicle's direction by detecting the earth's magnetism. An excitation coil and two perpendicular sensing coils are wound around the center of a ring core magnet. When AC voltage is supplied to the excitation coil, the magnetic center's flux changes and a voltage is produced by electromagnetic inducement in the sensing coil. When there is no external magnetic field, the flux change produces a symmetrical waveform. When an external magnetic field H is applied at right angles to output coil Vx, it is superimposed on the magnetic field generated by the magnetized current, and the flux changes to become asymmetrical (see Figure 7). Output voltage is developed in proportion to the rate of change of the difference. When external magnetic field H is applied at an angle ϕ, the output voltage Vx and Vy can be sensed and, using the relationships shown below, vehicle direction can be calculated:

$Vx = KH\cos(\phi)$, $Vy = KH\sin(\phi)$
where ϕ can be calculated from: $\phi = [\tan(Vy/Vx)]^{**}(-1)$

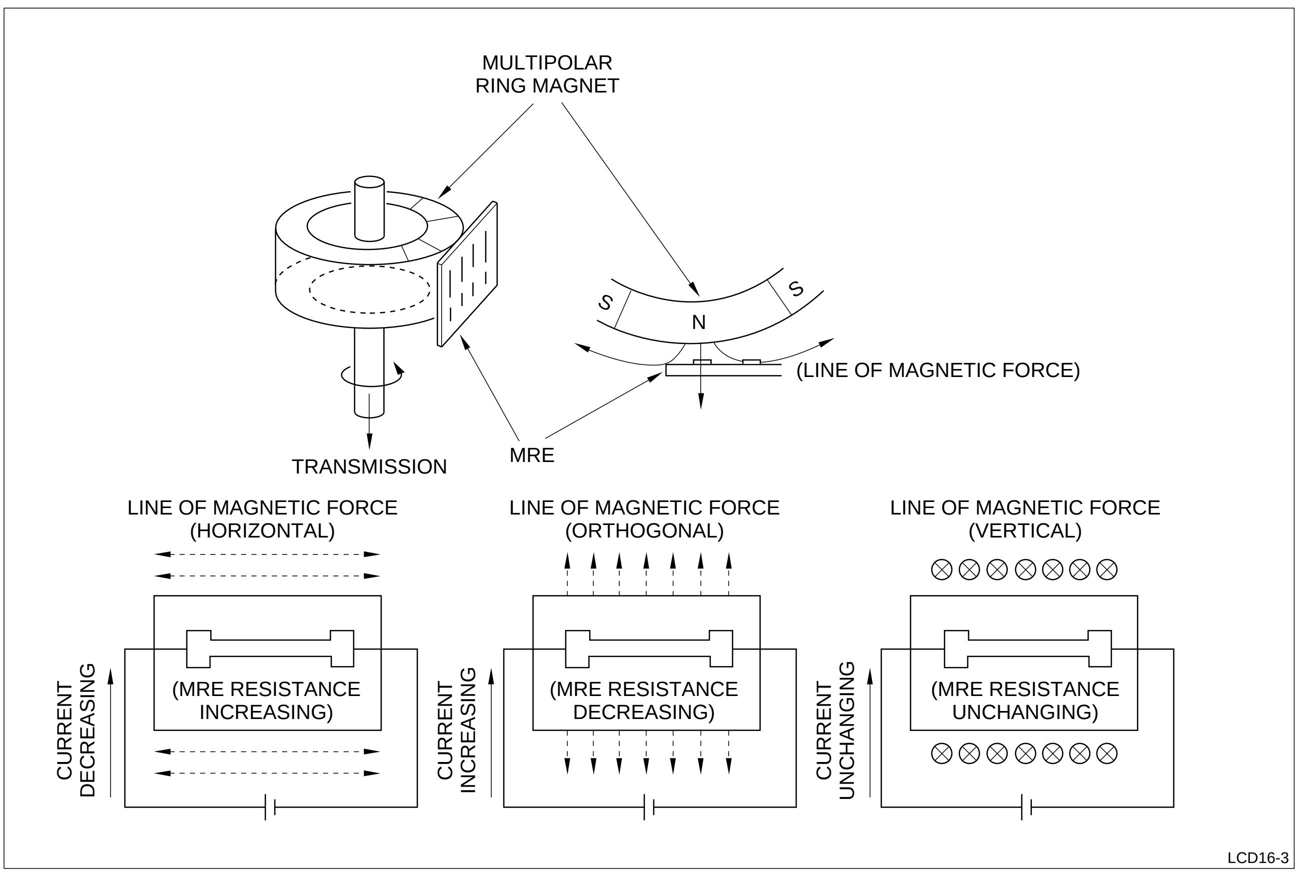

Figure 3. Operating Principle of MRE

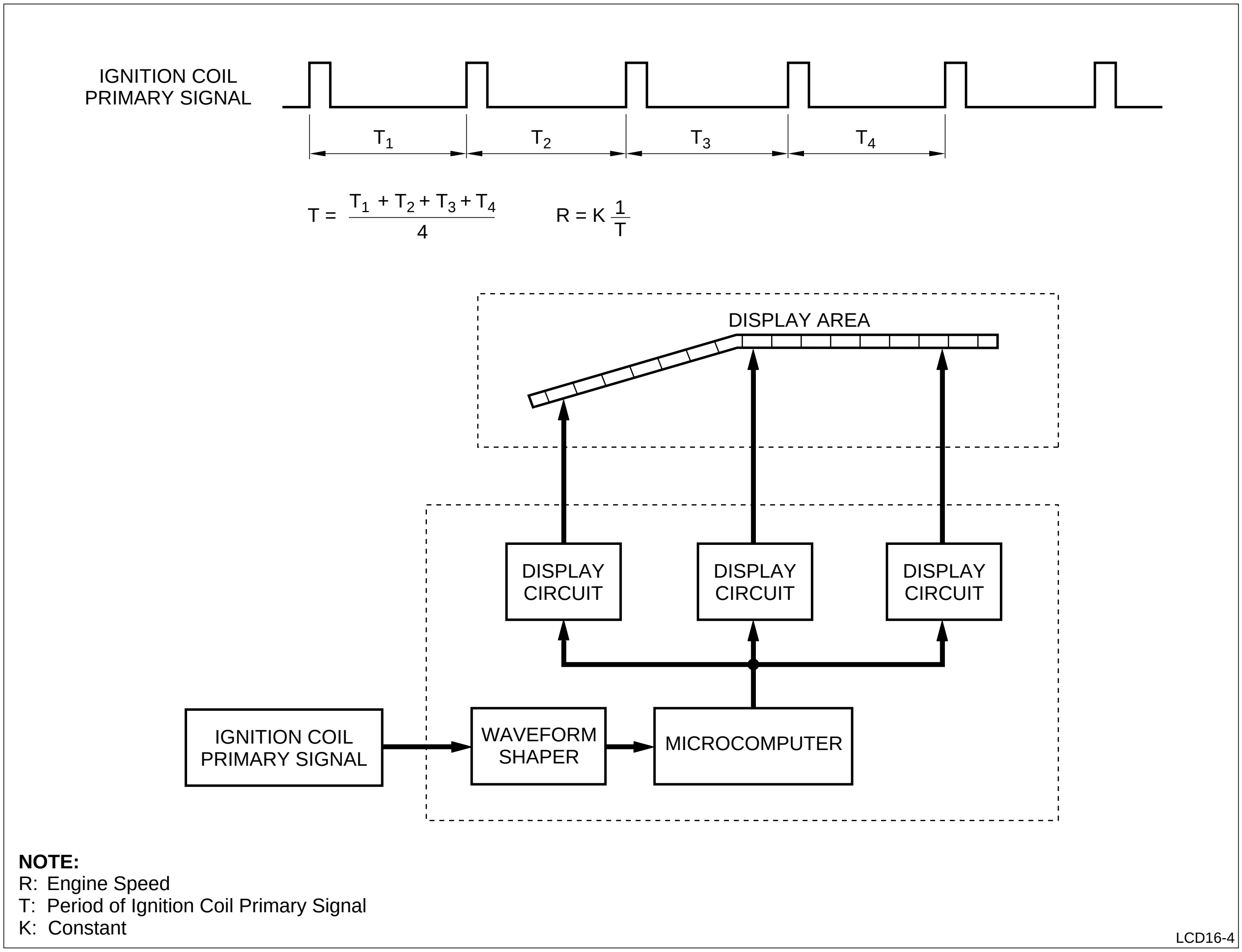

Figure 4. Tachometer Calculations and Systems Architecture

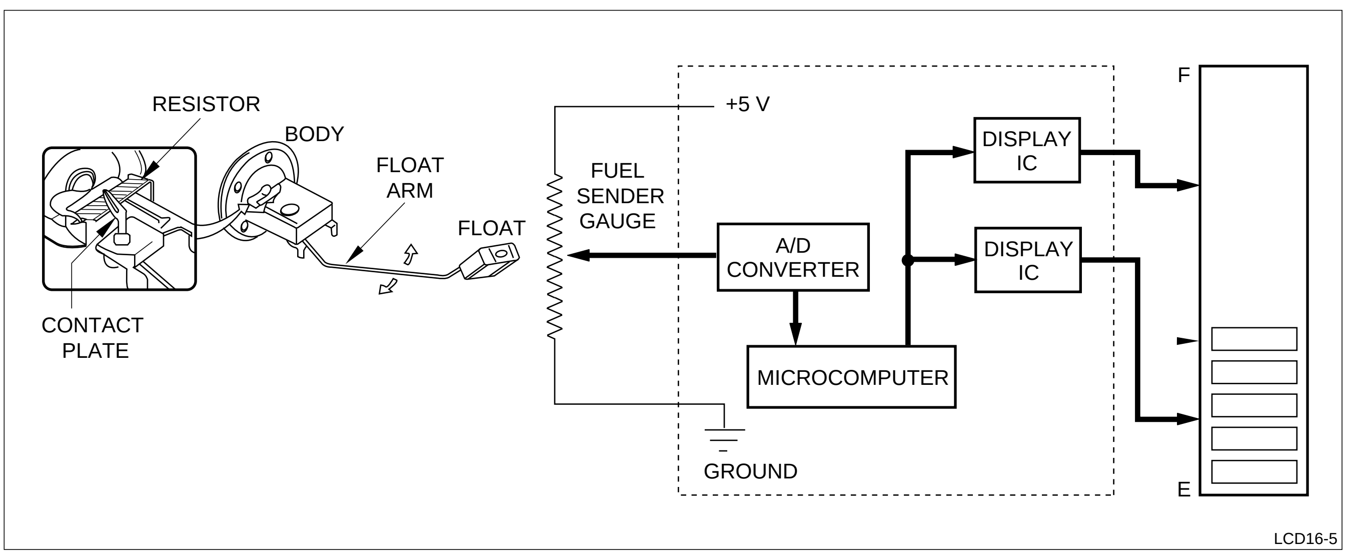

Figure 5. Fuel Sender Structure and Fuel Gauge System

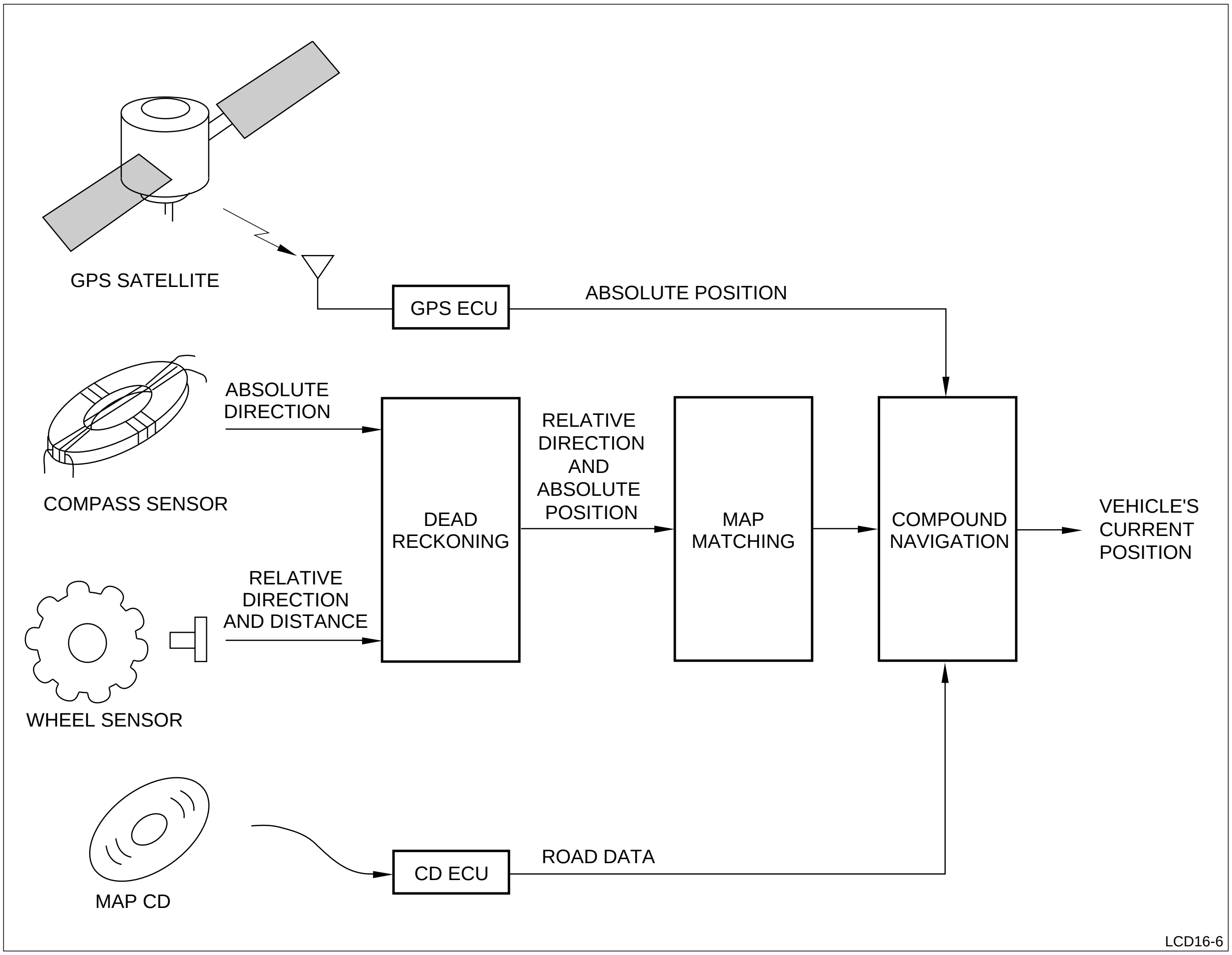

Figure 6. Navigation System

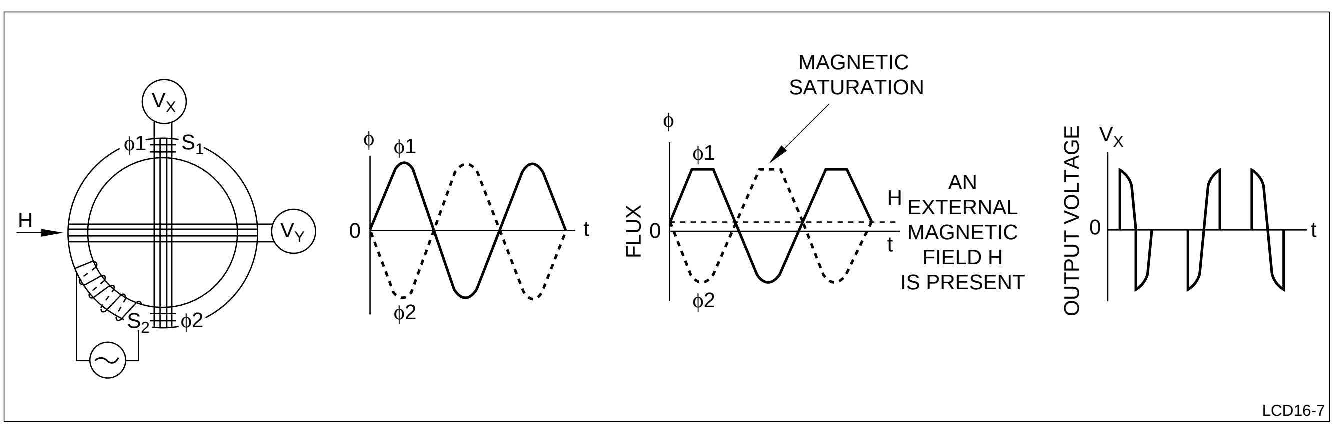

Figure 7. Basic Compass Operation Principles and Output Voltage Waveforms

Wheel Sensor

Front wheel pulse sensors that are used for ABS applications can also double as directional transducers for a Navigation system. The vehicle's turning is detected and calculated by taking the differences in the distance traveled by the left and right wheels (see Figure 8).

When the vehicle turns θ (rad) at rotation radius R, and each wheel rotates with the same rotation center, paths such as those shown in Figure 8 can be drawn for each wheel. Distance traveled, Li and Lo, by the front wheels is expressed by the following equation with the rear wheels rotation radius Ri and Ro for each wheel.

$Li = Ri\theta;\ Lo = Ro\theta$

The rotation radius for each wheel is expressed in the following equation, where the rear wheel's rotation radius is R, the wheel base is L, and the tread width is K.

Ri = [R**2 + L**2]**(1/2);
Ro = [(R + K)**2 + L**2]**(1/2)

The ratio P of the distance traveled by the inner and outer wheel circumference gives the following relationship.

P = Lo/Li = [(R + K)**2 + L**2]**(1/2) / [R**2 + L**2]**(1/2)

OR

R = {K + [(K**2) – (P**2 –1)(P**2 – 1)(L**2) – (K**2)]**(1/2)}/(P**2 – 1)

Based on the unique values of wheel base L, tread width K, and by calculating the ratio P of the distance traveled by the front wheel's inner and outer circumference, rotation radius R for the rear wheels is obtained. Accordingly, the vehicle's instantaneous turning angle θ_i can be found by the following equation:

θ_i = Li/Ri = Li/[R**2 + L**2]**(1/2)

Where the total turning angle is the summation of θ_i for i = 0 to n.

Dead Reckoning

Dead reckoning is a method of determining the vehicle's position based on summing direction vectors determined from inputs, such as the compass and the wheel sensors. The distance traveled along a two-dimensional path can be measured using the following equation where X is east-west and Y is north-south.

$Xn = Xo + SUM(L\sin\theta_i)$;
$Yn = Yo + SUM(L\cos\theta_i)$ for i = 0 to n

Where L is the magnitude of the distance vector.

Since geomagnetism may be temporarily disturbed by such influences as when the vehicle passes over a metal bridge or travels next to a large truck, employment of wheel sensors adds to the system's robustness. Figure 9 illustrates the general method of calculating vehicle position.

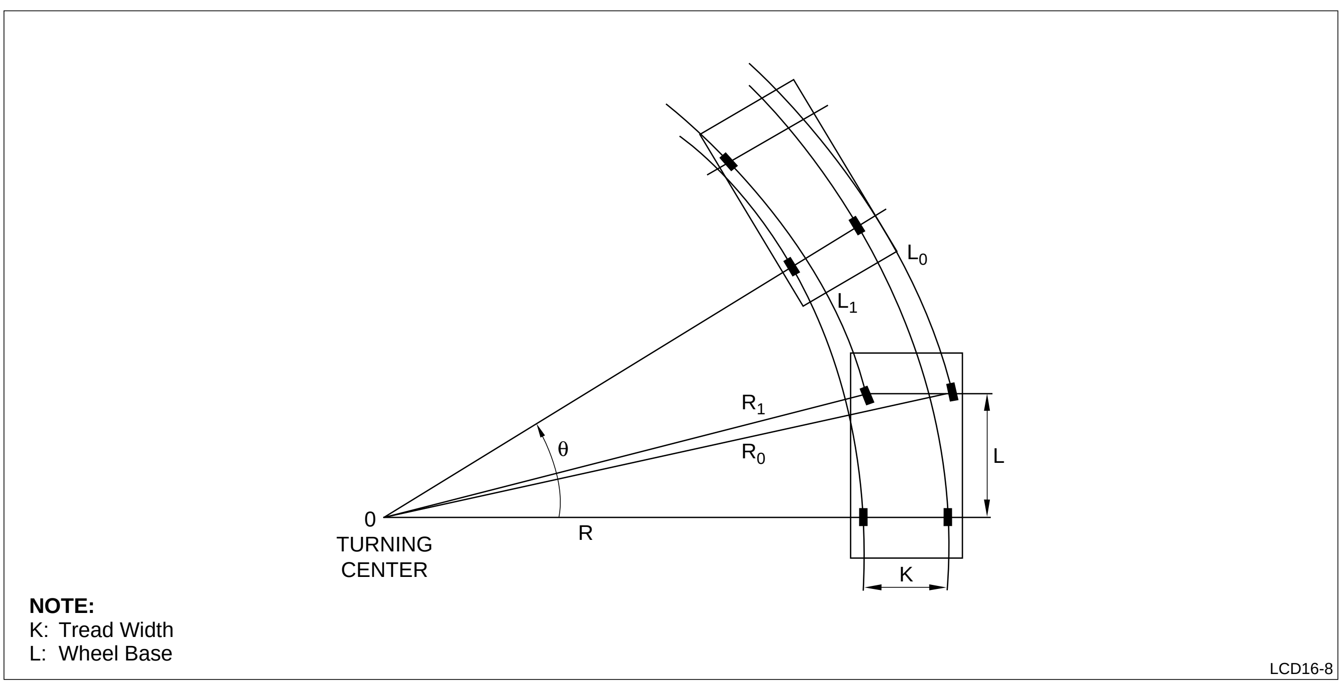

Figure 8. Wheel Travel Path

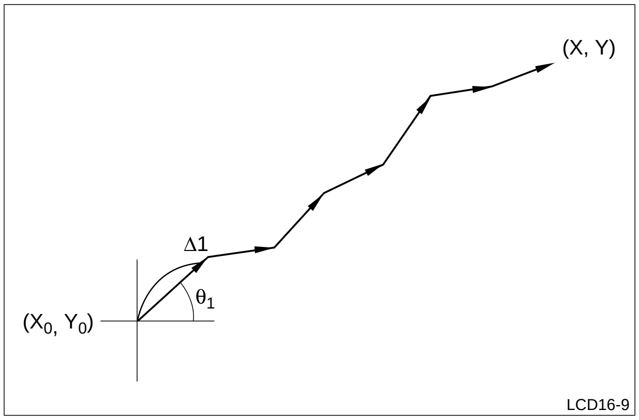

Figure 9. Vehicle Positioning by Vector Summation

Map Matching

Map matching is a method of determining the vehicle's current location by correlating the vehicle's path, obtained through dead reckoning, with the known roads in the area and determining which road the vehicle is on. Once a correlation is found between the road direction data and the dead reckoning calculations, the vehicle's position is updated and the distance traveled is calculated. When the vehicle reaches an intersection with many potential paths, directional calculations are made for each. Then, based on and the vehicle sensor inputs, tracking continues until a strong correlation is developed for one of the available paths. Road shape data, like node distance and direction traveled, are stored on a removable memory media like CD-ROM. Figure 10 illustrates some simple mapping concepts.

GPS

GPS is a satellite-based triangulation system of determining vehicle positioning. The transmission signals are modulated by their preassigned frequency codes, and use spread spectrum coding to gain noise immunity. The relationship between the receiving point position (X, Y, Z) and the satellite position (Ui, Vi, Wi) is determined by the following equation:

$$Pi = \{[(X - Ui)**2 + (Y - Vi)**2 + (Z - Wi)**2]**(1/2)\} + R$$

Where Pi is the distance between the satellite and the receiving point, and R is the positional error resulting from the time difference between the satellite and the receiver. The concept works by measuring the distance Pi between the satellite, the receiving point, and the satellite positions (Ui,Vi,Wi). To enhance accuracy, signals from four satellites are used, and by solving the four dimensional simultaneous non-linear equation, the receiving point positions (X, Y, Z) can be determined.

The satellite's positions are tracked closely from the system time tables and transmission data. The distance Pi between the satellite and the receiving point can be obtained during reception by measuring the time difference t1 (the time it takes for radio waves transmitted from the satellite to reach the reception point) of the epoch signal (synchronized signal) transmitted from the satellite. Figure 11 depicts the measurement theory behind the GPS.

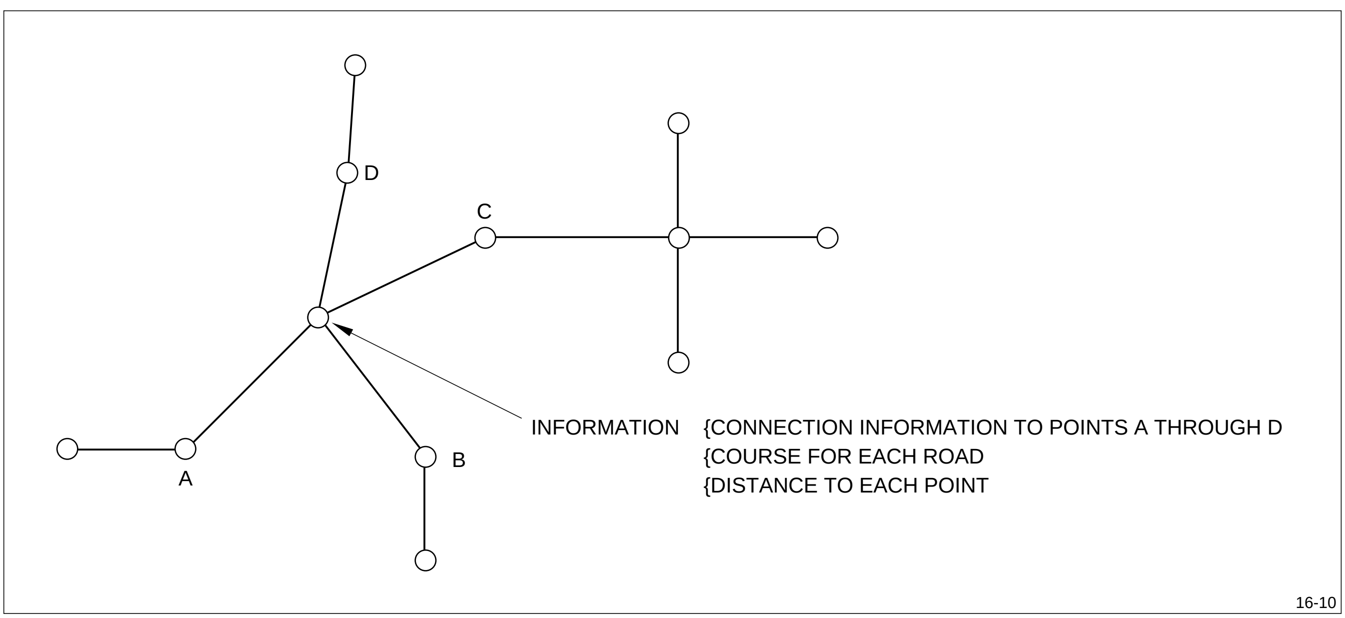

Figure 10. Map Matching and Road Shape Node

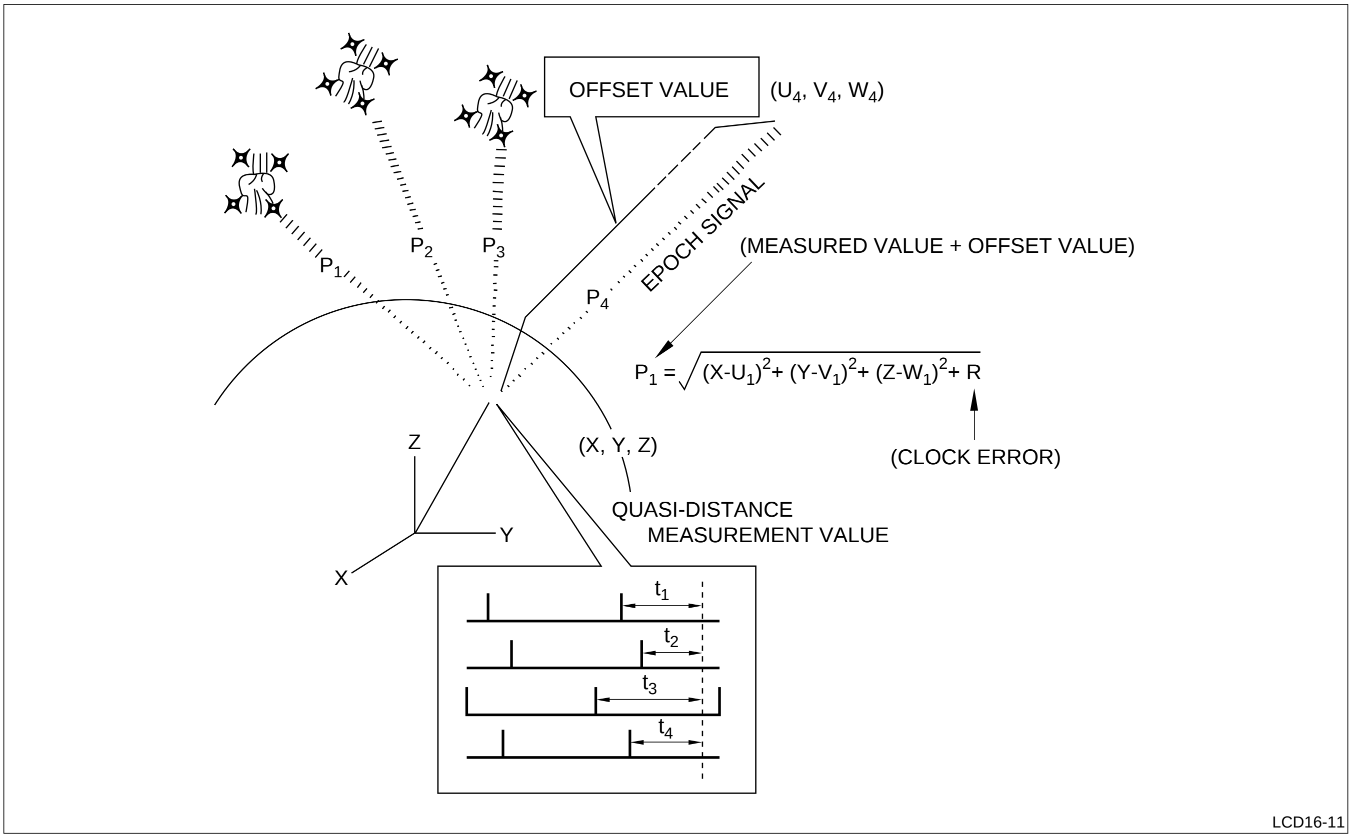

Figure 11. GPS Position Theory

Route Guidance

Besides reporting the vehicle's current position, the navigation system can also provide route guidance functions. The route guidance function reviews the road network and calculates the best route to be taken based on time to destination or shortest distance. This is accomplished through repeated distance summation calculations that account for all available routes, after which, the shortest route is chosen based on projected distance and travel time. In the future, information such as traffic conditions, traffic routing, and parking information will also be presented to the driver in real time. To accomplish this, roadside tele-terminal posts will be integrated into the highway infrastructure to function as communication links.

CONCLUSIONS

An overview of current and future LCD applications was presented in a top-level approach, including a review of some basic systems architectures. In addition, some of the fundamental governing equations where presented for review in order to enhance the depth of understanding. Finally, beyond covering the simple digital meters, multi-information systems where discussed, with a special emphasis on describing Navigation systems.

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Editions: No. 1, 1995
Printed and bound in the U.S.A.

Ref. No. SMT95012