The Evolution of Automotive RF Integration

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Since the early days of RF (radio frequency) components, automotive engineers have seen the innovation inherent in these tiny slices of quartz, and have steadily been using this technology to develop more and more complex RF and wireless tools and gadgets for the driver to enjoy.

From humble beginnings with the very first in-car radio through to the latest automotive radar developing towards driverless cars, RF has steadily become more and more integral to the automotive industry, providing both added safety and desirability to the vehicles we drive, and driving innovation that would otherwise be impossible to achieve.

Like the products they produce, the automotive and RF analogue design industries have grown together over the years, working hand in hand to develop some of the funkiest driver technology available on the market today.

As with the very best of partnerships, each industry has pushed the other to develop and create step-change technology, driving them both forward (if you'll excuse the pun) and meaning they are able to satisfy the increasing demand of this consumer-led industry.

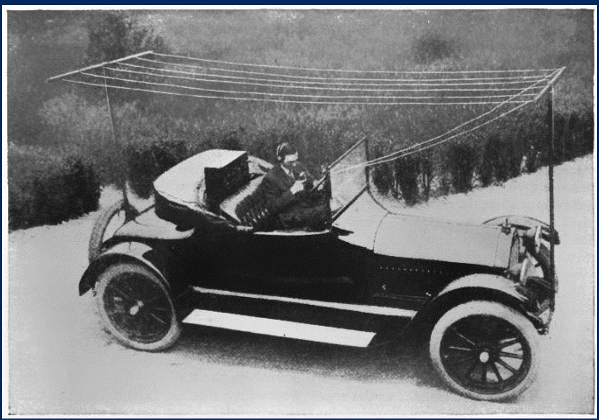
This eBook takes a brief look back over the history of RF/Automotive integration and presents the, occasionally incredible, changes that have taken place within these industries over the last 90 years. Many of these changes were only able due to the brilliant inspiration, creativity and determination of industry leaders who continue to steer this powerful industrial partnership through turbulent times.

Along with an overview of the development of various RF applications within the automotive industry we'll take an in-depth look at how the advancement of frequency products has allowed these types of innovation to flourish. We'll also look at the supporting role we expect RF frequency products to play in the future of RF integrated cars, and recommend the types of products we believe will drive the next stage of innovation.

Humble beginnings:
Vehicle Radio to In-car Infotainment

We begin with the very first use of RF technology within the "automobile", to use a contemporary term: the car radio.

With the introduction of wireless radio to the masses the drivers of the, ever more popular, motor car began experimenting with amateur car radio installations, including some very novel designs!



Amateur Car Radio Installation 1919

Radio was the birthplace of wireless RF integration with the automotive industry, and remains one of RF design's key roles within the industry today.

The invention of radio and the availability of original cat's whisker radios of the early 1900s brought about a phenomenon of public engagement. For vintage technology fans nothing quite beats winding your own coil and connecting the cat's whisker wire to a crystal of Galena.

Cat's whisker radios were soon superseded however, as were other in-car audio products including the wireless, the cassette player and the CD player. Traditionally in-car audio entertainment technologies are driven by the mass-consumer market and so follow the trend of consumer goods themselves. Thus new products are created to replace old ones only once they have already been proven within the consumer market. It is then perfected for the automotive environment through the development of new designs of RF product.

The present in-car (and let's not forget on-bike) audio market is well-developed and companies such as Bose, Bang and Olufsen, Alpine, and Harman take advantage of the very latest sound-production technology through the latest wireless communication and Bluetooth technology.

How is it done?

At the heart of the latest audio and infotainment technologies lie microcontrollers, often with inbuilt serial bus communication, event timing and interrupt functions.

To perform accurately timed tasks, the microcontroller requires an accurate clock. The accurate clock is provided by an oscillator made up of an on chip amplifier and an off chip crystal. This clock signal can then be multiplied to higher frequencies with a Phase-locked-loop and/or divided down to lower frequencies to provide the timing signals necessary.

An example of a task requiring accurate timing is the reception and transmission of serial bus messages. In modern automotive systems extensive use is made of serial busses to reduce the amount of wiring needed.

The type of crystal required by these microcontrollers can vary by manufacturer but for microcontroller designs that have been long-established we usually recommend a larger crystal such as the GRX-530. The GRX-530 is functionally similar to leaded package parts but combines the convenience of a modern surface mount package with the low ESR associated with canned crystals.

This low ESR means this crystal integrates well with older-style oscillator circuits contained within long-established microcontroller designs.

For newer-style microcontrollers designers can take advantage of the GRX-330, a significantly smaller crystal which leaves more board space for designers to work with. However, there are design considerations to be taken into account when working with smaller crystals - for more information see our whitepaper Shrinking the Crystal Resonator. One example would be the oscillator circuit within the microcontroller must be able to accept a higher gain and lower load capacitance than those of the older style.

Most microcontroller manufacturers will be able to provide advice on this and our sales engineers are used to dealing with these questions on a daily basis.

Microchip Microcontroller

In-Car Bluetooth Systems

No article on automotive RF integration would be complete without a mention of the development of Bluetooth technology. From an early start, Bluetooth quickly became essential to our everyday life and was a step-change in automotive communication development.

Initially created to enhance communication between mobile phones, resourceful automotive engineers quickly saw the potential of this new technology and harnessed it within the first in-car Bluetooth mobile connection devices, appearing on the market in 2001. From here automotive Bluetooth has developed to become an integral part of all modern vehicles, allowing not only hands free integrated mobile communication, but also GPS, in-car health monitoring and music streaming.

In-Car Bluetooth Communication System

How is it done?

A radio chip is at the centre of this technology, allowing Bluetooth communication via short-link radio. In the most up-to-date version of this technology, Bluetooth Smart chips are used.

Every radio needs a good frequency reference and the most cost effective solution that provides sufficient accuracy for Bluetooth is a quartz crystal. A Bluetooth Smart chip within the product, such as those produced by CSR, Texas Instruments and STMicroelectronics, then use this crystal to create a reference oscillator that is then used to control the transmit and receive frequencies. The accuracy of that frequency directly affects range and link reliability.

> **“It helps that the construction of the GRX-330 was designed to withstand the rigours of the automotive environment.”**
>
> **Chris Watts, Chief Engineer, Golledge Electronics Ltd**

Miniature ceramic packaged parts, such as the GRX-330, provide a solution that requires only a small board area, leaving more space for an engineer’s custom product design, and are fully compatible with modern SMT production lines.

Thanks to Bluetooth, today’s driver has more technology at their disposal than ever before and Bluetooth SIG, the Bluetooth trade association, takes the automotive use of its technology very seriously. They are currently championing their Drive Smart, Drive Safe initiative to promote safe driving techniques and you can find more information on their initiative here: http://www.bluetooth.com/Pages/Drive-Smart.aspx

Plug-in electric hybrid car

Electric Motor Drives

With the advent of electric-powered and hybrid cars, frequency products have become essential to the core functionality of the car.

Thanks to the uptake of many different types of vehicle manufacturers, from the city-loving commuter's dream like the Toyota Prius, through to the track-blitzing Formula E cars being developed today, electric and hybrid technology is becoming more and more prevalent in the automotive industry.

The Golledge MCSO1 CMOS oscillator, adapted for automotive quantity production, was integral to the development of electric motor drive control technology for the mass market. These oscillators were used to independently control multiple electric motors on the same vehicle.

How is it done?

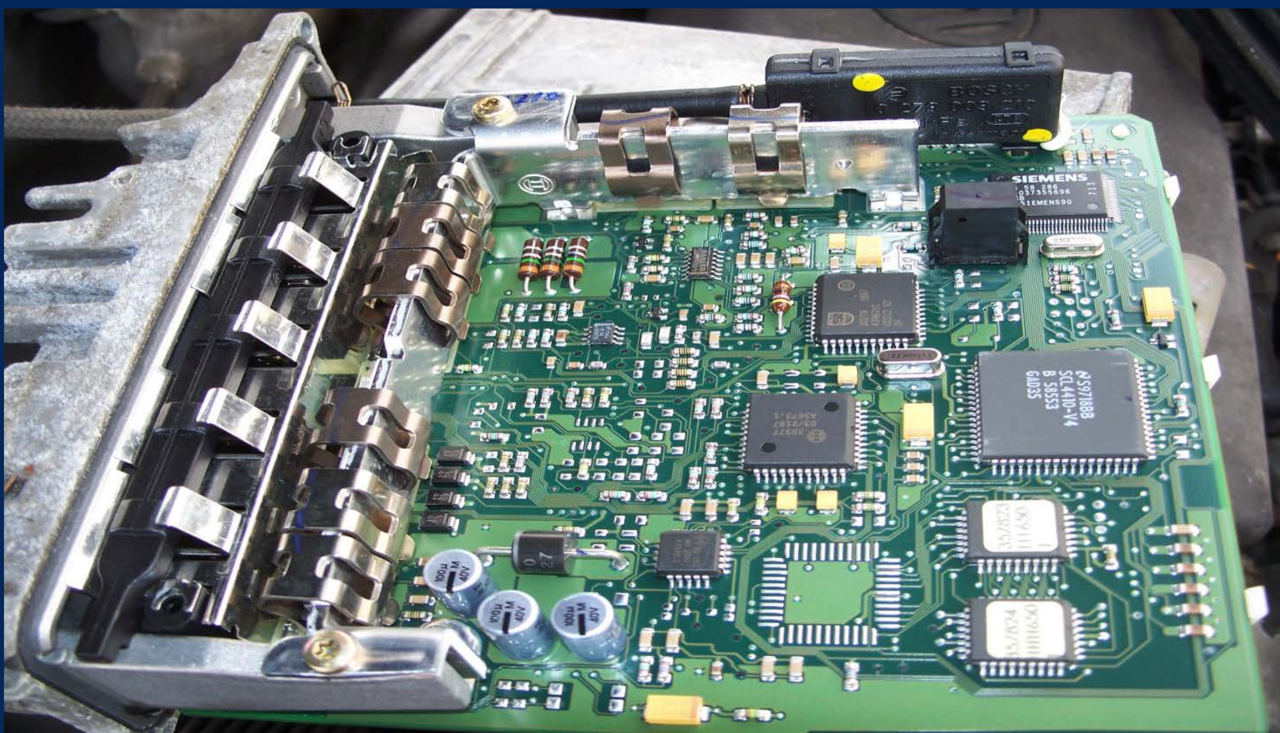
Within the electric motor drive a microcontroller, connected to a crystal frequency reference, provides communication between the drive and the other components of the electric vehicle power train, such as the battery management system. This communication is transmitted via the internal CANbus system of the vehicle. More information on CAN systems can be found at the CAN in Automation site: http://www.can-cia.org/

Again, systems with an embedded microcontroller benefit from the small board space required by miniature surface mount crystals such as the GRX-330 and GRX-320, but only if the microcontroller oscillator circuits can accept the design implications of the smaller crystal (in older cases the GRX-530 is still recommended). Temperature resistance is also key to this application and so these types of crystals can be provided with a wide operating temperature range.

Engine control units (ECU)

Originally developed in the 1930s for use on aircraft, these units really are the brain of a vehicle. Today the main component of this whole system is the microcontroller chip (CPU) at its heart, driven by a frequency controlling crystal or oscillator. Modern ECUs may contain up to 40MHz processors, and use a precision automotive crystal to ensure accurate timing. This means accurate communication between the integrated systems of the powertrain within the vehicle is assured.

The engine bay of a vehicle is an extreme environment for electronic components, where they must withstand high shock and vibration conditions, along with temperatures exceeding 100^{o}c on a regular basis. This is where automotive qualified parts come into their own. The knowledge that qualified parts are able to withstand the harsh automotive environment, coupled with the accuracy they can offer, make these types of products the standard for frequency control for ECU units.



The ECU of a Volkswagen Golf Mk.III

Formula 1 cars require sophisticated telematics systems

Telematics and Racing telemetry

On the cutting edge of vehicle design, racing cars have always led the pack when it comes to automotive technology. Here we take a closer look at vehicle telemetry and the part these types of system have played in developing the racing industry, along with the frequency products behind the advance.

Vehicle telematics systems are normally made up of GPS or GNSS modules, Bluetooth modules, and custom telemetry links providing back-to-base communication, contained within a robust dongle or module casing to withstand the stress of the automotive environment. This is particularly important in racing vehicles as the stresses these components undergo in racing situations is greater than those normally found in on-road cars.

How is it done?

Very accurate frequency control products are needed to provide the timing for GPS systems

The microcontroller at the heart of telematics devices takes its timing from a tuning-fork crystal which when combined with, a low-power amplifier built into the chip, forms an oscillator. The oscillator provides the reference for the timer and the RTC peripherals of the microcontroller. These are often used for timing the period a device spends sleeping to save power as well as keeping track of date and time.

GPS performance depends on frequency accuracy. The better the accuracy the quicker a fix can be obtained and the better the chip's ability to cope with poor signal strength from the satellites. This is because the GPS receiver relies on correlation to extract the GPS satellite signals from the background noise. The greater the frequency uncertainty the greater the range of correlations the receiver has to try in order to find the signals hidden in the noise. For best results a TCXO should be used, however crystals such as the CM8V and GRX-330 also allow miniature, very low power, time keeping circuits and frequency references.

Dynamic Tyre Pressure Sensing

Being able to see an up-to-date indication of the pressure within the vehicles tyres means drivers are able to stay on top of vehicle efficiency, and above all stay safer. Originally developed for use within luxury vehicles, this application quickly permeated the whole automotive market due to the inherent safety benefits.

How is it done?

A transmitter is fitted to the rim of the wheel which transmits data from an incorporated pressure sensor. This data is received by the ECU via a telemetry receiver and CAN communication. The ECU can then take this information and act accordingly.

The short range radio link from the transmitter on the rim of the wheel to the ECU needs a frequency reference that can withstand the extreme vibration and temperature variations found in the wheel. As the pressure transmitter is battery powered low current consumption is also needed.

Due to the extreme environment inherent in this application: the extreme G-forces, high temperature, and shock and vibration conditions present at the wheel, specialist parts and testing above the normal AEC-Q200 level is normally required. Always contact your supplier's engineering team in this instance. If you have a query relating to a tyre pressure monitoring frequency control requirement our team will be happy to advise you, please contact us at sales@golledge.com.

Tyre pressure is paramount for vehicle safety and efficiency

Fleet management systems increase business security

Vehicle and fleet tracking

There are several different types of vehicle tracking and fleet management technology available on the market today. Most trackers work off GPS principles and the simplest fleet management systems work off this technology alone. Higher-tech locate-and-recover systems also use transponder technology, in addition to GPS, to trigger a distress signal when a vehicle is stolen.

How is it done?

Vehicle trackers work by sending location updates from a GPS receiver to a central server using GSM data services (Global System for Mobile communications). Using GSM to transmit the location reports means that coverage is multinational.

In the case of GPS locate and recover tracking systems a transponder is used to trigger the emission of an RF identification signal which is then received by multiple tracking base stations.

Both GPS and GSM signals require stable frequency references, and for most applications this would ideally be a supplied by a TCXO for added accuracy.

In areas where no GSM coverage is available, when communication must be sent over long stretches of seawater for instance, satellite communication services supplement the required signal. These sensitive satcom receivers need good front end filters to avoid being blocked by strong out of band terrestrial signals. SAW filters provide this level of sensitivity of filtering combined with a small PCB footprint. Tight tolerance and low phase noise TCXOs are also required as the reference to generate the receiver local oscillator and transmit carrier.

The amount of data being sent from each vehicle within these types of systems is so small that fast data services of 3G and 4G are not needed. However, as GSM services are turned off in the future these devices will need to migrate to new low bandwidth services. Fortunately as part of the dawning of IoT these low bandwidth services are now being considered.

Fully connected cars are fast becoming a reality

Connected Car

As the industry moves closer and closer towards the development of connected cars, the technology needed to drive this advance is still evolving.

How is it done?

Current systems often use custom boards including M2M WiFi, GPS, DAB, Bluetooth, GSM, 3G, 4G, and CAN connection modules within the same system.

Connected cars bring with them an increase in the amount of wireless signal, and therefore tighter RF filters are required to prevent undesirable signal cross-over.

BAW filters can provide superior RF performance for these types of application, particularly offering a lower insertion loss.

For the microcontrollers required within each of the wireless communication modules, signal accuracy can be achieved through the GRX series of crystals, with AEC-Q200 qualification as standard combined with the ease of surface mount and, in some cases, significant board space savings.

Sources

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