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White Paper

Tear Down: Breath Alcohol Ignition Interlock Device Redesign

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Drunk driving caused 11,654 deaths in the US in 2020, according to the NHTSA. One way to ameliorate this situation is to allow persons who have been convicted of a DUI offense to install a Breath Alcohol Ignition Interlock (BAII) device in their vehicle. If the user's breath alcohol exceeds a certain limit, the vehicle is not permitted to start. This is typically a voluntary program. It allows the person to keep their job and maintain their living necessities. Most BAII users are highly conscientious and just want to get their life back on track. However, as a program supervised by the court, often in lieu of incarceration, the consequences of violation are dire. From our perspective, the designer of a BAII device, the consequences are equally serious. If our device detects and reports false positives, it will cause considerable grief to the user. On the other hand, if the system is easily defeated, then a dangerous driver is permitted on the public roadways.

A BAII device typically consists of a handheld unit into which the user breathes. This is cable connected to a second enclosure that has been wired into the vehicle's electrical system. That operation is performed at certified repair facilities. The handheld unit has a graphic LCD screen, an audio annunciator, and a four key interface. It conveys simple instructions to the user with minimal distraction and ambiguity.

There is generally a complex protocol governing the BAII system. How much Breath Alcohol is permitted? If the user fails the first test, is he or she permitted another? How long afterward? During a drive, random retests are usually required. How often? What if we detect high breath alcohol? Should we engage the vehicle's emergency lights? Call 911? Tampering is a huge problem. The Internet is rife with suggestions on how to beat BAII systems. One requirement of a BAII is the ability to detect an actual human breath, as opposed to, say, a blast of canned air. This requires measuring the flow rate, both positive and negative, duration, and breath temperature and humidity. Often the user is directed to hum into the BAII device, which requires audio sensors. Some protocols require that a photograph of the driver using the BAII device must accompany every test. This in turn requires a USB camera, storage, cellular communication, and a plethora of back-end handling requirements.

The accurate measurement of Breath Alcohol itself is far from trivial. The best way is to use a fuel cell. The fuel cell must be precisely heated, and the BAII device is not allowed to draw more than a few 100 mA of current from the host vehicle, and only while that is operational. So we need to detect when the vehicle is operational, which can be surprisingly difficult. A pump is necessary to maintain a constant gas flow through the fuel cell. The fuel cell and flow measurement must be periodically calibrated. Usually, this may only be performed at the facilities that install the BAII. We use a lithium battery to store reserve energy. The BAII system must meet automotive environmental specs for temperature, humidity, shock, and vibration.

Every US state, and often jurisdictions within the states, differs in the details of their protocol. Politicians and state officials are constantly changing these protocols. One import of this is that firmware maintenance becomes a challenge. Simple parameter changes, such as 'change maximum rolling retest time from 12 to 15 minutes', can be pushed over the air and stored in EEPROM. Firmware version upgrades can also easily be re-flashed, but the big problem is with the integrity of the original firmware architecture. Its coherence and economy are easily lost. Patchiness often results, with the inevitable proliferation of bugs. Customers seldom allow deep refactoring of the code base. So the firmware architecture must be structured with a high level of abstraction and an anticipation of major protocol changes.

One of the largest US manufacturers of BAII devices approached us in 2021 to completely redesign their aging design. It had originally been developed in the 1990s. The design was based on the venerable 8051 processor. Over 50,000 units had been fielded. Many units were failing, and keeping up with protocol and technology updates was impossible. Moreover, several key components are no longer commercially available.

The redesign, now installed in thousands of vehicles, and growing rapidly, uses an ARM Cortex M4F processor and QSPI Flash, as well as ancillary MCUs and modules. It runs FreeRTOS. The jurisdiction protocol is executed as a strict state machine. The redesign has completely new analog sensors, heater and pump controls. It supports a USB camera, GPS, LTE cellular, and BLE. Planned future upgrades include true IOT functionality to assure data security.

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