Ohhhhmmmm … Ohhhhmmmm Part 3: A brief history and explanation of CAN bus)

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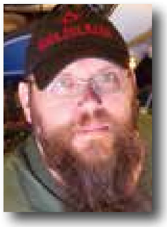


IT USED TO BE that electrical systems on motorcycles were easy to understand and trace. Wiring went from the light bulb to a fuse to (eventually) the battery. If the bulb blew, you replaced it. If the fuse popped, you replaced it. Maybe there was a relay in between; you could replace that, too, and most of the time one of those three things would result in your light working again.

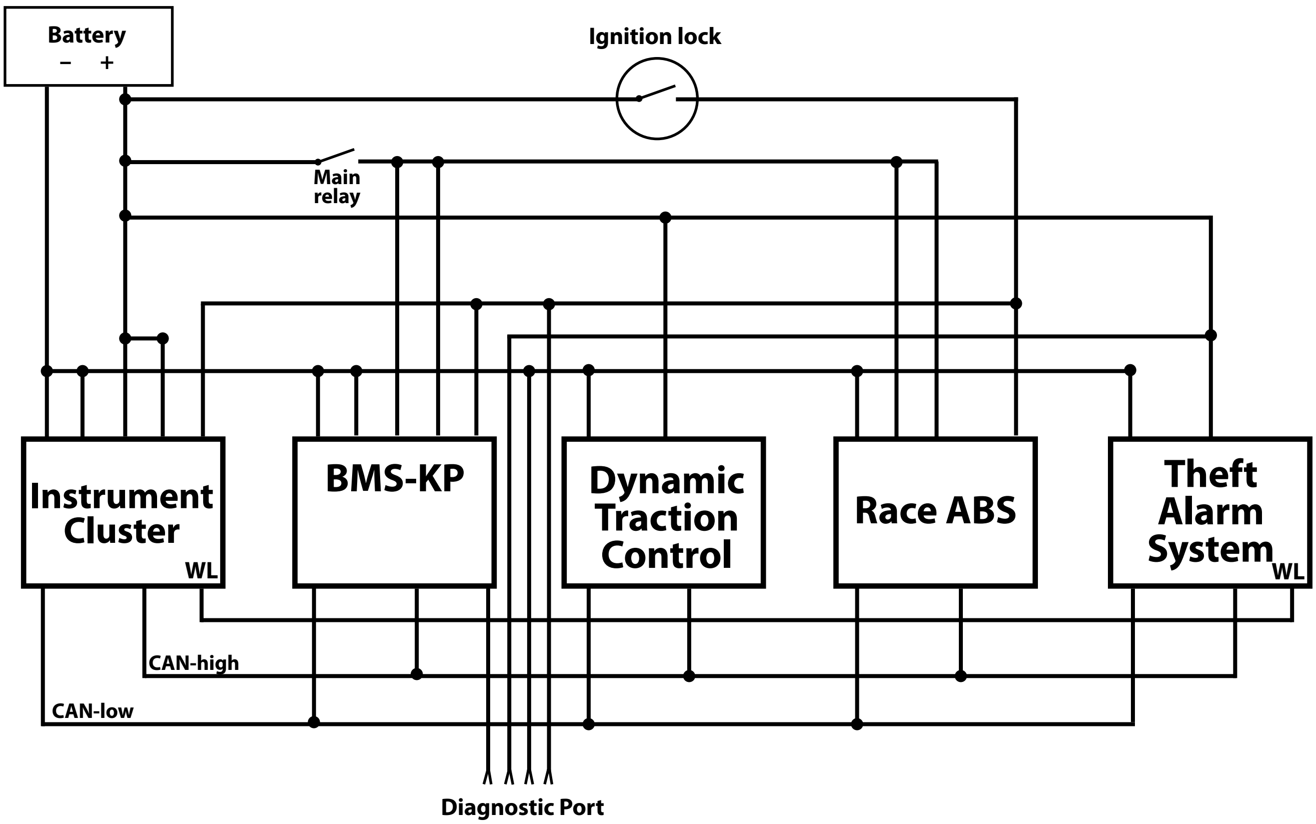
Not so much anymore. Starting in 2004, BMW switched its motorcycles from the old way to a new way: CAN bus. CAN stands for Controller Area Network; "bus" in this context is a little more difficult to describe. In a strict electrical sense, bus would be short for busbar, a common ground point for a number of circuits. From a computing standpoint—which makes more sense when it comes to the modern electrical systems of motorcycles—it would be short for omnibus, a Latin word meaning "for all." From that perspective, it's more accurate, because in a computer bus, signals can be transmitted in parallel or in serial, which I'll explain right now.

Consider three connection points in a circuit. One point (A) supplies power, the other two (B, C) need power. If wires connect A to B and A to C, that is a parallel circuit, since if B stops functioning, C will continue to function. In a serial circuit, A connects to B and B connects to C; if B stops functioning, C won't work either. Think of a string of Christmas tree lights. If one bad bulb takes out the whole string, that's a serial circuit. If the lights continue to twinkle even when one is out, that's a parallel circuit. Both types of circuits have their strengths and weaknesses, and thus are more appropriate for this system or that system based on the electrical needs of the motorcycle.

Probably the most apt path to quickly understanding CAN bus is comparing the system to the human body. If your brain

The wiring harness of a motorcycle – such as this one from an R 1150 RTP – can be considered the spinal column of the electrical system. The connectors hook up to various components and transmit power and data as needed to everything on the motorcycle.

2010 S 1000 RR Control Units



This is a simplified illustration of some the ECUs on a 2010 S 1000 RR. A number of things are left out, such as fuses, relays, resistors, connectors and other things in the circuit. The purpose here isn't to give a comprehensive look at the wiring of an RR, but rather to show the interconnectedness of the CAN bus system and how all the ECUs communicate with each other.

had to have a nerve connecting it directly to every possible pain point (full parallel circuitry), your body would be overloaded with nerve fibers. Instead, nerves spread out through your body like the tributaries of a river and connect to your spinal column (think of it as the main run of a wiring harness), which keeps the number of wires needed to a minimum, yet still allows all the information to pass both directions. If it were an electronic system, we would classify the human body's nervous system as a serial-parallel circuit, with aspects of both types of systems.

Thinking of CAN bus as a nervous system for your motorcycle works as well, except for one thing: your body has only one brain, while your motorcycle has a number of them. The electronic control units (ECU) on your bike include the main computer, called a *zentral fahrgestelle elektronik* (ZFE – central chassis electronics), a traction control, an inertia unit for the ABS on really advanced bikes, the ABS unit itself, hill hold, quick shifter, wheelie mitigation, and even the motor that adjusts the windshield. The CAN bus system allows all these controllers to communicate digitally with each other without overloading any one of them, improving signal reliability and creating a robust, centralized system to control all the electronic aspects of the motorcycle.

To understand more how CAN bus works, let's break down a packet of CAN bus data. Each packet is eight bytes in size, and one byte contains eight bits. CAN bus packets have eight components, as follows:

- SOF: 1 bit, Start of Frame; "Hey, pay attention, information follows!"
- CAN-ID: 11 bits in CAN 2.0A, 29 in 2.0B, Extended Identifier; lets all systems know where the data is coming from, whether it be a wheel speed sensor, an inertia device, or the ABS unit
- RTR: 1 bit, Remote Transmission Request; enables ECUs to request data from other ECUs in the system
- Control: 6 bits; tells the system how long the message is
- Data: the actual message can be anywhere from 0 to 64 bits in length
- CRC: 16 bits, Cyclic Redundancy Check; ensures the data is transmitted properly
- ACK: 2 bits, Acknowledgement; checks the CRC
- EOF: 7 bits, End of Frame; "Okay, I'm all done now!"

Under normal operation, the ECUs don't store much in the way of data; they usually only create a record to store when something goes wrong or transmit data in real time. Data loggers and diagnostic tools can retrieve these data points, which we often experience in the form of fault codes. Your BMW Motorrad dealership has computers that can read this data, and you can read it for yourself with a tool called a GS-911, made by a company called HEX Code out of South Africa. Technicians can use that real-time data to fine-tune a race bike; similarly, if your bike is having a problem, a tech can not only read fault codes but observe real-time data to develop an understanding of what's gone wrong with the bike. Getting into how the bits and bytes coming out of the CAN bus get decoded is better explained by an engineer, so you'll have to take it on faith that it does what I say it does.

One of the notable things about CAN bus is it can send signals constantly or intermittently, with intermittent signals being sent based on time triggers or event triggers. This is what makes throttle-by-wire possible, and thus both digital cruise control and on-the-fly remapping of ignition and fuel injection based on selecting a ride mode. The technology needed to time-trigger CAN bus changes didn't come about until after 1999, and it took a few years to perfect the protocols and get the hardware down to a size suitable for motorcycles. That's why you don't see throttle-by-wire until the S 1000 RR debuted, even though the RR had a hybrid throttle (throttle cable to rheostat, rheostat to computer; call it partial throttle-by-wire to facilitate the riding modes).

The kicker is that as far as motorcycles go, there is no single standard CAN bus protocol that all manufacturers have to follow. Cars and trucks have a standard, which is why you can use an OBD-II reader on any modern vehicle, but motorcycle manufacturers have so far been left to their own devices. That is in the process of changing, and more motorcycle makers are anticipating the day when all bikes have to have OBD-style connectors and their ECUs will need to speak a common dialect of hexadecimal code. When a standard comes, it will most likely be driven by legislation from the European Union; certainly for BMW motorcycles, the EU drives many changes, which is why bike makers have to keep updating their engines to adhere to emissions standards.

BMW and some other European car makers came up with LIN (local interconnect network) bus just before the turn of the century as a way to make CAN bus integration less expensive. Seems all those sensors, connectors and computers were raising the cost of the vehicles too high, too quickly. LIN bus is a type of CAN bus, but with a slightly different protocol often referred to as "slave-master;" this is expressed in vehicles with a broadcast serial network of one master and up to 15 slave nodes. What we refer to as CAN bus on many (but not all) BMW motorcycles is actually LIN bus, but the underlying concepts are largely the same, so while there are differences and the terms are not completely interchangeable, it's not the biggest thing we get wrong when discussing our bikes.

CAN bus isn't the end of the road, mainly because it has some inherent limitations. First and foremost, data can only flow through CAN bus at one megabit per second (1Mbps). The data packet size of just eight bytes also restricts the utility of CAN bus. The next technology in the queue is being called CAN FD, where FD stands for flexible data-rate. CAN FD features 64-byte packets and a max speed of 8 Mbps, vastly increasing not just the amount of data that can be transmitted, but the speed at which it flows. CAN FD is much closer to being actual real-time data transmission than CAN bus. The weakness as far as motorcycles are concerned is that CAN FD is intolerant of current leakage, which means motorcycle electrical systems will have to leap forward in reliability and robustness before CAN FD can make its way onto two wheels. Even though academics are still arguing about some of the subtleties of CAN FD, car makers are already on the job, working with semiconductor designers to bring CAN FD closer to real-world usefulness.

With the rise of cloud computing, the growth of the Internet of Things and steady improvement in Wi-Fi CAN bus analyzers and data loggers, it is conceivable that in the near future, our motorcycles will be fully and fearlessly connected to each other and the Mother Ship in every way. Picture a day when BMW Motorrad can send firmware updates to your K 2200 GT directly from Munich. Inter-operability between motorcycles and other road-going vehicles is another probability, with vehicles of all types emitting enough electrical signals to attract the attention of nearby aliens in their flying saucers along with the autonomous vehicles all around them on the world's highways. Once scientists defeat the one megabit per second data transmission rate of CAN bus, who knows what the next step will be in motorcycle evolution?

Things connected to the BMS-KP in an S 1000 RR

- Ignition switch
- Ignition ring antenna
- Start/stop/mode button
- ABS-DTC button
- Clutch switch
- Throttle grip position sensor
- Brake switch
- Crash sensor
- Gear position sensor
- Sidestand switch
- Battery
- Main relay
- Starter relay
- Radiator fan relay
- Fuel pump
- Diagnostic port
- ABS control unit
- DTC control unit
- Instrument cluster
- Crankshaft sensor
- Camshaft sensor
- Throttle flap sensor
- Engine temperature sensor
- Air temperature sensor
- Fuel pressure sensor
- Oxygen sensor 1 & 2
- Knock sensor
- Shift assist mechanism
- Speed sensor
- Fuel injection valves (pre & main)
- Throttle actuator
- Intake actuator
- Interference flap actuator
- Exhaust flap actuator
- SAS valve
- Fuel vent/purge valve