The electronics of the K models

The following article by René Füllmann appeared in the electronics magazine ELO in 1987. I would like to thank him for the images he provided and his kind permission to reprint them!

BMW K75 - an electronic experience

Yesteryear technology is a thing of the past. BMW relies on the most advanced electronics. The K75 three-cylinder and the K100 four-cylinder shine with balanced engine concepts combined with excellent chassis. ELO took a close look at the BMW motorcycle electronics.

You sit. The feet are still in contact with the ground. Insert the key and turn it to P (Park - the parking lights are on!).

The relief relay clicks quietly. It switches all electronics to "standby" mode. Now the emergency ignition switch is moved to the middle position. The instrument cluster is illuminated. The N lamp, which indicates whether the transmission is in neutral, lights up bright green. Next to it in the tachometer field, the digital shift display - BCD coded, the diode matrix is in the instrument cluster - is set to 0. The cold start enrichment, the choke is turned on and held in position 2, the indicator light "comes" to position 1.

It can only be started if:

the transmission is in neutral,

the engine does not rotate above 711 rpm,

if a gear should be engaged, e.g. B. at intersections, only when the clutch is disengaged (clutch lever pulled),

the emergency ignition switch is in the middle position.

The starter button is pressed. However, a lot of things happen before the engine starts.

Fuel injection electronically controlled

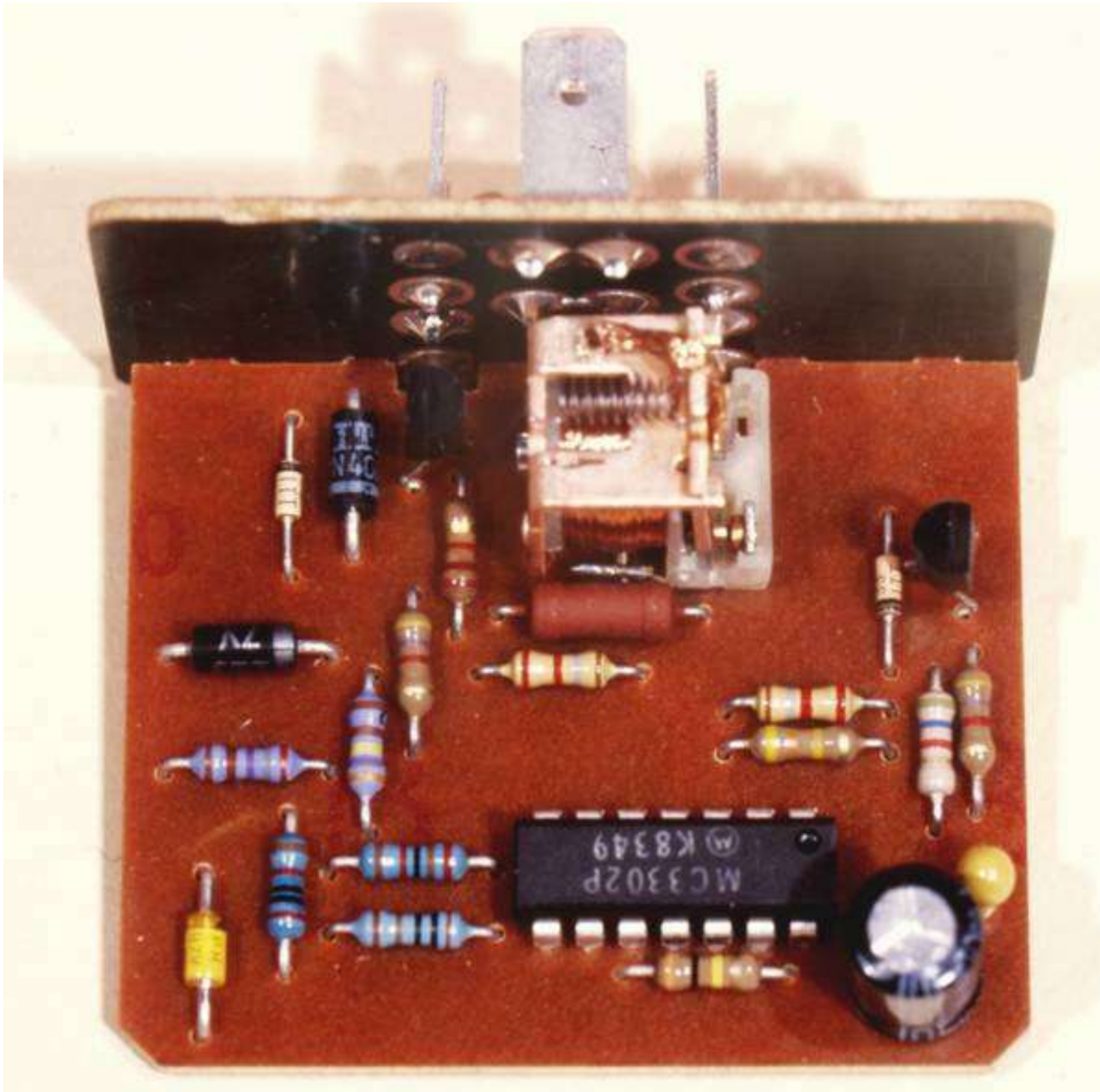
The fuel system consists of an electric pump, filter and a control valve. Basically, the operating pressure difference between the nozzle and the negative pressure in the intake duct is always a constant 2.5 bar. There is therefore approx. 2 bar excess pressure or 3 bar absolute pressure at the nozzle. There are also systems with 3 bar, but on the BMW motorcycle we are dealing with 2.5 bar.

The fuel injection now works as follows: For each engine revolution, based on the signal from the Hall sensor (mounted on the crankshaft), a pulse is sent to the injection control unit. The same amount of injection per revolution reaches all three intake ports (K100: four, as it has four cylinders), in parallel, so to speak. It is controlled by the position of the damper flap (depending on the air pressure set) in the air flow meter, which adjusts a potentiometer with its axis.

The air flow is created by the suction power of the suction motor. You should not confuse the air flow meter's air flow meter flap with the throttle flap (four in total) - operated by the Bowden cable on the throttle twist grip. You need a throttle valve system per cylinder because the valve control times are so short at high engine speeds, and the K75 and K100 rotate up to a maximum of 8800 rpm, so that the air from one cylinder could flow back into the intake duct of the next cylinder. In sports engines, such as the BMW M3, a throttle valve system is installed for each cylinder. But the more forcefully the throttle twist grip opens the throttle valves of the intake ducts, the greater the negative pressure in the air flow measurement duct becomes. The damper flap is opened further by this negative pressure and the potentiometer thereby changes its parameter for the injection control unit. The further the damper flap is “pulled open” by the negative pressure of the naturally aspirated engine, the greater the amount of fuel that is swirled by the injection nozzle into the air sucked in in each intake duct. There is an NTC resistor in the direction of the air filter behind the air flow meter's storage flap. It measures the temperature of the air sucked in because, as is well known, warm air has less oxygen than cold air, which means that less fuel is injected. These measuring methods are essential in order to achieve a homogeneous filling per revolution. And not just this. Finally, it is also important to protect the environment appropriately.

The air flow meter and the mixture

During the cold start phase, the gasoline-air mixture is richer, meaning it contains more gasoline. The sole decision for cold start enrichment is made by an NTC resistor (temperature sensor), which is located parallel to another NTC sensor in the coolant circuit. The latter is responsible for switching on the electric cooling fan and the maximum temperature.



Above: *From 103°C the fan mounted behind the cross-flow cooler comes on, from 111°C the warning lamp lights up.*

Dipl.-Ing. (FH) Wolfgang Meyer, chief motorcycle electronics developer and himself an enthusiastic BMW two-wheeler fan: “In the start program at inevitably very low speeds, we always start from the rear clock edge of the Hall sender, which is 6 degrees before TDC (top dead center of the piston). Once around 700 revs have been reached, the processor reverses the ignition program. It emanates from the front edge of the Hall sensor pulse - which is, by the way, a pure rectangle. The ignition is not controlled in the traditional way, i.e. depending on the speed using centrifugal force and vacuum adjustment."

The engine is running

The starting process took less than half a second. The three-cylinder started without any gas and got going very smoothly below the tank. I hold the choke lever in position 2 for about 10 seconds. Then I release it. It clicks into position 1 of the cold start enrichment with a soft click. Now I want to know. Switch on the main driving lights, lamp and brake check: pull the foot and hand brake. I'll give it some gas. The engine beneath me takes it calmly and follows willingly. The speed is now around 1200 rpm. I pull the clutch and put it in first gear. The LCD zero within the tachometer disappears and becomes one. At the same time, the idle gear control went out. Then I let the clutch come soft. She rolls. Like a bike so light.

Ignition is very important in the combustion engine

Ignition occurs with every engine revolution, including during the exhaust cycle. This technology is implemented on all motorcycles, even the BMW boxers. The ignition point is determined by the Hall sensor. While it sits on the camshaft on the boxers, it is located on the extension of the crankshaft on the K75 and K100. But no hook without eyes. Special holographic preliminary examinations had to be carried out first in order to minimize the susceptibility to wear on mechanical turned parts. On the K100, the rotating window part - it only has one window - has been reinforced with a bar so that it can meet the requirements. Since there are two magnets on the base plate of the Hall sensor, there are two signals per revolution. The ignition voltage requirement of the engine is also important. This depends on how cleanly the air-petrol mixture is burned. The engine runs in the test (engine test bench) under a wide variety of load conditions. The burned mixture (CO value) is checked depending on the load range and ignition voltage. Using the knowledge gained, electronics can be used to guarantee clean combustion by adapting the ignition voltage to the respective load range. This can happen by regulating the current flow in the ignition coil. With the K75 and K100, the closing angle control and current limitation ensure that the ignition voltage is constant across the entire speed range.

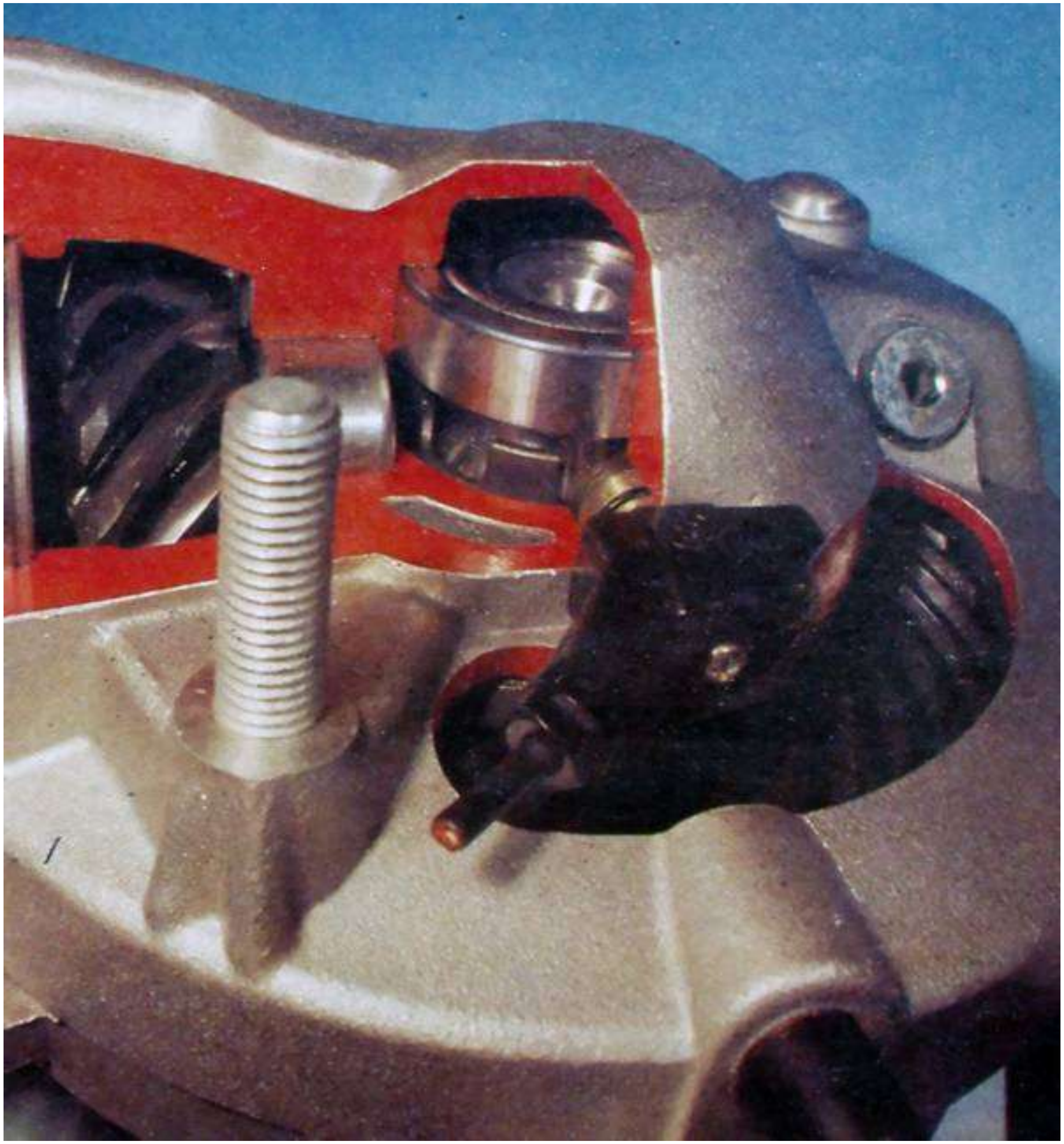
> **Hall effect, what is it?**
>
> The Hall effect is the phenomenon discovered by the American physicist EH Hall in 1879. In a current-carrying electrical conductor, an electrical voltage gradient occurs perpendicular to the direction of the current and perpendicular to the direction of the magnetic field lines in a homogeneous magnetic field whose field lines run perpendicular to the direction of the electric current. By. Charge carriers flowing through the conductor are deflected laterally by the Lorentz force acting on them and accumulate on the lateral boundary surfaces of the conductor until an electric counterfield generated by their space charge, the so-called Hall field, has formed, which deflects the Lorentz force just compensated. In the stationary state that then arises, an undeflected current flows again.
>
> Pretty theoretical, isn't it? So to put it simply: There are two permanent magnets on the base plate of the Hall sensor unit. A semiconductor layer is arranged opposite each of them. A slotted disc runs in the gap through both parts. If the window is open, the magnetic field works differently than if the rotating metal surface in between is closed. The changing magnetic field creates a barrier layer effect in the semiconductor layer, the change in which is proportional to the rotational speed of the slotted disk.

The problems with the physical limits of the ignition coil increase with the number of cylinders it operates. In the six-cylinder in BMWs, the ignition coil is charged six times with one camshaft revolution, i.e. every two crankshaft revolutions. And at some point at high speeds, due to the inductance of the ignition coil, the current flow no longer comes within the range to build up the field. One reason why two ignition coils fire on the K75 and K100. What is important is the current flow that creates the magnetic field in the inductor. By switching off the current flow at the current maximum, a powerful spark is generated. The prerequisite for such technologies is, of course, contactless operation of the ignition coil. And the closing angle control has another advantage: On the one hand, you can regulate the heat load on the coil if you reduce the current consumption at low speeds, because the time of the current flow also represents a measure of the power loss of the ignition coil. A cylinder fires every two engine revolutions. If you divide this result for the BMW three-cylinder K75 by a factor of 3, you get an ignition offset of 240 degrees crankshaft rotation distance per cylinder. In plain language this means: a cylinder is fired every 240 degrees. The ignition control signal must also be processed accordingly. In order to save one Hall sensor, BMW only used two, but they were offset from each other by 120 degrees and had two windows in contrast to the K100. This is also offset by 120 degrees because, for reasons of simplicity, ignition takes place in the combustion cycle, just like in the other models.

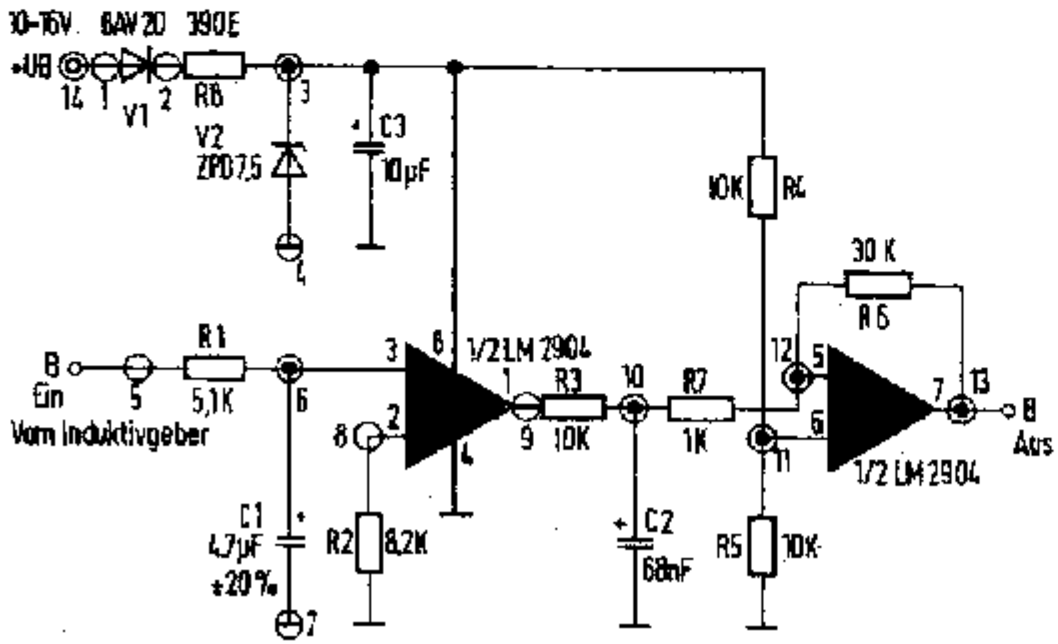
From the position of the two windows in relation to the sensors, the engine electronics (ignition control unit) recognizes which “pot” should be combusted when. And it works like this: For example, the "window pane" located on the crankshaft axis first makes a signal, then it continues to rotate, makes two signals and finally one again.

No chattering speedometer cable

There is no shaft driving the speedometer. It's of the electromechanical variety. A stationary inductive encoder - which, by the way, produces a perfect sine wave - contains a coil and permanent magnets. Both react to the periodic field disturbances caused by the pulse generator sleeve mounted on the ring gear of the rear wheel. An "electrical" cable, not a "mechanical" one, connects the pulses to the electronics.

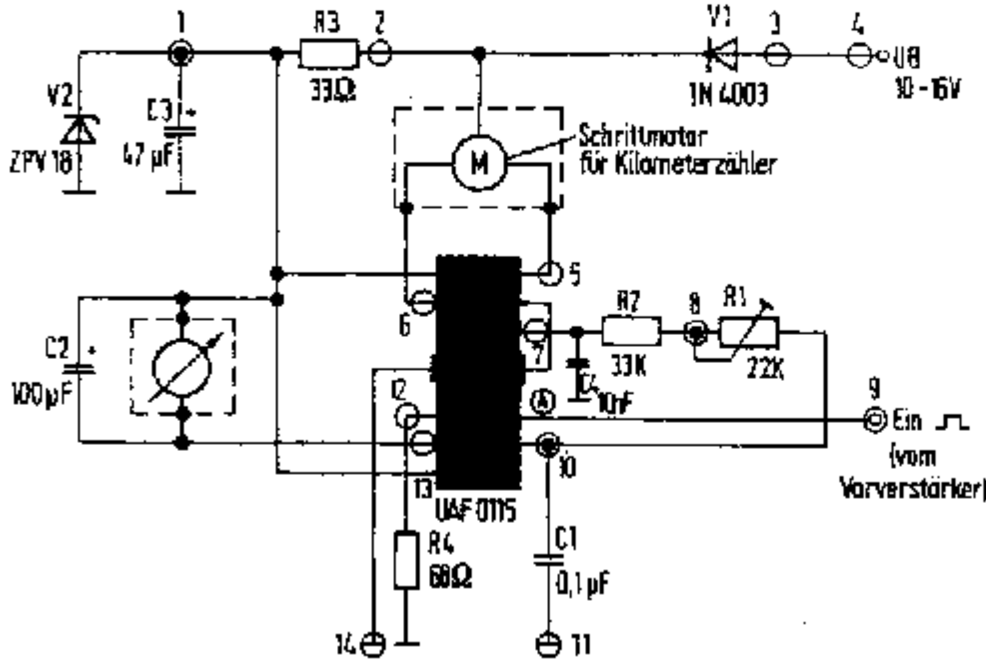


Above: *Speed and distance measurement on the K75 and K100 is carried out electronically with an inductive sensor.*

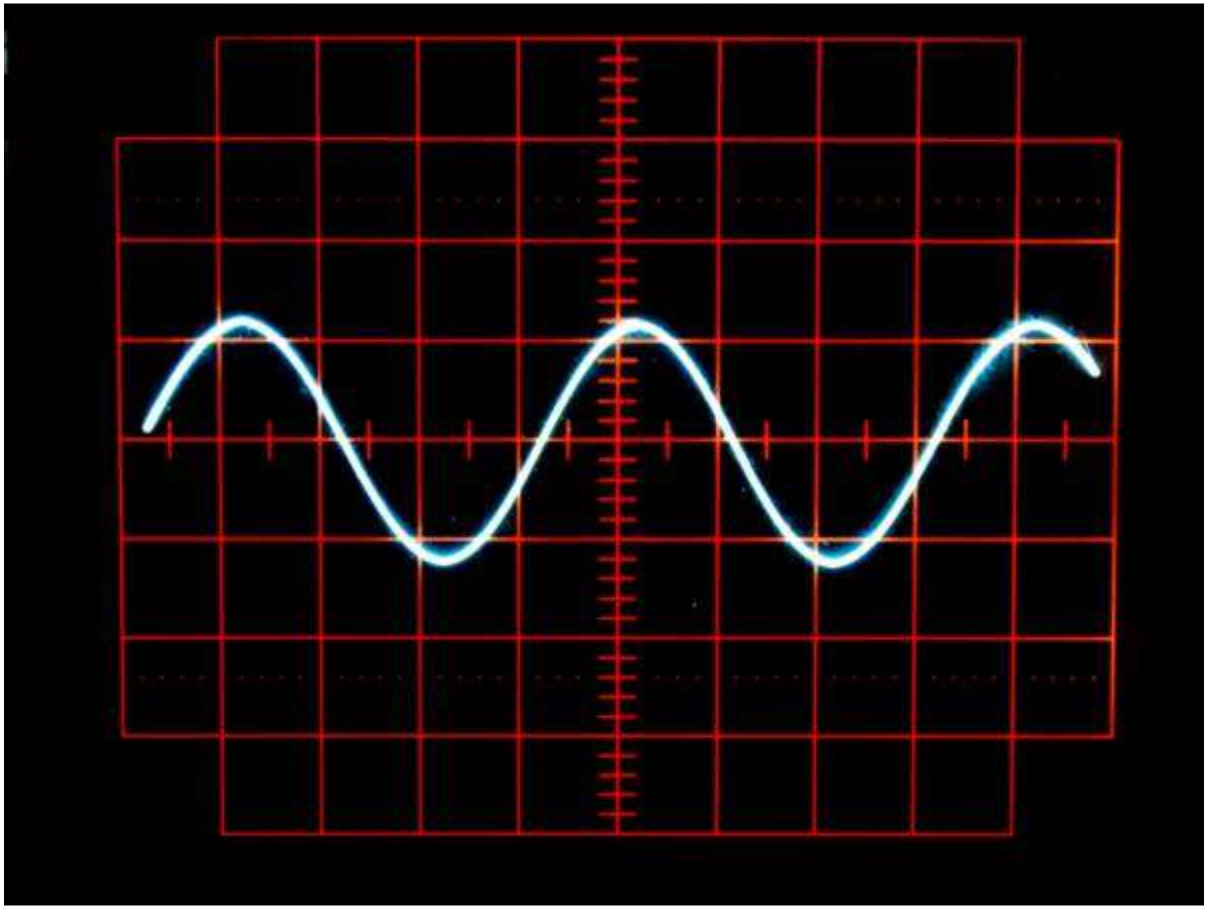


Above: *Designed by Motometer from Leonberg: preamplifier for speedometer*

Below: *From the preamplifier it goes into the tacho circuit*



They are integrated and displayed on a heavily damped instrument. The rear wheel travels 2 m per revolution. Six pulses per revolution are passed on to the electronics - 20.4 Hz at 50 km/h, 39.4 Hz at 100 km/h and 76.0 Hz at 200 km/h. However, the vibrations from the “underground” are tough. They can be quite misleading. But here too there is a clever trick.



Above: *A clean sine wave with 5V* $_{rms}$ *amplitude. At 50 km/h it is 20.4 Hz, at 100 km/h 39.4 and at 200 km/h 76.0 Hz.*

Below: *The speedometer and tachometer are electronic, the odometer is powered by a stepper motor.*

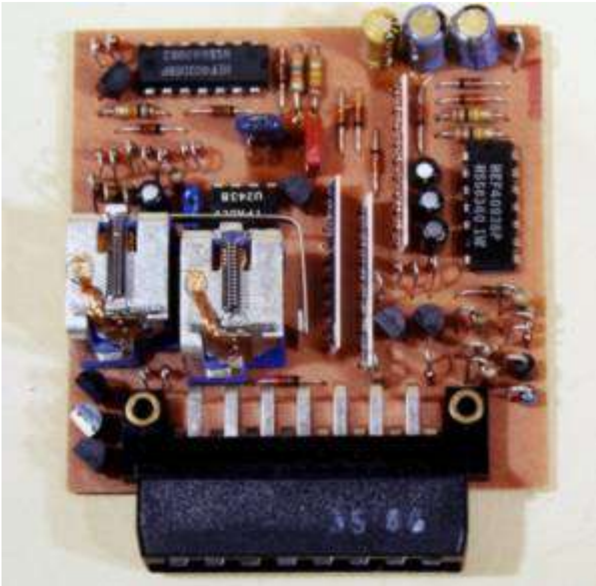
The thing with instrument damping

There is a disk at the end of each extended moving-coil instrument axle. It is grooved and runs in a chamber filled with silicone oil, the bottom of which is also grooved. Grooved so that the silicone oil does not tear off easily when rotating. In order for the associated mechanical damping to be possible, the torque had to be increased, because ultimately the pointer must not become too sluggish. So the tachometer has to be B be able to keep up with the engine speed changes.

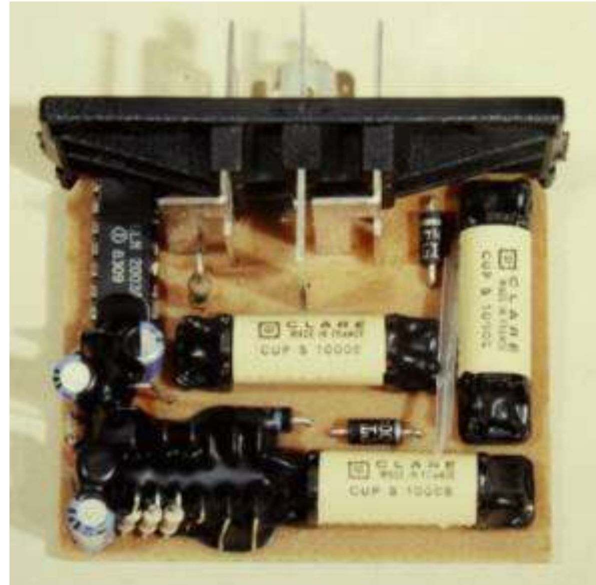
Driving and almost unimportant things

After turning on the indicator, it switches off automatically either after 210 m +30 m -50 m or when stationary after 10 s ± 3 s. The three-cylinder purrs, almost vibration-free. Motorcycling of the very modern kind.

Under the seat there is a lamp control unit, flasher and hazard warning flasher, starter relay, temperature switch, relief relay, fanfare or horn relay, EKP (electric fuel pump) relay and the Little Fuse fuses with the fuse cover. "Relay, relay, where is the modern technology?" Voltage drops across semiconductors still make this technique practical.



Above: *The indicator board with relay prevents voltage drops*



Above: *Reed relays monitor the lamp circuits. If a lamp fails, the warning indicator light lights up.*

Downhill we go, steeply down. I slowly ease off the gas and shift down to third gear. The K75 hangs on the gas, that's crazy. It now brakes like a diesel, where the exhaust gases are returned. I can confidently take fourth place, I hardly ever use the brakes. Only if the curves approach too quickly at some point do I brake slightly beforehand.

The principle of fuel cut-off

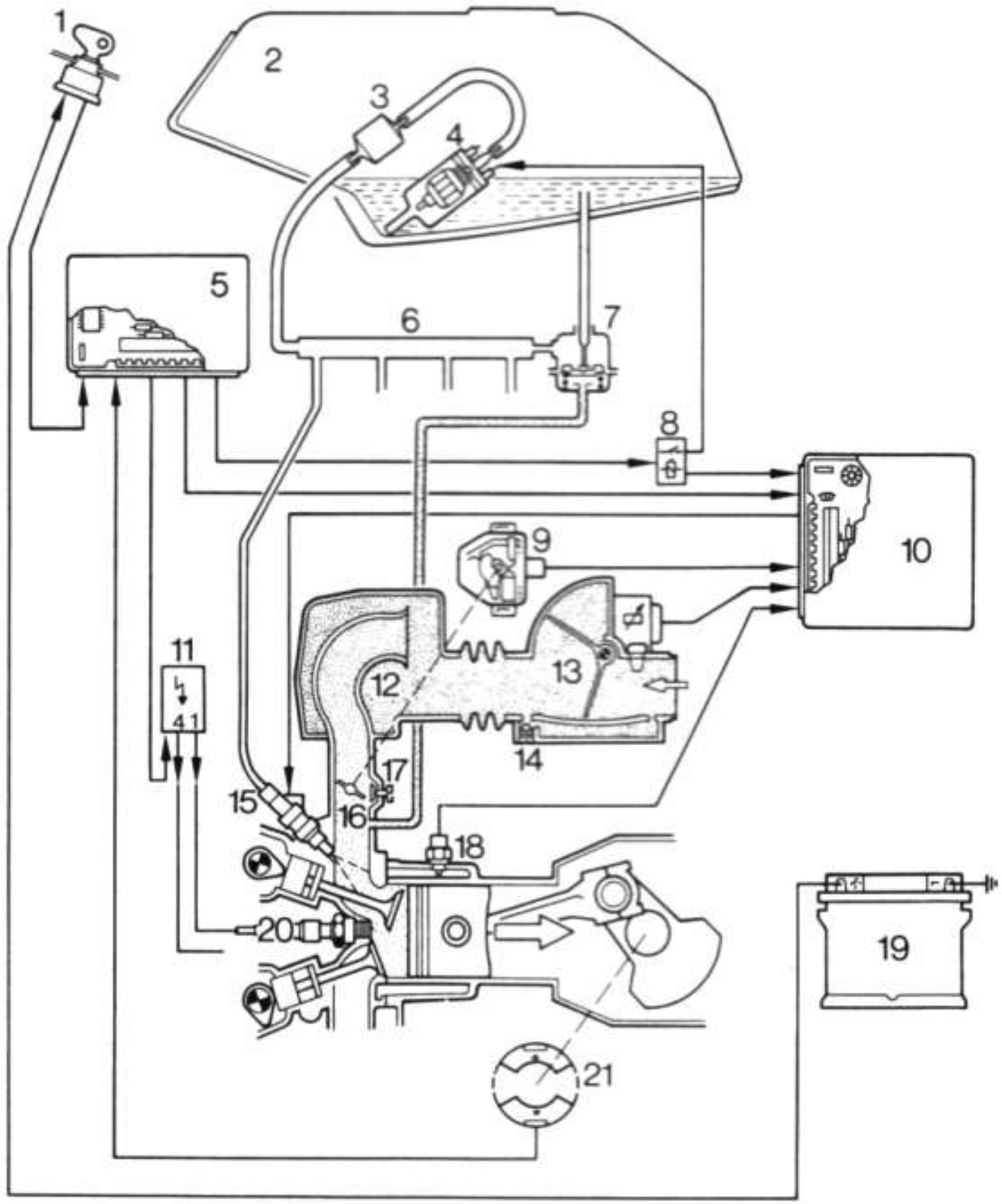
Roughly speaking, the fuel cut-off is actually nothing more than a fuel saving, but at the same time you are happy to accept a loss in comfort. Depending on the road conditions at the time, a sudden load change can result in considerable "jerking" due to braking torque or renewed acceleration. The fuel cut-off becomes effective above 2000 rpm. The ignition control unit passes on the information from the Hall sensor sensor to the injection device. So far so good. But now it's becoming electromechanical. It is located on the throttle valve: the throttle valve switch. When the gas is withdrawn, a contact closes. It activates the fuel cut-off. No more fuel is injected. This creates a braking effect. The journey slows down. The speed becomes even lower. If it falls below 2000 rpm, the electronics switch. Depending on the volume of air sucked in, a corresponding lambda is generated, ie z. B. more fuel is injected than if the engine were only rotating at 1000 rpm, since significantly more air is still sucked in through the bypass via the still closed throttle valve. And this has an influence on the position of the air flow meter's baffle flap and ultimately on the amount of fuel injected.

So if you brake your "conventional" car down the hill in low gear at 5000 rpm, the throttle valve bypass allows the engine to consume a lot of fuel. Only when idling would it be less, but at least just as harmful to the environment, because asbestos would then be released from the brake pads into the ambient air.

"A modern concept," I think. "I wonder if it limits the speed?"

At 8700 1/min the speed is "electronically" limited. You control for retarded ignition. This causes the power to drop. If the 8700 1/min is maintained despite driving downhill and is increased even further, the fuel supply is interrupted at 8800 1/min .

The combination of the fuel and intake system, the injection system, the electronic measurement and control as well as the ignition system:


1
2
3
4
5
6
7
8
9
10
11
4 1
12
13
14
15
16
17
18
19
20
21

Ignition master switch
Fuel tank
Fuel filter
Electric roller cell fuel pump
Ignition control unit
Fuel distribution bar
Pressure regulator
Fuel pump relay
Throttle valve switch (activates fuel cut-off)
Injection control unit
Double ignition coil (one each for cylinder 1/4 and 2/3)
Air collector
Air flow meter
Bypass propeller
Injector
throttle
Idle adjustment screw
Coolant temperature sensor, NTC resistor
battery
spark plug
Hall sensor , on K75 with two windows, on K100 with one window
René Füllmann