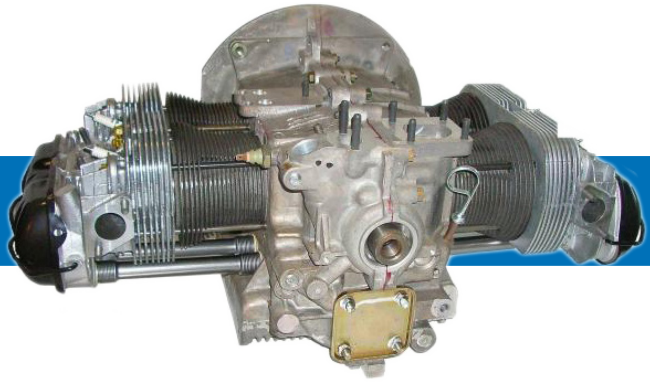
# Paruzzi Magazine

*Technical Publication for the classic Volkswagen*

**02**









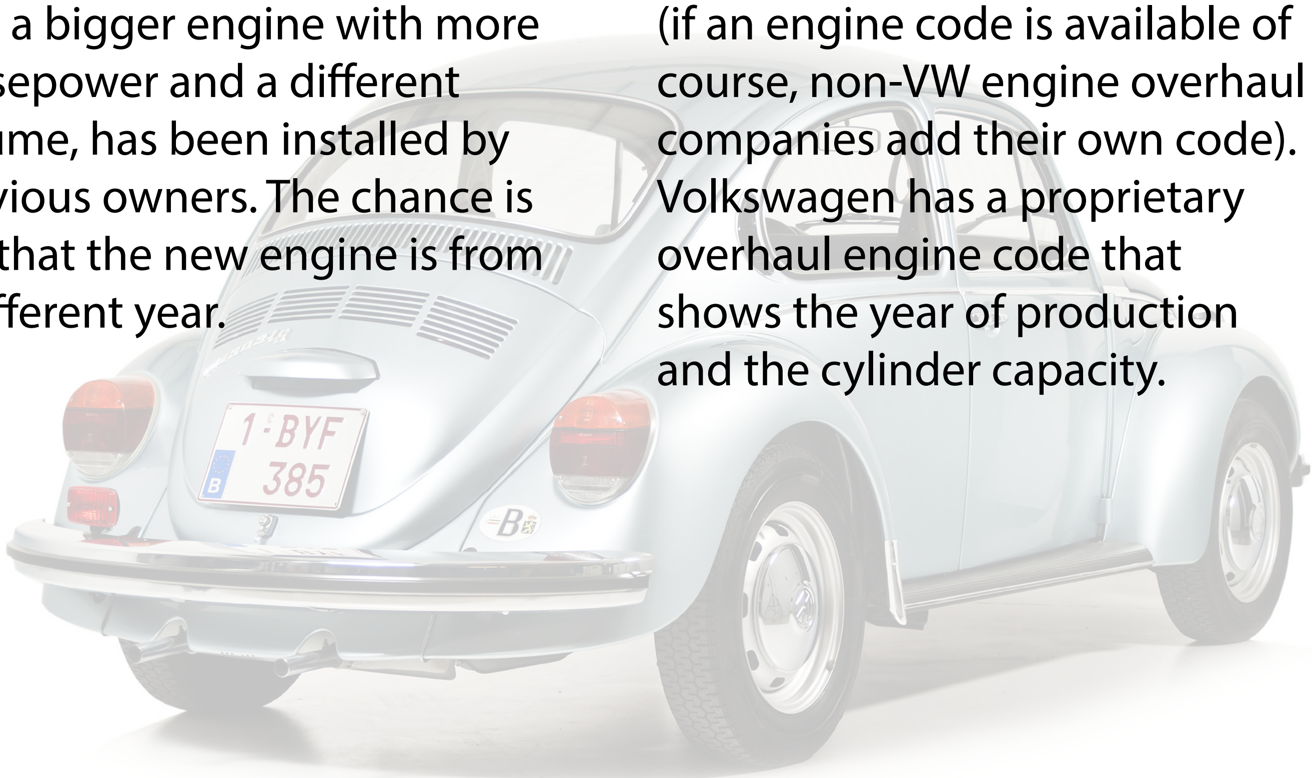
## VW engine types

You need to know the type of engine you have in the rear of your Volkswagen before you start tuning or repairing your air-cooled love one.

We have to warn you, a VW Beetle 1200 does not always have the original  1200 cc air-cooled engine in the back. Air-cooled boxer engines are interchangeable without the need to adapt the body or chassis. It occurs quite often that a bigger engine with more horsepower and a different volume, has been installed by previous owners. The chance is big that the new engine is from a different year.

We will not discuss the difference between single and double port engines, we will not discuss all the differences between all the engines we are presenting in this article. We will mainly focus on the air-cooled VW engine types and codes.

If your engine was replaced by a rebuild engine from Volkswagen, it may have a slightly different engine code, a different combination of letters (if an engine code is available of course, non-VW engine overhaul companies add their own code). Volkswagen has a proprietary overhaul engine code that shows the year of production and the cylinder capacity.






# online application

We have created an online application that will help you to retrieve the information about your engine. Just enter your engine code into this application, and we'll tell you what the cylinder volume of your engine is, in which Volkswagen type this engine should be found, or used to be built in, and finally the car built year this engine belongs to.

There is also an overview of all the engine types and where they belong to.

The standard Volkswagen engine code will tell you which engine type you have and it will reveal the cylinder capacity. The first letter(s) are unique for each type of engine and the cylinder volume. The engines up till July 31, 1965, didn't have these letters in front of the engine code, you will read only a series of numbers for these Vintage Volkswagens.


**Model year: 1971 Type 1**
**Period : 01.08.1970 / 31.12.1970**
**Size : 1,3 L**
**Power : 32 kW / 44 HP**

**Engine number :** AB029702 Check

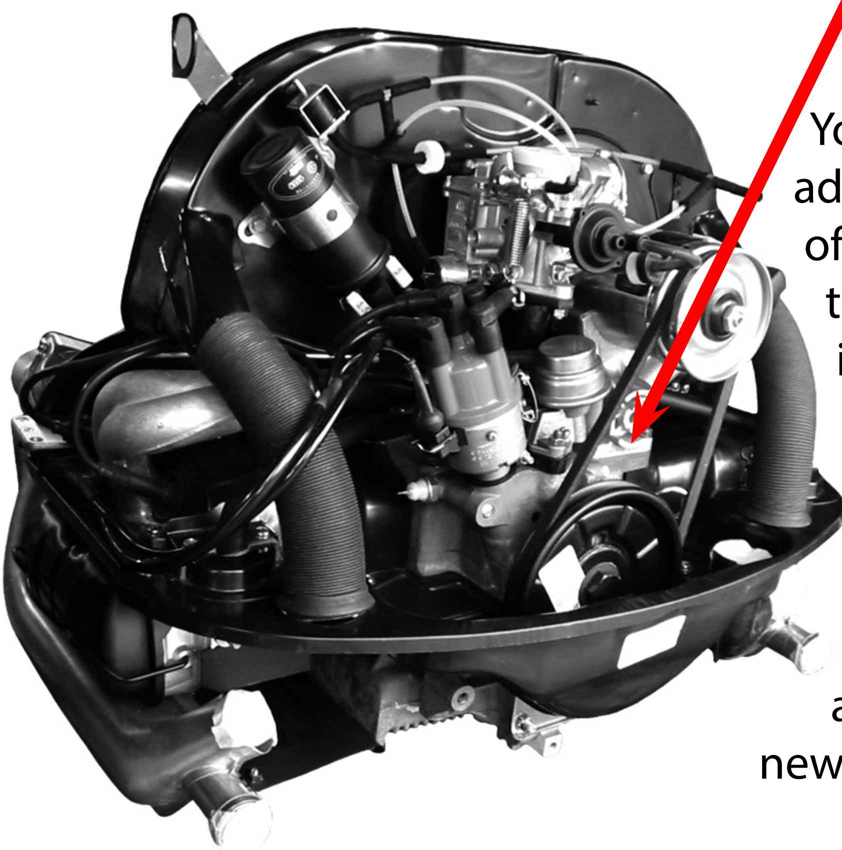
# #04 Engine

## VW type 1

The type 1 boxer engine is the original air-cooled engine that was built in the first VW Beetle from day 1 until the end of the production, it was also the engine or all Karmann Ghia models (except the type 34), the Kübel / type 181 and the Volkswagen Bus. There were many changes made to this type 1 engine along the way, we'll explain that in article # 6 in this magazine.


**type 1** **AB029702**

The engine code is located below the generator stand (dynamo or alternator). You will remark an additional "X" at the end of the engine code on the picture above. This indicates that this engine has been overhauled by Volkswagen at some point of time. Independent overhaul companies may add an aluminium plate with a new engine code instead.





# types and codes

| VW type 1 engine type | volume (cc) | kW | hp | Built Years | |
|---|---|---|---|---|---|
| | | | | from | until |
| 1-0 020 000 until 1-0695 282 | 1131 | 18 | 25 | 1943 | 31/12/1953 |
| 1-0 945 526 until 4 050 000 | 1200 | 22 | 30 | 31/12/1954 | 31/07/1965 |
| D | 1200 | 25 | 34 | 1/08/1965 | 31/12/1985 |
| E | 1300 | 27 | 37 | 1/08/1965 | 31/07/1970 |
| F | 1300 | 29 | 40 | 1/08/1965 | 31/07/1970 |
| AC | 1300 | 29 | 40 | 1/08/1970 | 31/07/1975 |
| AB | 1300 | 32 | 44 | 1/08/1970 | 31/07/1973 |
| AR | 1300 | 32 | 44 | 1/08/1973 | 31/07/1975 |
| L | 1500 | 29 | 40 | 1/08/1966 | 31/07/1970 |
| H | 1500 | 32 | 44 | 1/08/1966 | 28/02/1971 |
| AG | 1600 | 32 | 44 | 1/08/1970 | 31/12/1975 |
| AF | 1600 | 33 | 46 | 1/08/1970 | 30/09/1992 |
| B | 1600 | 34 | 47 | 1/08/1969 | 31/07/1970 |
| AH | 1600 | 35 | 48 | 1/08/1971 | 31/07/1974 |
| AE | 1600 | 35 | 48 | 1/08/1970 | 31/12/1972 |
| AL | 1600 | 35 | 48 | 28/02/1973 | 31/12/1978 |
| AM | 1600 | 35 | 48 | 28/02/1973 | 30/09/1974 |
| AD | 1600 | 37 | 50 | 1/08/1970 | 31/07/1973 |
| AS | 1600 | 37 | 50 | 1/08/1973 | 31/12/1979 |
| AJ | 1600 | 34 | 50 | 1/08/1974 | 31/01/1980 |
| ACD | 1600 | 34 | 50 | 1/10/1992 | 31/07/2003 |

# #04 Engine

## VW type 3

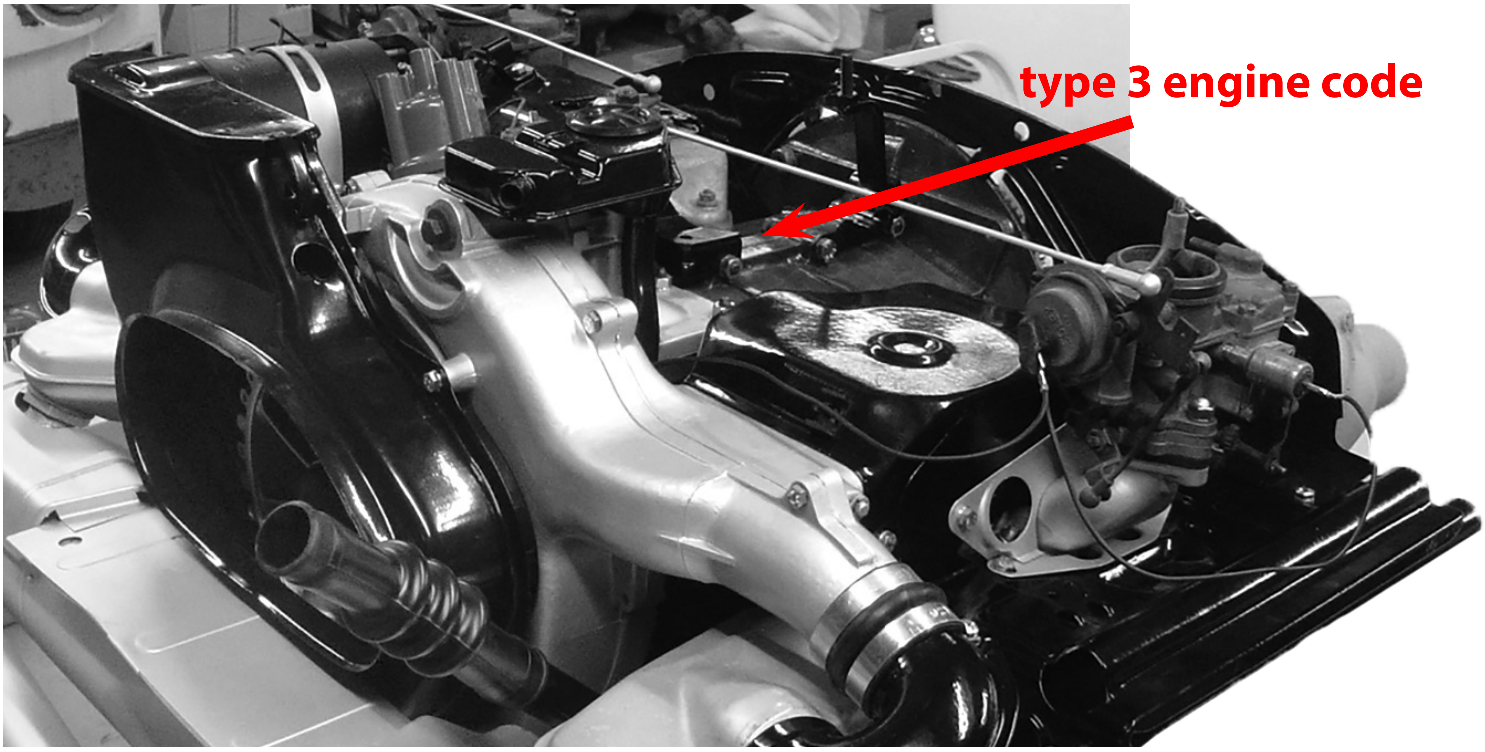
De type 3 boxer engine was especially designed for the type 3 Volkswagen in the early 1960's (Notchback, Fastback, Squareback). The type 3 engine looks a lot like the type 1 engine, the main difference is that the design of the engine parts such as fan housing, oil cooler, offered more clearance in the back of the car, more luggage space was available, a feature that was needed to compete on the family car market segment.

You will find the engine code in the middle of the crank case, where both crank case halves join. You'll need to remove the air filter to read the engine code.

| VW type 3 engine types | volume (cc) | kW | hp | Built Years | |
|---|---|---|---|---|---|
| | | | | from | until |
| 000001 until 999999 | 1500 | * | * | 1/04/1961 | 31/07/1965 |
| M | 1500 | 30 | 41 | 1/08/1965 | 31/07/1973 |
| K | 1500 | 33 | 45 | 1/08/1965 | 31/07/1973 |
| P | 1600 | 36 | 49 | 1/08/1965 | 31/07/1973 |
| T | 1600 | 40 | 54 | 1/08/1965 | 31/07/1973 |
| U | 1600 | 40 | 54 | 1/08/1967 | 31/07/1973 |
| X | 1600 | 40 | 54 | 31/12/1971 | 31/07/1972 |

*** 4 different engine types were used (all 1500 cc), without engine identification**
**30 kw / 41 hp**
**33 kw / 45 hp**
**38 kw / 52 hp**
**40 kw / 54 hp**







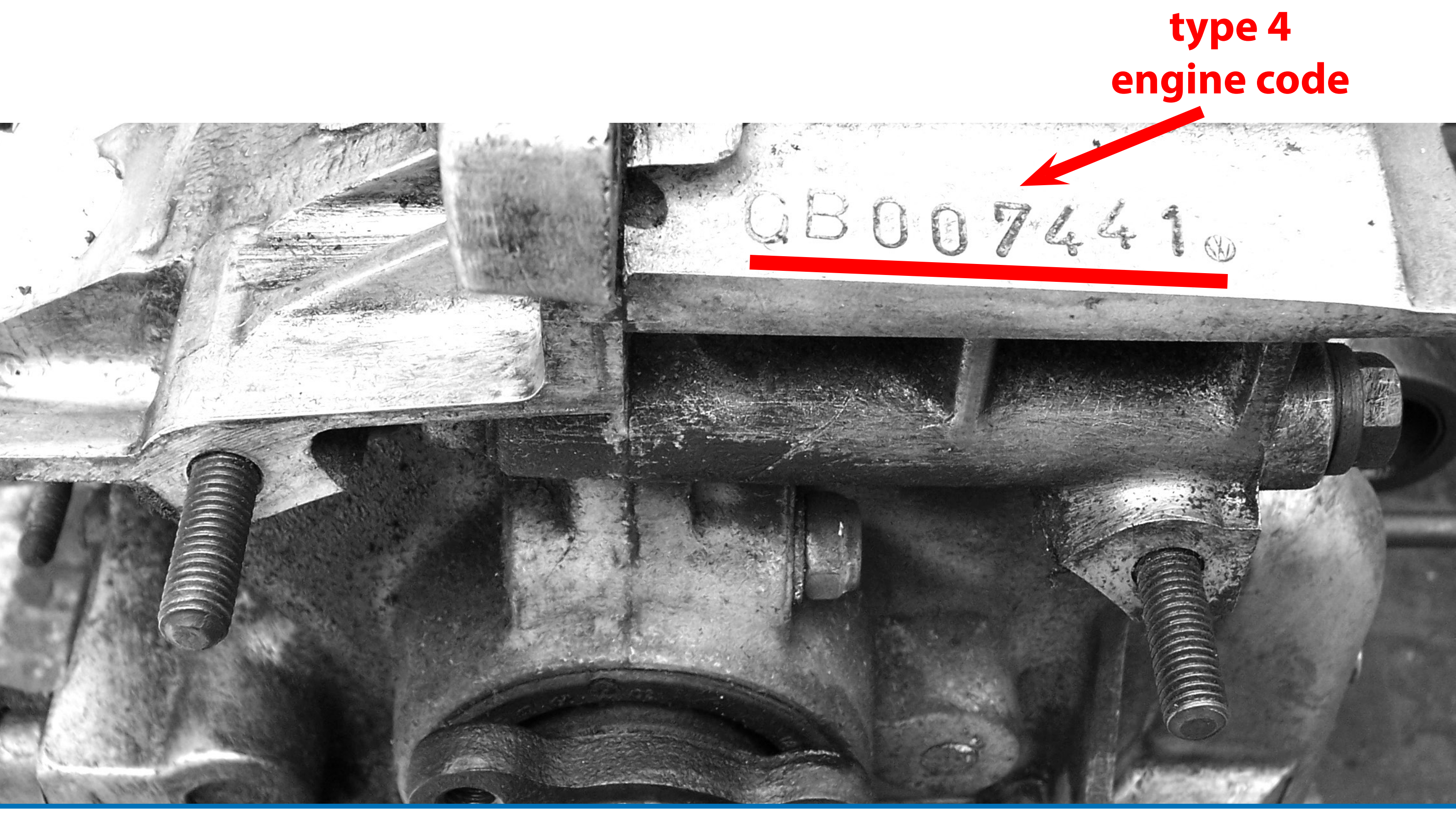
**The VW type 3 Fastback with the type 3 boxer engine in the back**

## VW type 4

The type 4 boxer engine was introduced together with the VW 411, this car was the next generation (2-doors or 4-doors) family car of Volkswagen in the late 1960's. The type 4 was also used to power the second generation, the VW 412. This type 4 engine was much more powerful than the "old" type 1, the type 4 was used in many other Volkswagen models later on.

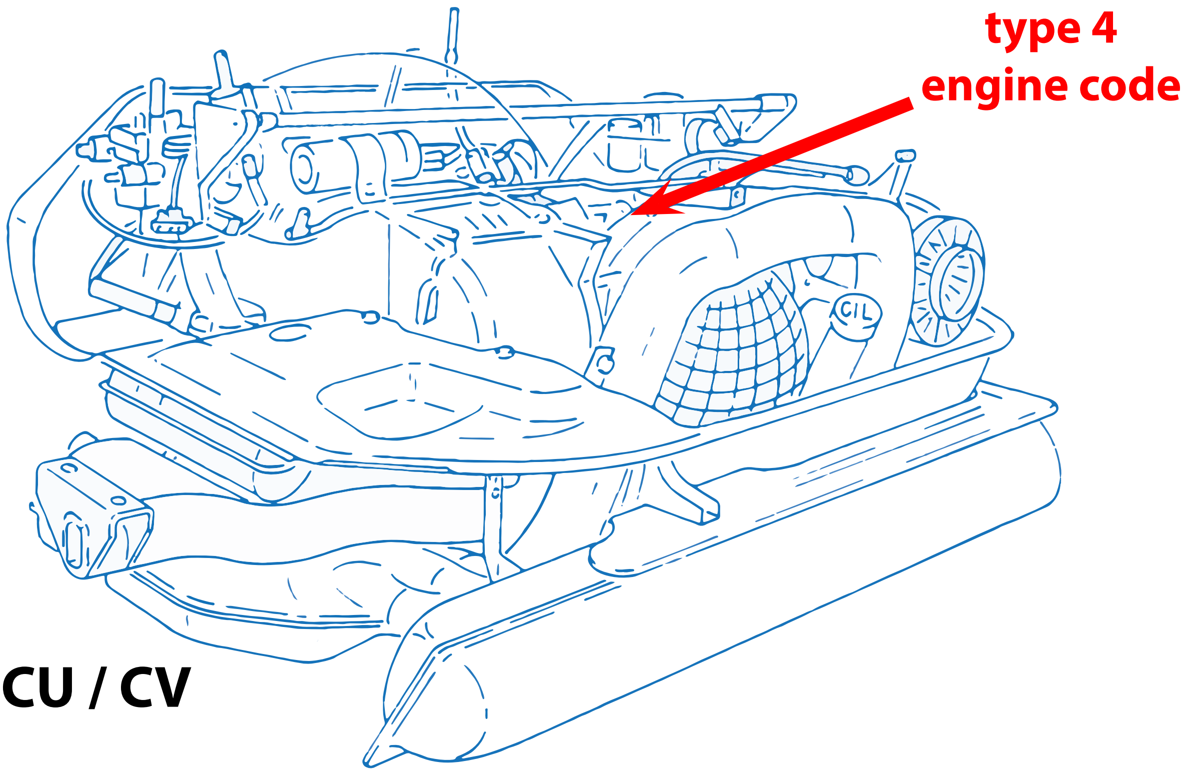
The Bay-Window Bus, the T25/T3 Bus and the Porsche 914 used the type 4 air-cooled boxer engine.

You'll find the engine code on the engine crank case, just below the crank breather. The Porsche 914 1700 cc is an exception, the engine code is located on the back of the crank case, close to the flywheel.




# types and codes

| VW type 4 engine code | volume (cc) | kW | hp | Built Years | |
|---|---|---|---|---|---|
| | | | | from | until |
| CA | 1700 | 49 | 66 | 1/08/1971 | 31/07/1973 |
| CB | 1700 | 49 | 66 | 1/08/1971 | 31/12/1973 |
| AP | 1800 | 50 | 68 | 1/08/1973 | 31/07/1975 |
| AW | 1800 | 50 | 68 | 1/08/1973 | 31/07/1974 |
| ED | 1800 | 51 | 70 | 31/12/1973 | 31/07/1975 |
| CJ | 2000 | 51 | 70 | 1/08/1976 | 31/07/1979 |
| GD | 2000 | 51 | 70 | 1/08/1975 | 31/12/1976 |
| GE | 2000 | 51 | 70 | 1/08/1976 | 31/07/1979 |
| CU | 2000 | 51 | 70 | 31/05/1979 | 31/12/1982 |
| CV | 2000 | 51 | 70 | 31/05/1979 | 31/12/1982 |



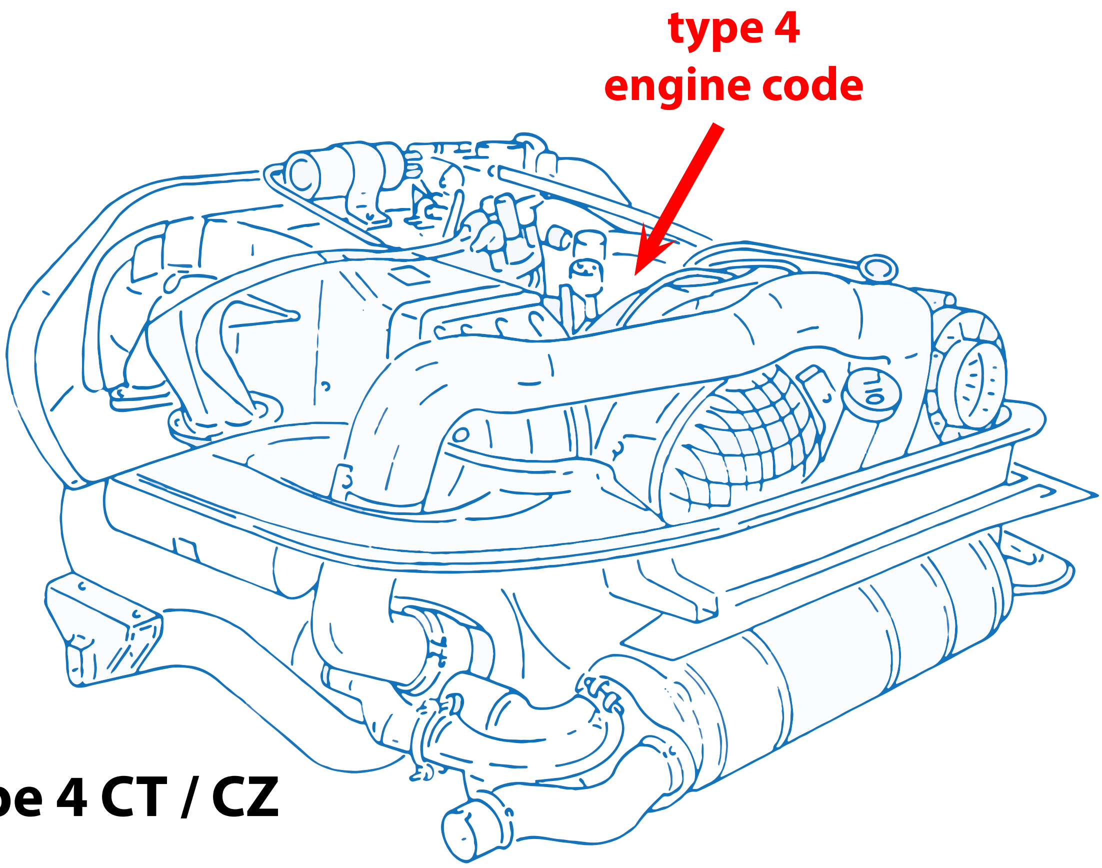

type 4 CU / CV

# #04 Engine

## VW CT / CZ

The CT / CZ type is a 1600 cc boxer engine used in the T25/T3 Bus from the end of May 1979 until 1982. This engine wasn't strong enough to support the "heavy" third generation Bus. These CT / CZ engines were replaced with more powerful water-cooled engines, the waterboxers.

| VW CT / CZ engine code | volume (cc) | kW | hp | Built Years | |
|---|---|---|---|---|---|
| | | | | from | until |
| CZ | 1600 | 35 | 48 | 30/09/1979 | 31/12/1982 |
| CT | 1600 | 37 | 50 | 31/05/1979 | 31/12/1982 |



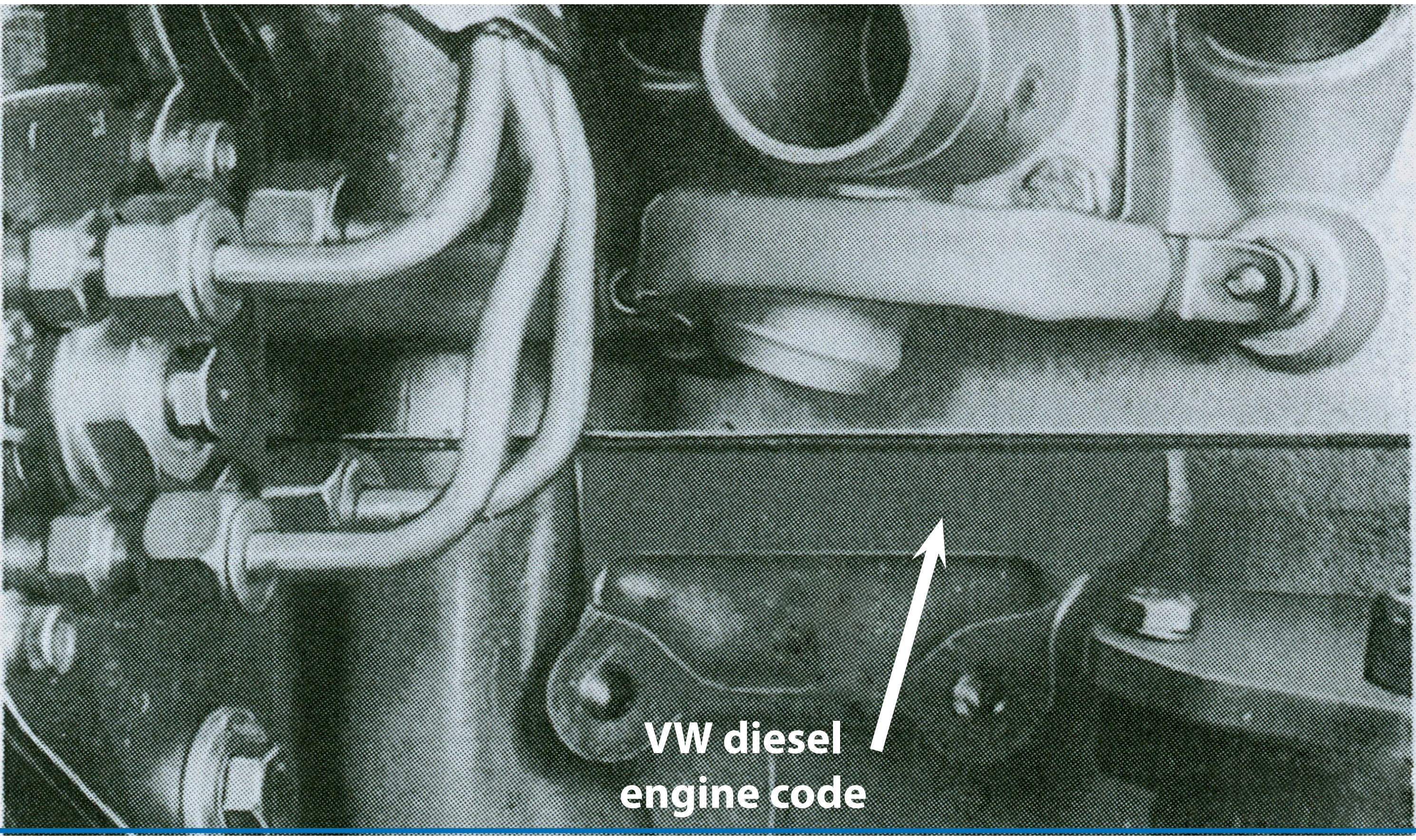

type 4 CT / CZ



# VW diesel

The first generation Volkswagen Bus with Diesel engine in 1981 was powered by the 1600 cc Diesel engine from the Volkswagen Golf, a 4 cylinder in-line type of engine. You'll find the engine code between the injection pump and the vacuum pump.

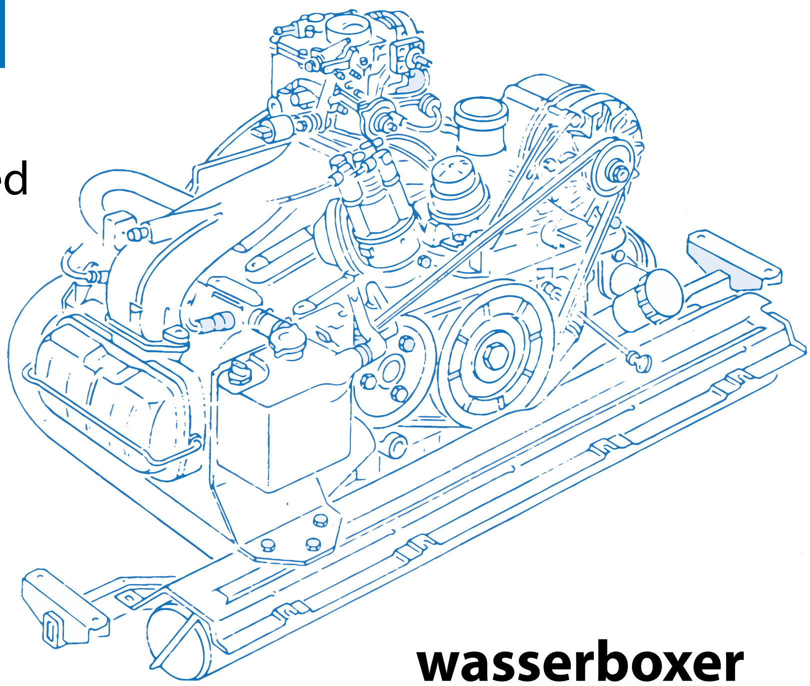
| VW diesel engine code | volume (cc) | kW | hp | Built Years | |
|---|---|---|---|---|---|
| | | | | from | until |
| CS | 1600 | 37 | 50 | 31/01/1981 | 31/07/1987 |
| JX | 1600 | 51 | 70 | 31/08/1984 | 31/07/1992 |
| KY | 1800 | 42 | 57 | 31/08/1984 | 31/07/1992 |



# #04 Engine

## VW waterboxer

The type 1 engine was redesigned to become a «Wasserboxer». More powerful, quieter, fuel efficient, this engine developed even further during the production years of the T25/T3 Bus. The first "Wasserboxers" were available as a 1900 cc with single or double carburetor (60 & 78 hp).



wasserboxer

| engine code | volume (cc) | kW | hp | Built Years | |
|---|---|---|---|---|---|
| | | | | from | until |
| DF | 1900 | 44 | 60 | 31/08/1982 | 31/07/1992 |
| SP | 1900 | 54 | 73 | 30/09/1986 | 31/08/1988 |
| DG | 1900 | 57 | 78 | 30/09/1982 | 31/07/1992 |
| DH | 1900 | 60 | 82 | 31/01/1983 | 30/06/1985 |
| GW | 1900 | 66 | 90 | 31/08/1982 | 30/06/1985 |
| SR | 2100 | 64 | 87 | 30/09/1986 | 31/07/1992 |
| SS | 2100 | 68 | 92 | 31/08/1989 | 31/05/1992 |
| MV | 2100 | 70 | 95 | 31/08/1985 | 31/07/1992 |
| DJ | 2100 | 82 | 112 | 31/07/1985 | 31/07/1992 |











BLUESTAR
1 · DNR · 165


B
MULTIVAN
1 · DNR · 165

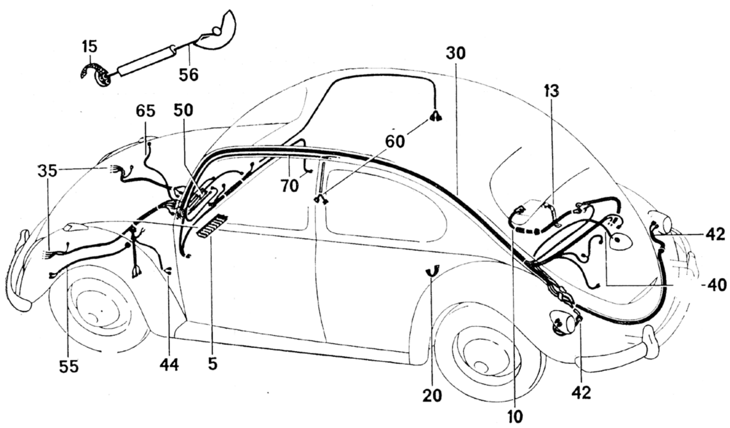
## 7 components

The electrical circuit is something that many of us have difficulties with, it is not that easy to understand. You have this complex wiring loom , a fuse box with many incoming and outgoing cables, it is discouraging.
It is quite difficult to diagnose an electrical defect if you can't simplify this complex circuit. If you finished restoring your VW, you will need a step by step approach to get your electrical components back to work.

So, let's try to do just that, simplify the Volkswagen electrical circuit. All cars are designed around the same electrical components, they have the same basic electrical circuit. Forget the electrical accessories for a moment, and concentrate on the basic electrical components you need to have your engine running.

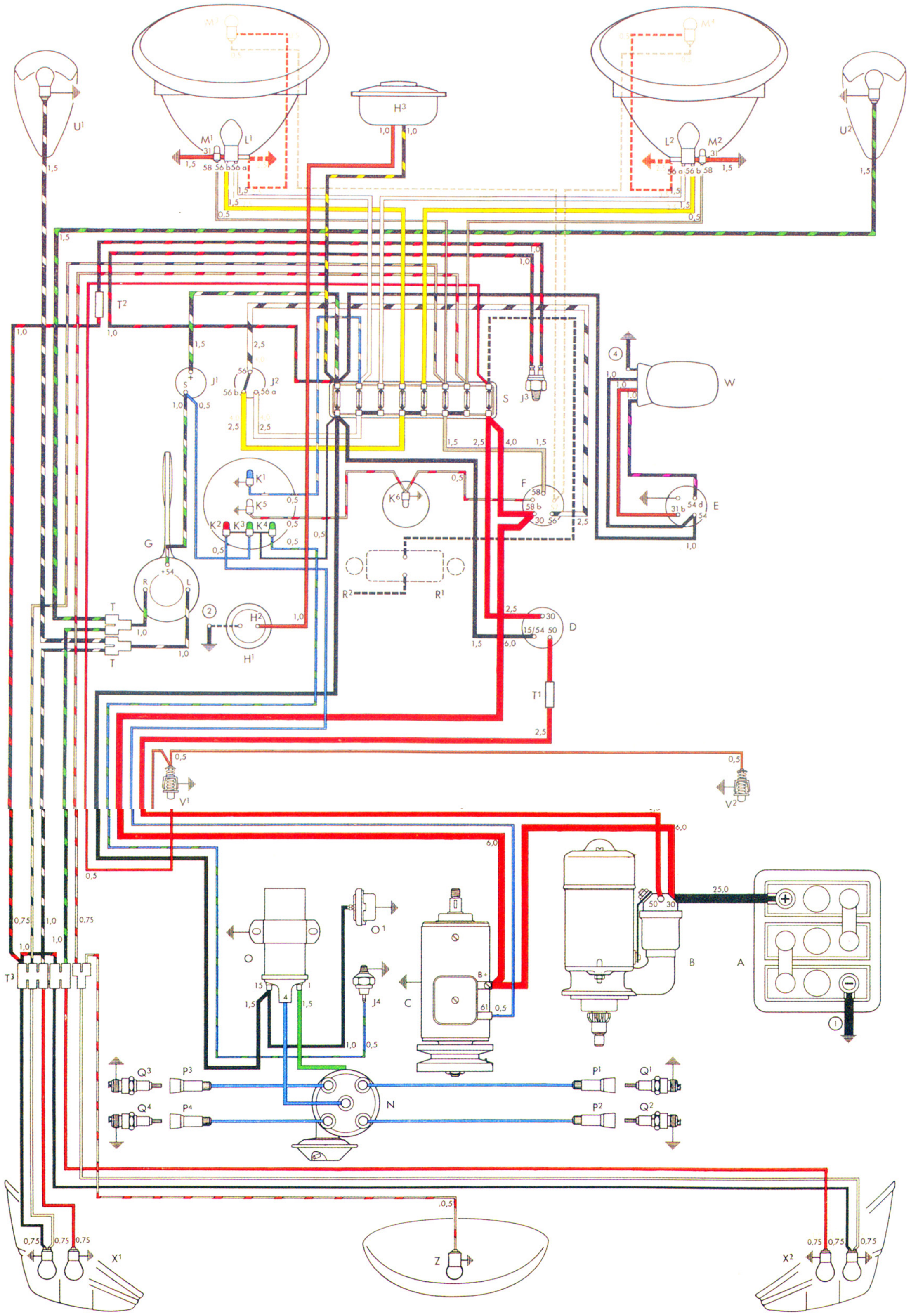
On your right, the complete electrical scheme for a 1960 Beetle. We will use this model because in these days cars didn't have too many accessories, so the electrical wiring is quite simple. Electrical schemes were drawn like this until the end of the sixties, you could still recognise the lay-out of the VW Beetle with headlights in front and so on.

Take a minute to look at this 1960 electrical wiring, it looks complicated at first, that is why we will simplify this for you on this article.






# VW Beetle 1200 electrical circuit 1960



# #05 Electrical

The most recent models are using a system where the components are logically grouped together, which resulted in a clean schematic, but sometimes hard to figure out for non-professionals. We won't use this kind of schematics here, we use the old type of representation.

All the car accessories received their electrical power through these cables, the headlights, rear lights, interior lights, brake lights, turn signals and so on.

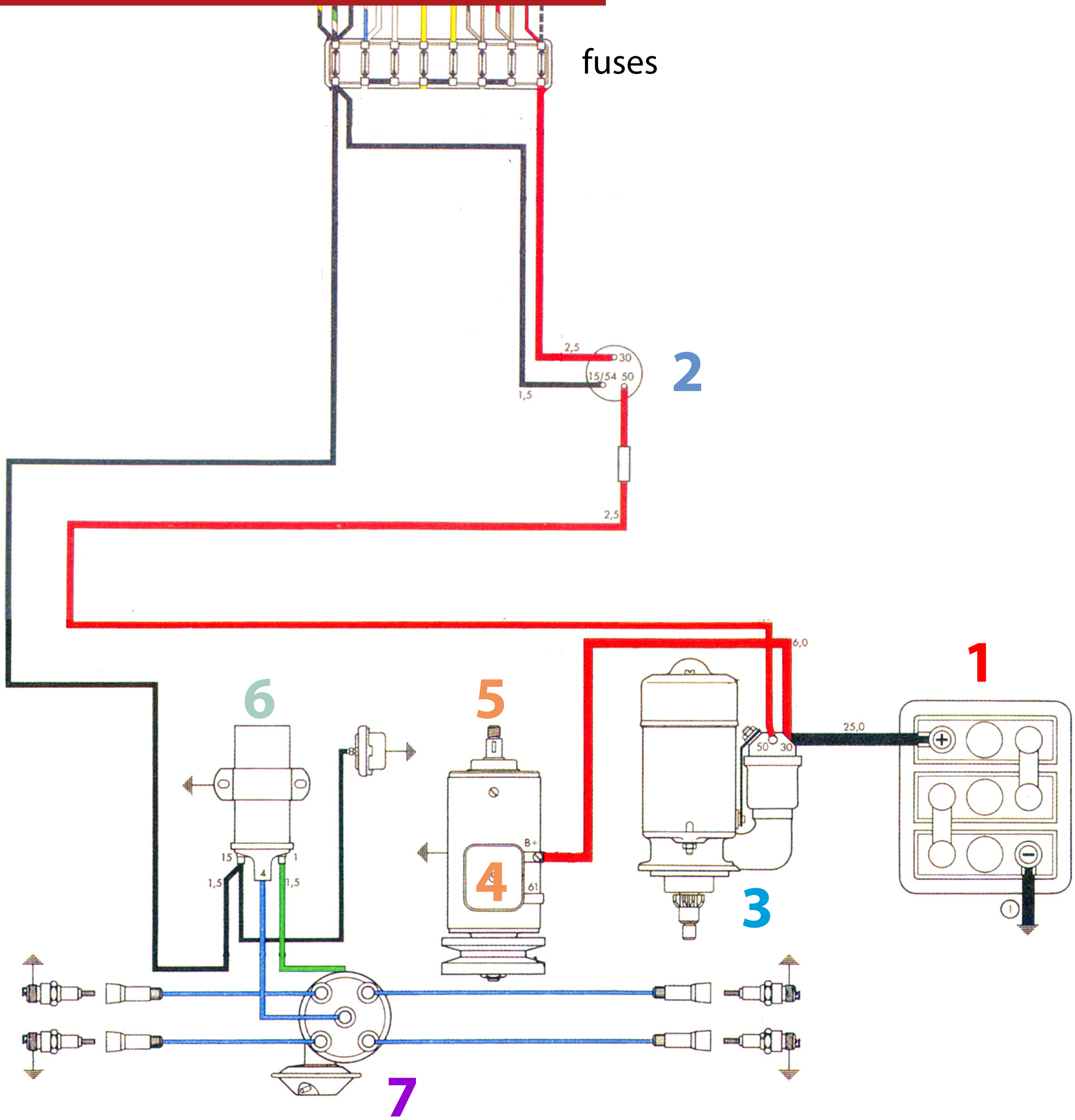
Accessories are not vital components, the engine does not need these to work properly. That is just what we want to achieve here, remove all the "unnecessary" electrical components to get a clear view on the 7 basic electrical parts our Volkswagen Beetle engine needs, nothing more. That is what you see on this basic electrical circuit on the right, it is the same circuit as the original one we shown just a page ago, but now you see only the basic elements you need for your engine to run.

The standard automobile electrical installation has 7 basic components:

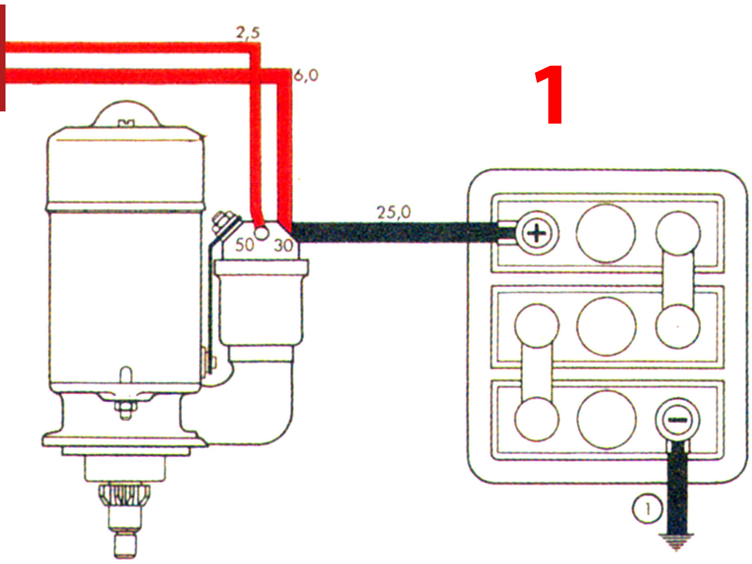
1. **the battery (12 volt or 6 volt for our classic VW)**
2. **the ignition key and the ignition switch**
3. **the starter**
4. **the voltage regulator**
5. **the generator (dynamo or alternator)**
6. **the ignition coil**
7. **the distributor, condenser and the spark plugs**



## basic electrical circuit



## the battery



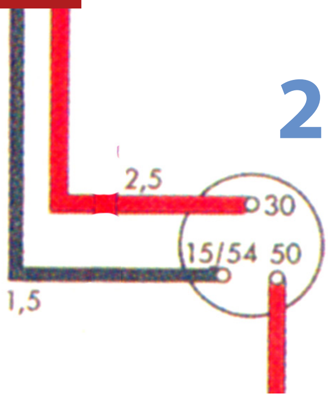

The battery is an important part of the electrical circuit, it will accumulate the electrical energy generated by the dynamo or the alternator. Battery is really not a good name, a car battery is an accumulator, but everybody calls it a battery these days.
If the electrical energy is not accumulated properly, or if the electrical energy is draining out of the battery for no reason, then the whole electrical installation will be faulty.

The negative battery terminal is connected to the electrical ground of the car, in the case of a Vintage Volkswagen, the chassis. The positive terminal is connected to the number 30 terminal on the starter. The electrical scheme also shows the wiring diameter, you see that the wire going from the battery plus to the starter is a 25,0 cable, the biggest cable you will encounter in your Volkswagen, so easy to recognise.

We have discussed the battery diagnose in our first edition of this digital magazine.



## the ignition key




The ignition key is the visible part of the ignition switch, it is located near the steering wheel, or on the dashboard depending on the model or built year you have. The ignition switch and the ignition key assembly can be one part or two separate parts, depending again on the built year.

The ignition key will take care of the security of your VW, so that one can't steel your vehicle just like that.

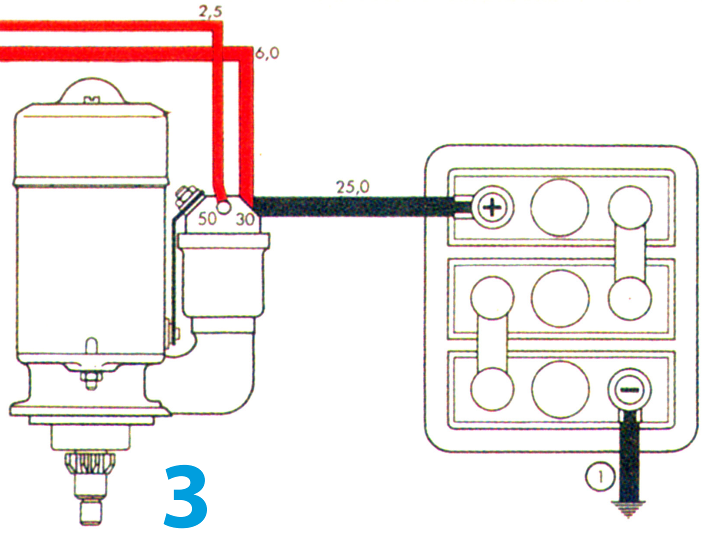
We have chosen 2 examples below, both show the ignition key assembly, without the ignition switch part. On the left is a model that fits the August 1967 until July 1970 Beetle. On the right a model that fits the 1970 Beetle onwards. You need to add the ignition switch to have a working system.

## the ignition switch

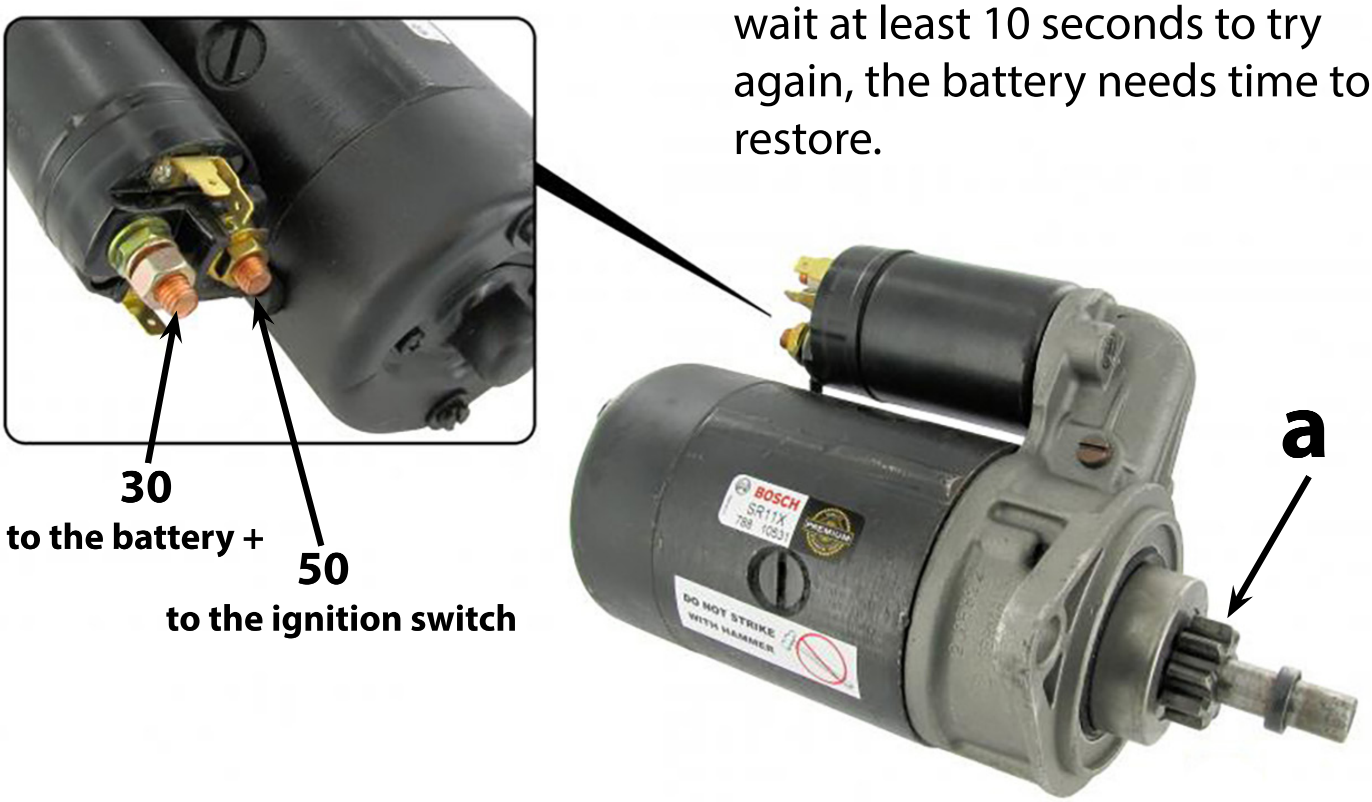
The ignition switch has different contact positions that will be used depending on the situation. The first position when turning the key clockwise will power on the accessories and power the ignition coil. When you turn the ignition key further clockwise the starter will crank the engine. The ignition switch is designed to support high electrical loads, the high current that is needed to rotate the starter runs through this ignition switch.

On the left, an ignition switch that fits the Beetle from August 1967 until July 1970, it fits the ignition key assembly shown on the page before this one. The ignition switch above fits the Beetle 1970 onwards ignition key. Below you see a combination of key and switch in one housing, this one fits the Beetle and Ghia starting August 1957 through 1967. Extended information about these product is available in the Paruzzi webstore, including tables with built years and VW type.

## the starter

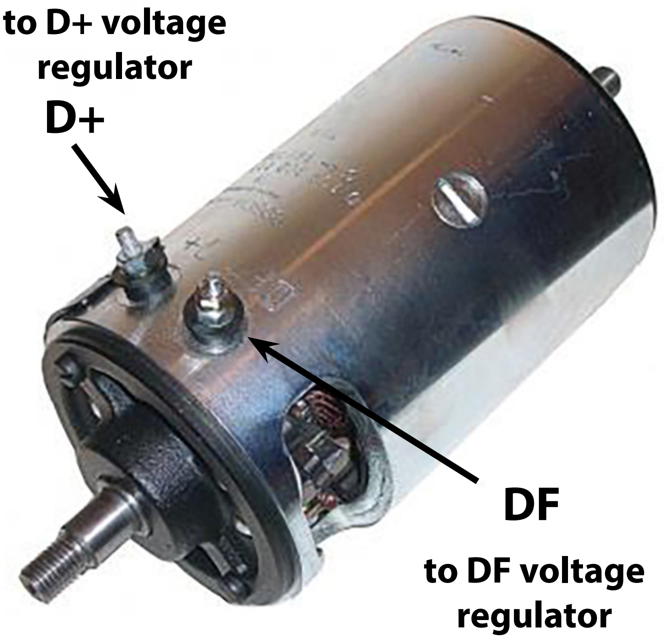



The starter will crank your VW boxer engine. It is a strong electric motor with a small gear (a) installed on an axle, this gear will rotate the flywheel to start the engine. The mechanical parts of the starter are very robust, it needs to develop a lot of kinetic energy to make it all happen. The battery provides the electrical power to feed the starter, the battery will lose a lot of its accumulated energy in a short period of time. The current the starter needs is about 90 A to 100 A (electrical current is measured in ampère) for a 12 V circuit. Never crank the engine for more than 10 seconds, wait at least 10 seconds to try again, the battery needs time to restore.

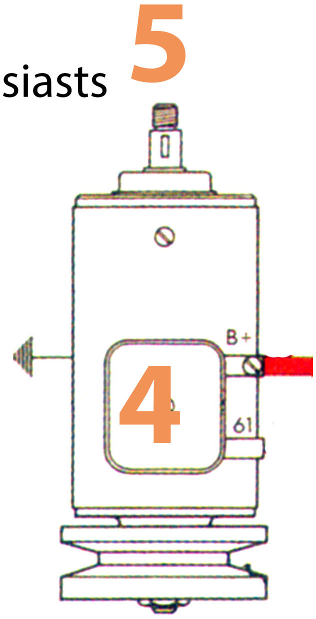


## the generator

A dynamo generates direct current, an alternator generates alternating current. Alternating current has to be rectified by an electrical rectifier such as a diode bridge, our Volkswagen needs direct current to operate.




A direct current generator in the picture above, also called a dynamo. There are two electrical terminals, B+ and DF. The voltage regulator for this type of generator is installed under the back seat inside the VW Beetle.

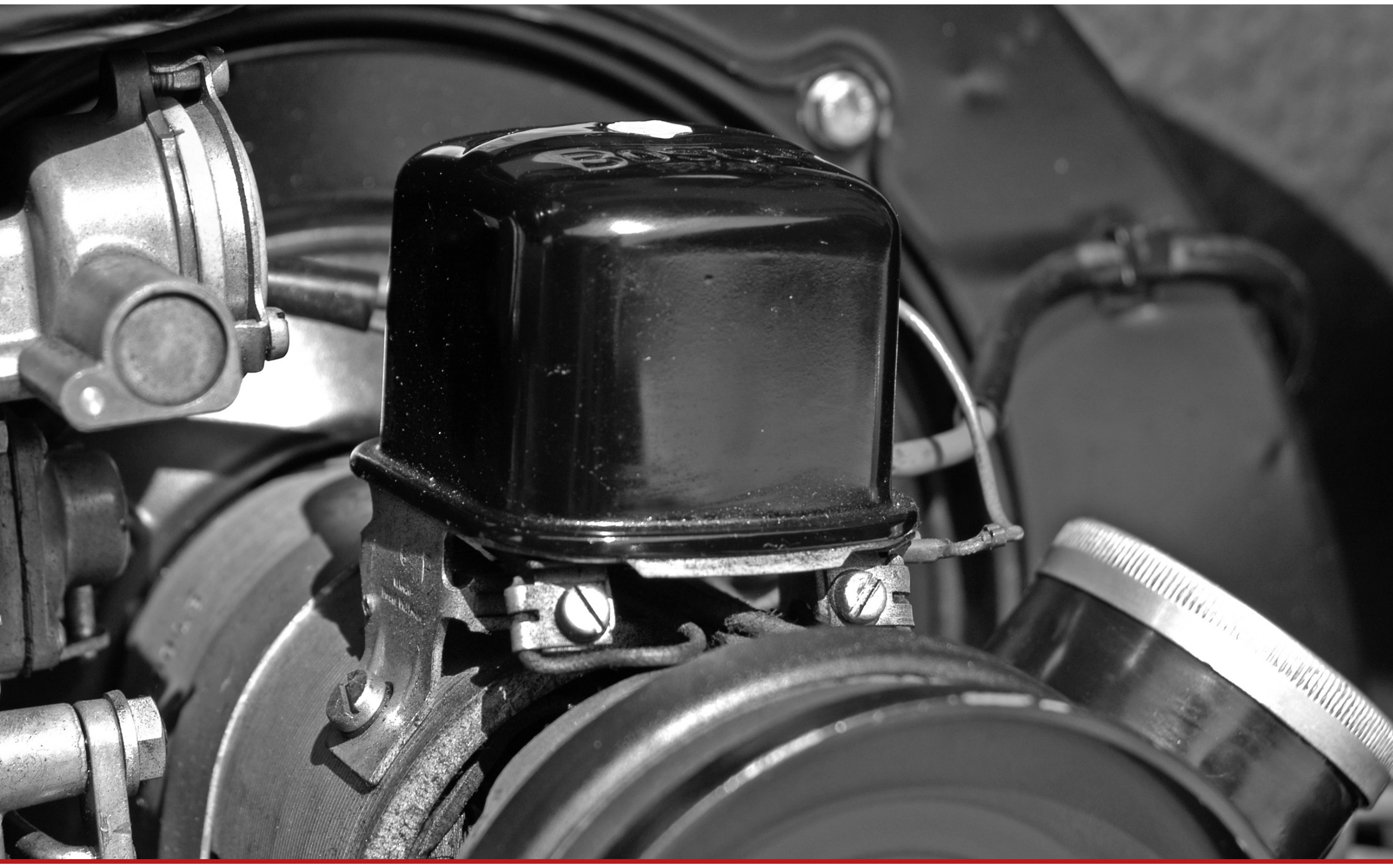



Many VW enthusiasts are used to say dynamo to any type of generator. In the old days, only dynamo's were installed in Volkswagens, that's why I guess. On the left you see a dynamo, on the right an alternator, both are generators really, they generate electrical power, lets both call them generators from now.



## the voltage regulator

The generator will load the battery while driving. The voltage regulator will make sure the output voltage of the generator never reaches a level that could damage the battery. The voltage regulator will also make sure that no current is draining back from the battery to the generator when the engine is idle.



# #05 Electrical

When the battery is fully loaded, the voltage regulator will disconnect the generator charging circuit from the battery. This will happen at a maximum voltage, the level is about 14,5 V for a 12 V circuit and about 8 V for a 6 V circuit. Once the battery is disconnected from the generator loading circuit, it is the battery only that will take care of feeding all the accessories including the engine ignition system. When the battery voltage drops under the value mentioned before, the voltage regulator connects the generator back to the battery.



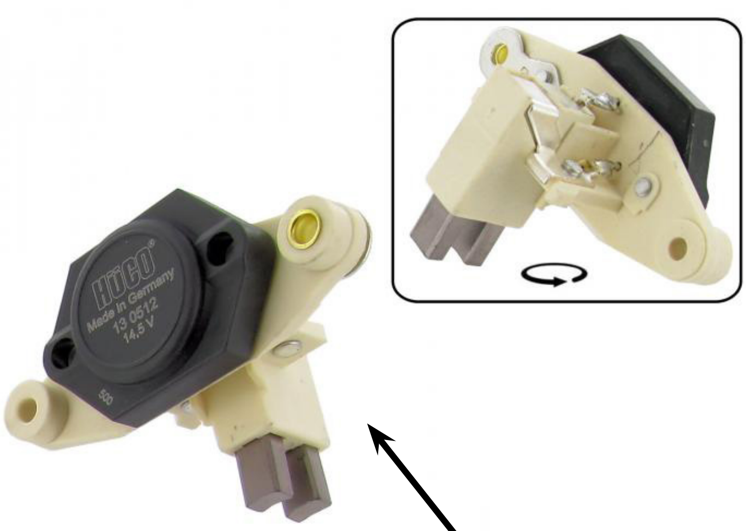
There are different types of voltage regulators depending on the type and built year of the Volkswagen:

1. The oldest VW models with a - direct current - dynamo have a mechanical voltage regulator installed on top of the dynamo as shown in the picture on the previous page and on the 1960 Beetle scheme. The B+ terminal is connected with the positive battery terminal, the 61 terminal is used to power the battery load light in the dashboard.

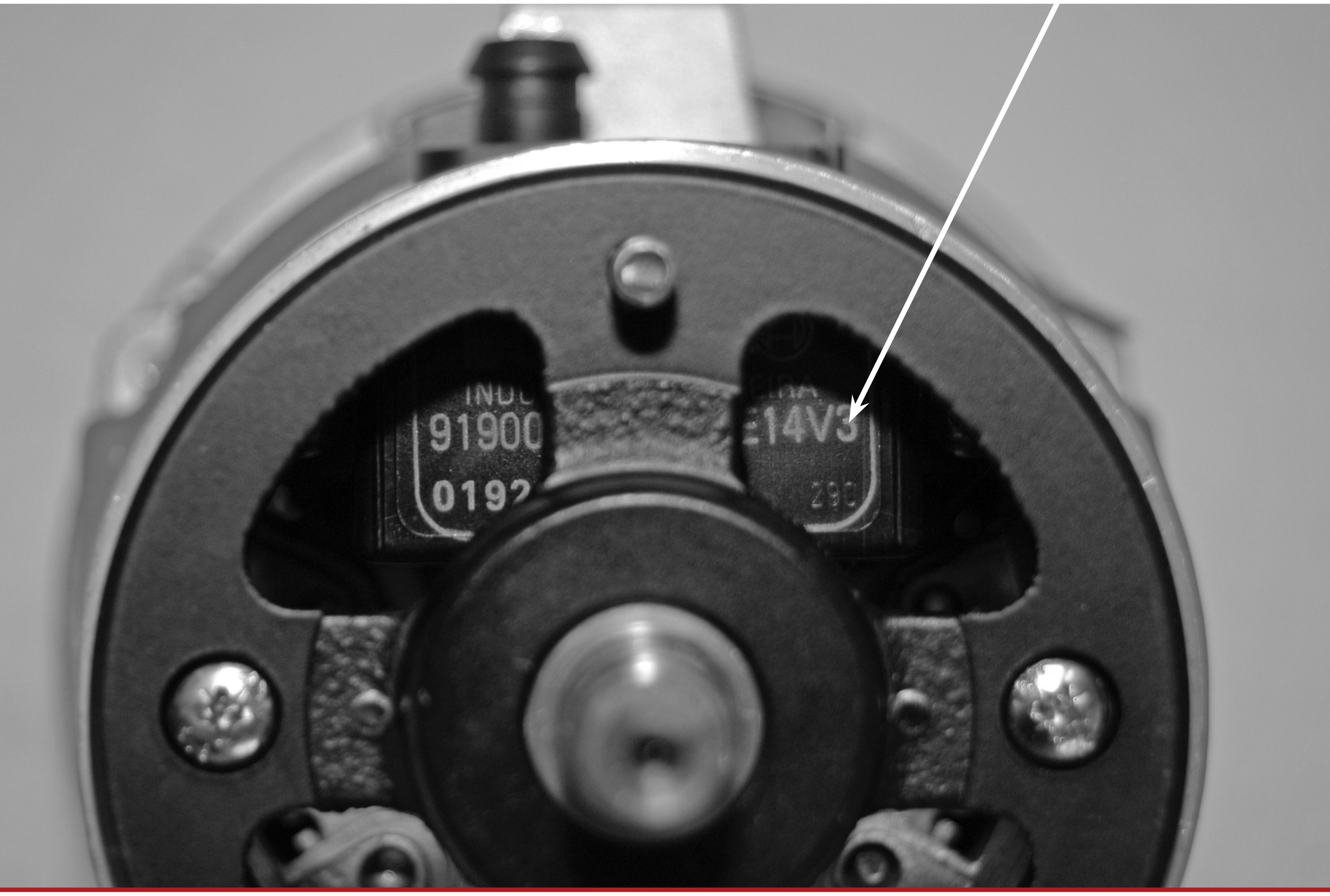
2. The younger VW models with a -direct current - dynamo have a mechanical voltage regulator installed under the back seat of the car, an example is shown in the picture left. The connections are shown on the previous page, D+ terminal is connected with the D+ terminal of the voltage regulator, DF terminal is connected to the DF terminal of the voltage regulator.



3. The latest VW models have an - alternating current - alternator installed, well most of the time, some standard Beetle models were equipped with a 6 V dynamo through the sixties and early seventies. The alternators have an electronic voltage regulator that is integrated in the alternator housing as shown in the picture below.

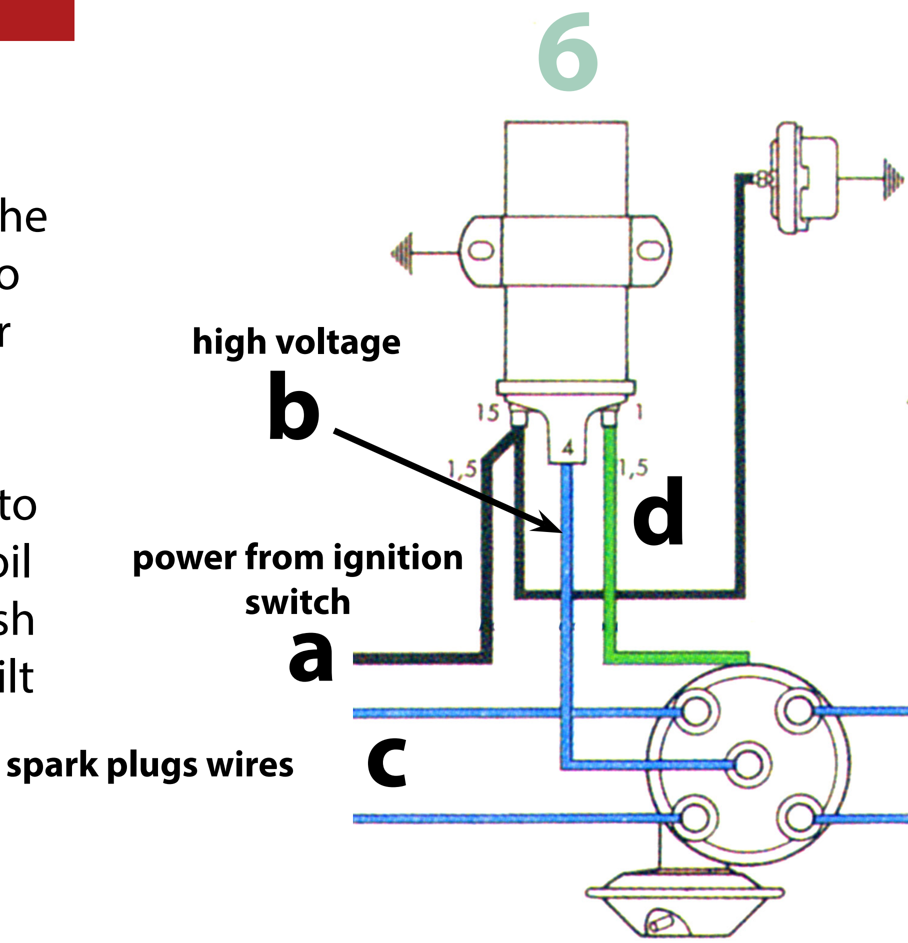



**the voltage regulator**

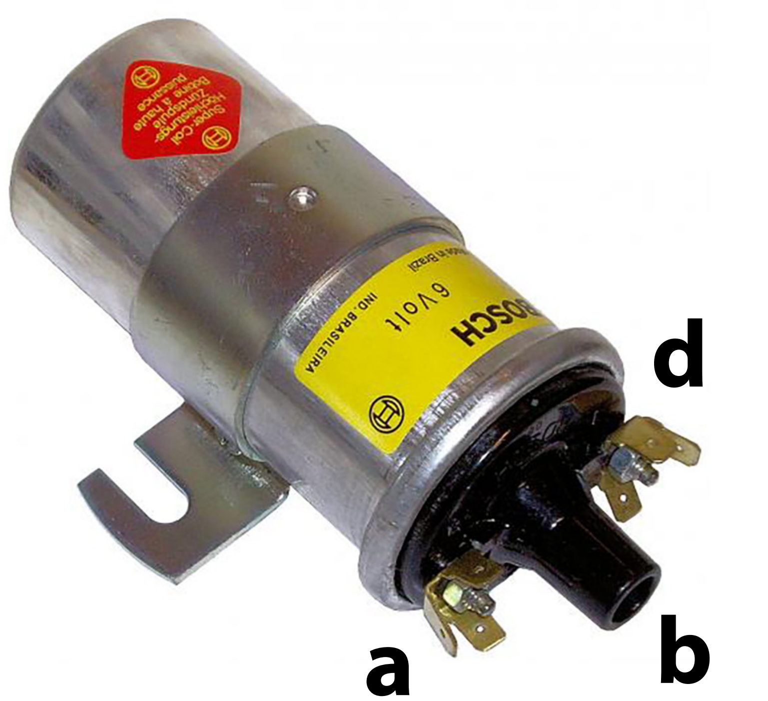


## the ignition coil

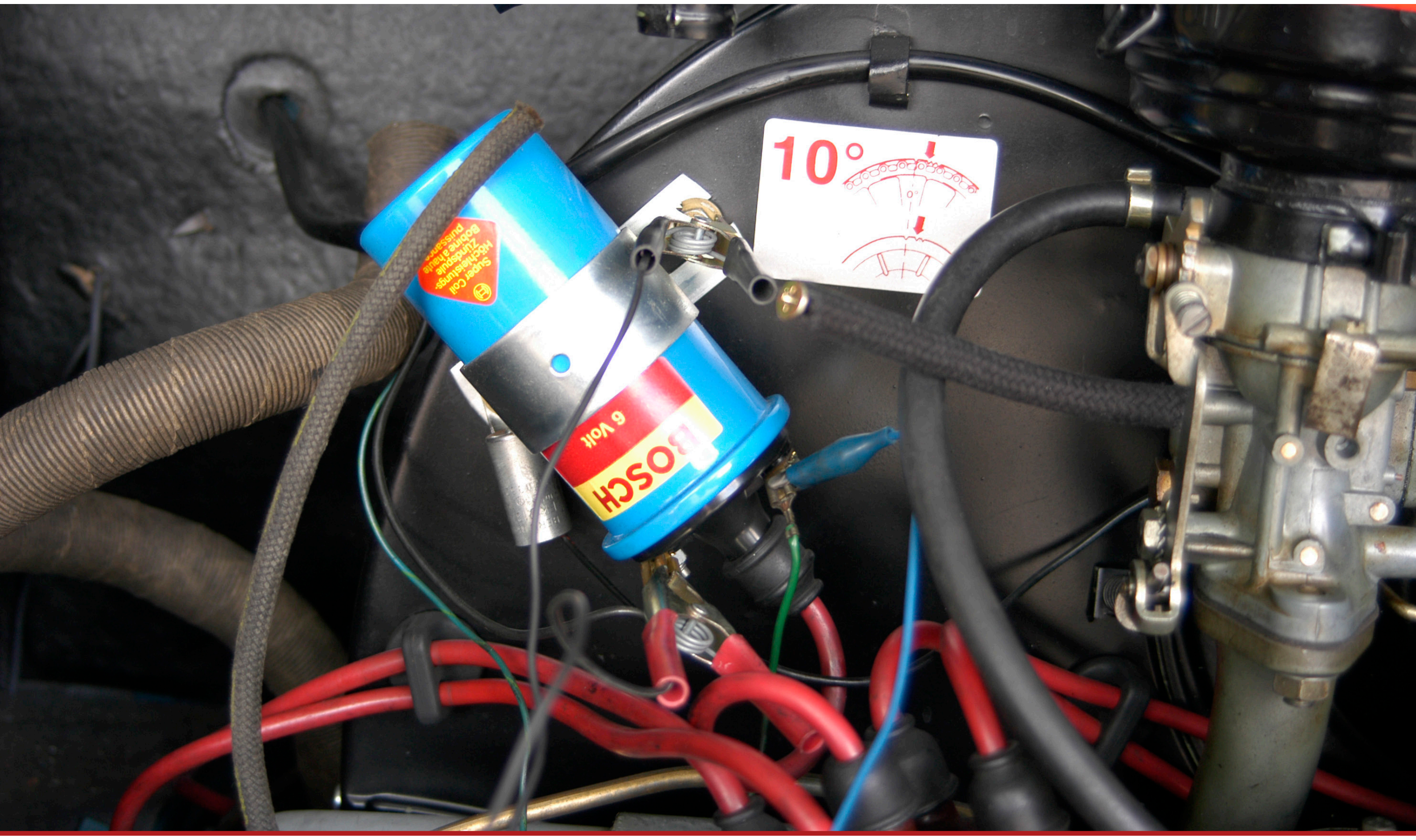
The ignition coil will receive electrical power when the ignition switch is turned on, the coil will send a high voltage to the distributor, the distributor will serve each spark plug at a time with a high voltage to produce the necessary spark to ignite the fuel mixture. The coil in our Volkswagen is from Bosh or Beru depending on the built year and type.




The input of the coil (terminal 15 or letter a in the scheme above) receives a low voltage of 6 V or 12 V from the ignition switch. The coil is an electrical device that transforms low voltage into high voltage (terminal 4 or letter b in the scheme above), this high voltage is fed into the distributor as mentioned before.

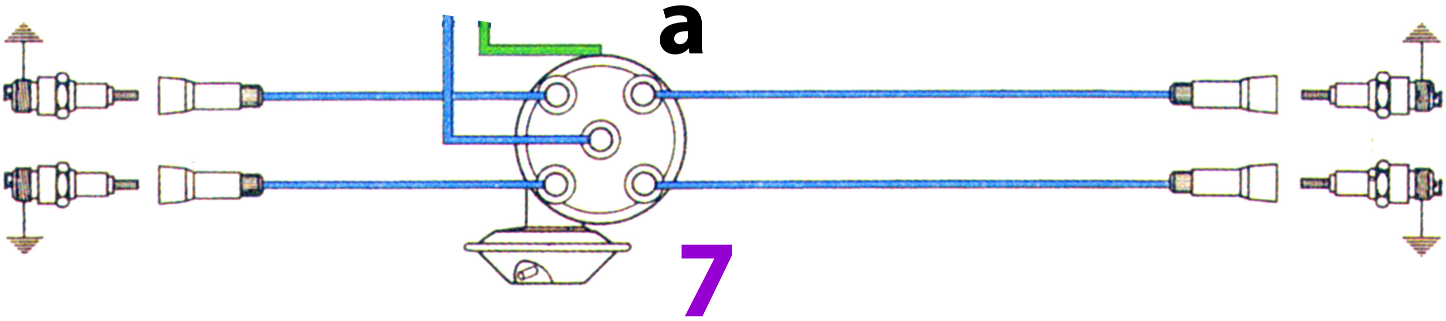


The ignition point in the distributor gives an electrical signal to the coil via the green cable (shown as letter d or terminal 1), the coil will generate a high voltage pulse that will be distributed to each spark plug. Terminal 15 powers the electrical choke, in case there is an electrical choke installed. Some older engines have a mechanical choke.



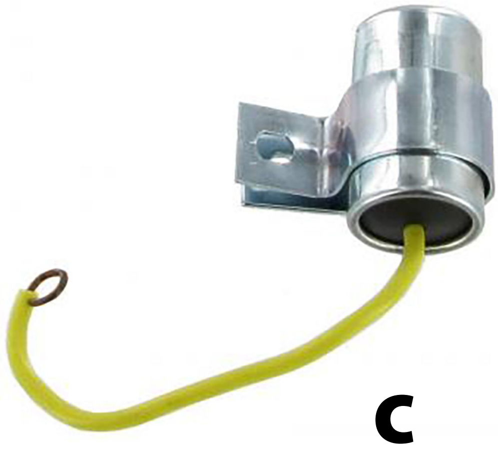
## the distributor

The ignition coil (b) generates a high voltage and sends it to the central high voltage connection of the distributor (a). The distributor is driven by the rotating crankshaft via a gear in the crankcase, the rotation is in sync with the movement of the push rods and the valves, the opening and the closing of the ignition point (c) follows the same rhythm. The distributor delivers the high voltage necessary to power the spark plugs.

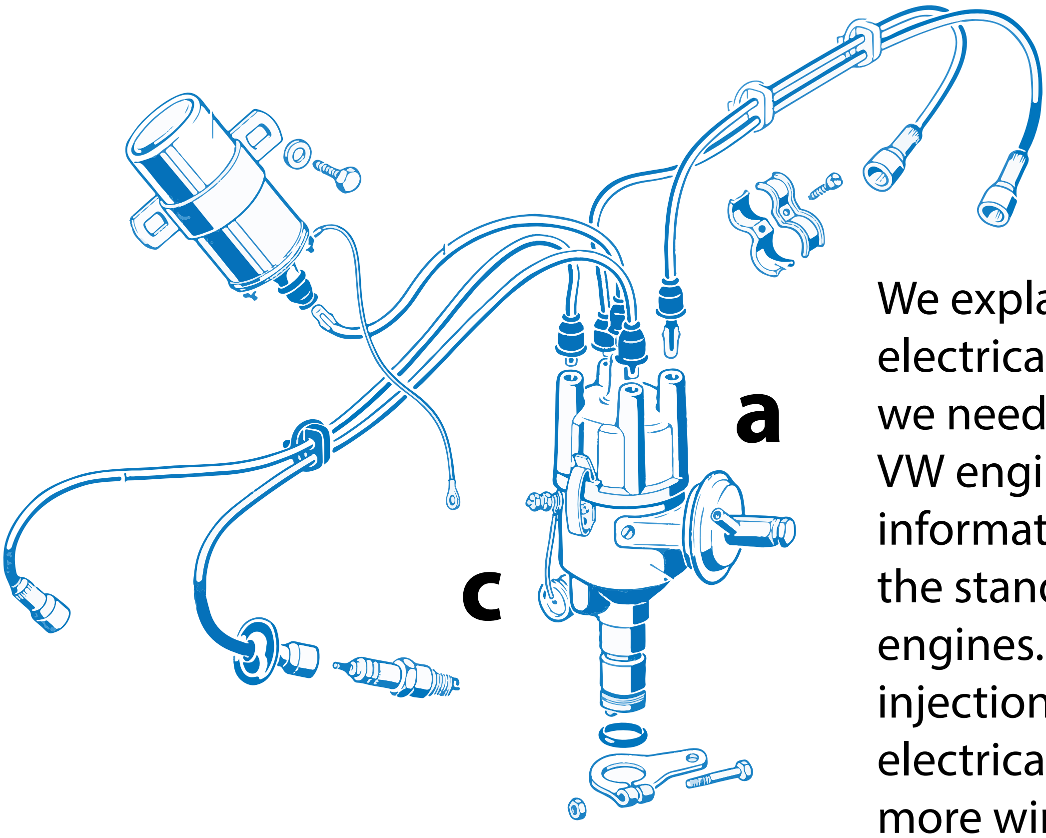






## the condenser



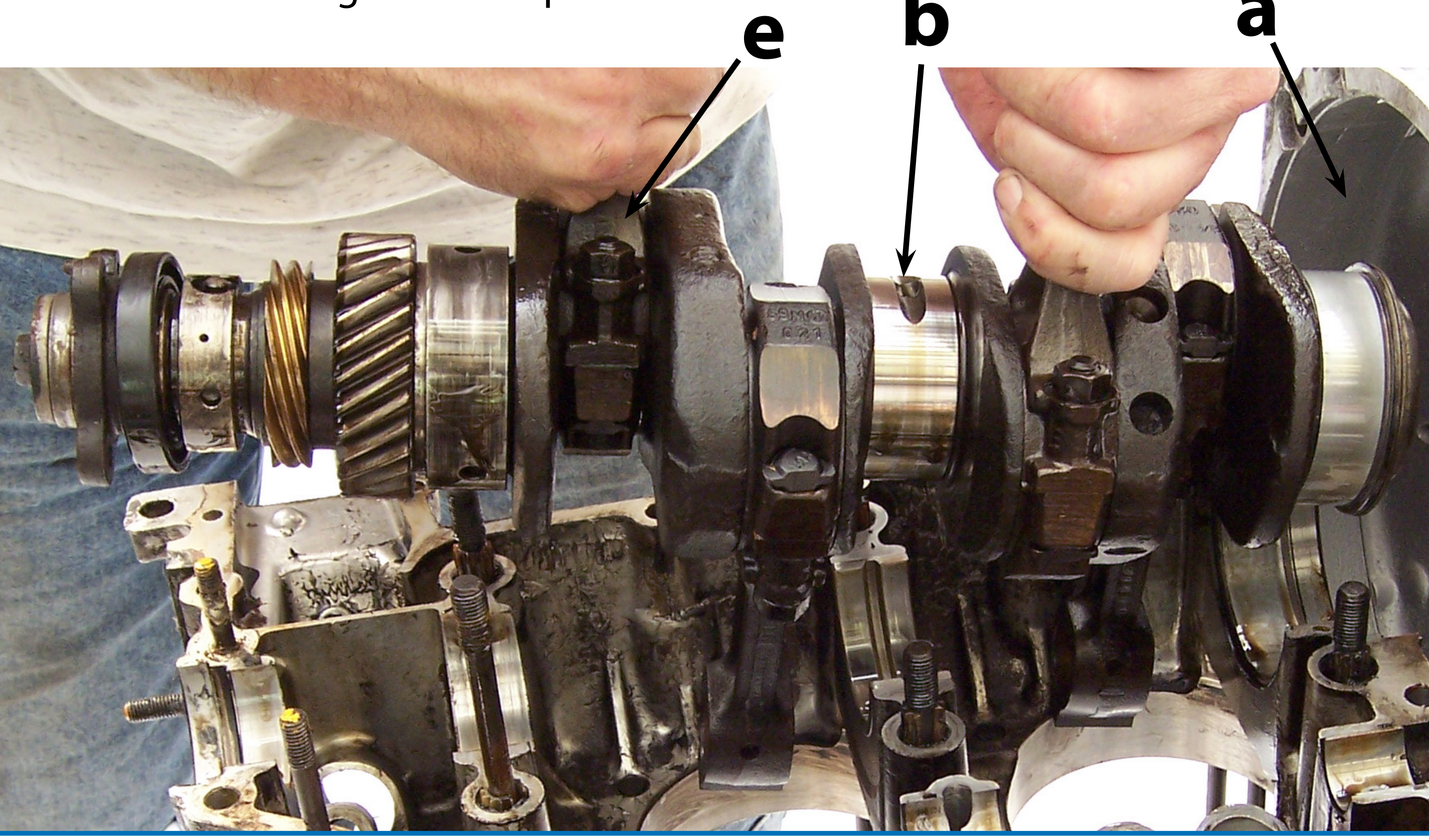

A very small part of the ignition circuit that one tend to forget, is the ignition condenser or capacitor (c). You won't find it on the electrical scheme, because it is a part of the distributor, and most of the time sold together as one product number. The condenser will remove the high current peak generated when the ignition point is opening or closing. Without this condenser, the ignition point would be damaged very rapidly. The condenser can tear down or be damaged in time and can be replaced independently from the distributor.



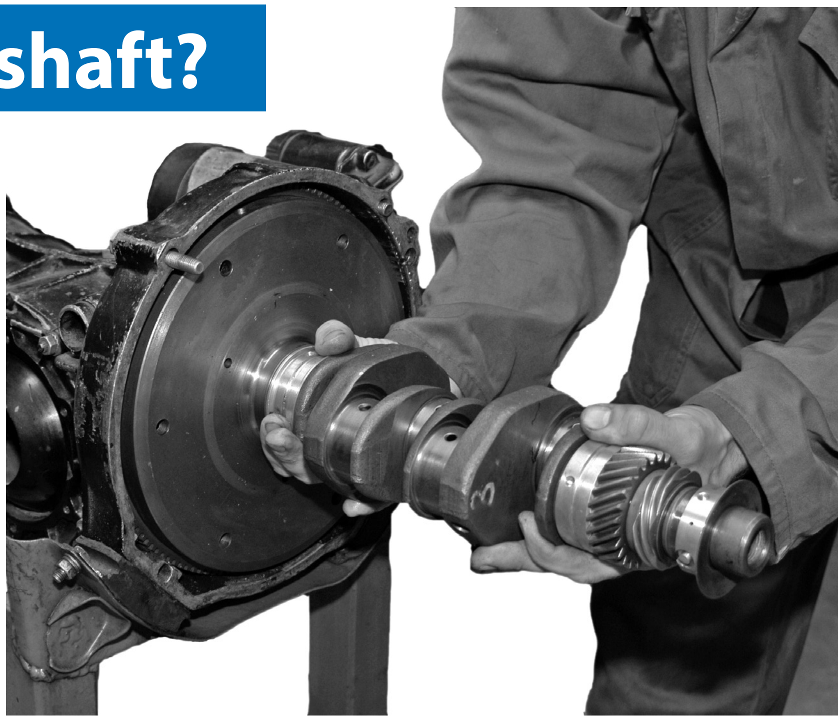

We explained the 7 basic electrical circuit components we need to have our VW engine running. This information is accurate for the standard carburetor engines. If you have a fuel injection engine then more electrical components and more wiring will be necessary to make it work.

## the crankshaft

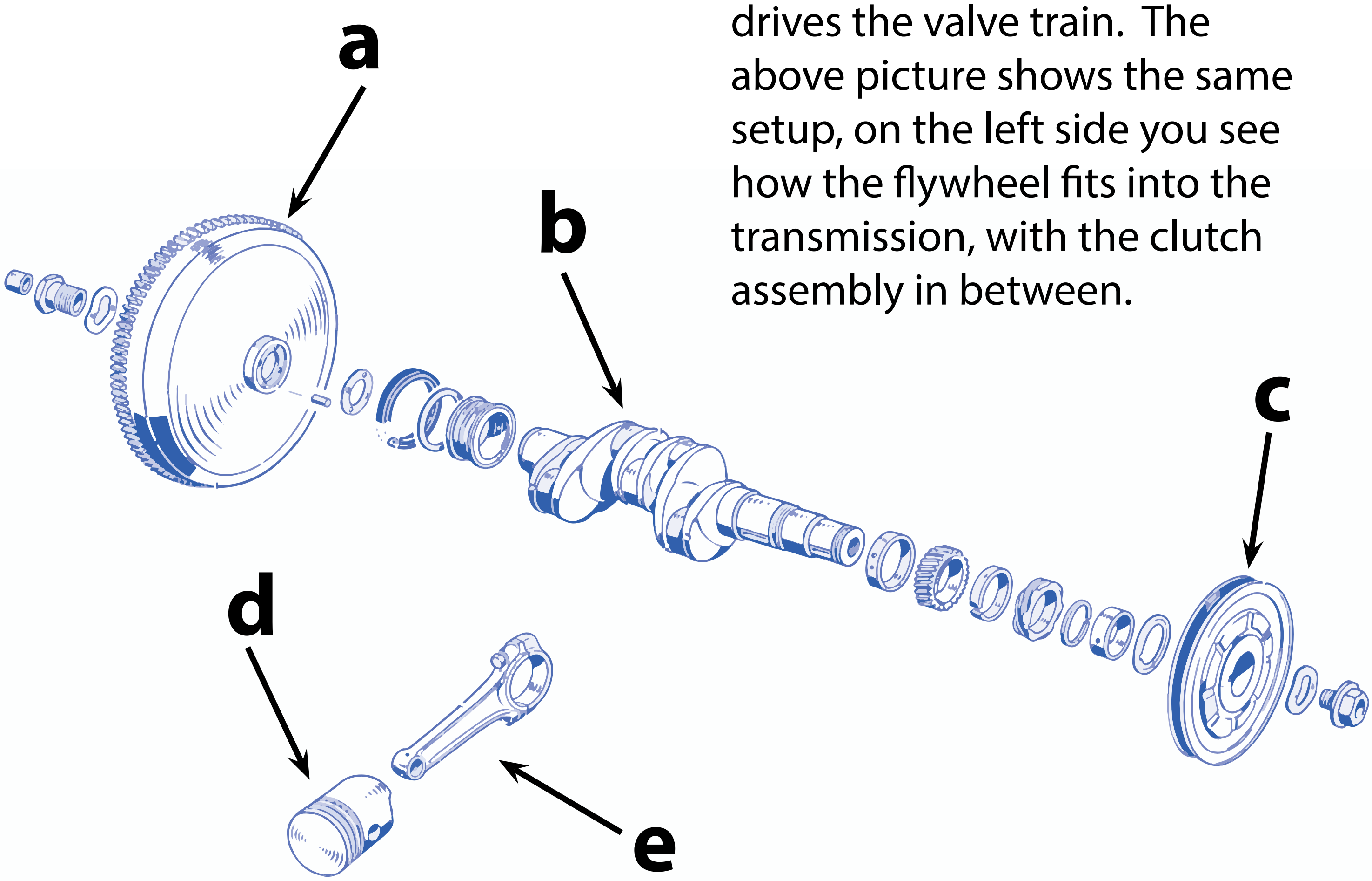
The crankshaft is te backbone of the engine. All the engine components spin around this crucial mechanical part. Its strength and performance characteristics are essential for a reliable engine. Especially if the engine needs to push a heavy Volkswagen Bus or when the engine is tuned for high performance. We will look into the design of the VW crankshafts and we will investigate which problems the pioneer engineers from Volkswagen have encountered and how they solved these problems. How they adapted the crankshaft to fit into bigger and more powerful engines. Below you can see a crankshaft (b) with connecting rods (e) dismantled during a complete engine overhaul. On the right side of this picture, you will recognize the flywheel (a).



## where is the crankshaft?



We have drawn the flywheel (a) and the crankshaft below (b). On the right side is the crankshaft pulley (c). Everything rotates around the crankshaft, the pistons (d) are driven by the connecting rods (e), the crankshaft also drives the fuel pump, the distributor and the camshaft, the camshaft drives the valve train. The above picture shows the same setup, on the left side you see how the flywheel fits into the transmission, with the clutch assembly in between.



## crankshaft specs

The crankshaft specifications are relatively simple: be as strong, stiff and robust as possible at the lowest cost possible. Strength however has many aspects: tensile strength and hardness are part of it. Extreme strength usually goes along with high brittleness: something is very hard, but a relatively small blow in the wrong direction and the part shatters in many pieces. Very high strength can also go along with low fatigue resistance. Not something you'd want in the vibration rich environment of a crankcase.

A crankshaft does not just need to be very stiff, but also very 'tough': a small amount of deformation of the crankshaft has to be possible without losing its shape permanently (good elasticity) , many cycles of deformation without breaking (fatigue resistance). The crankcase manufacturer can work with:

**1. Composition**
**2. Manufacturing**
**3. Design**

**Chromoly (Crm-Mo) crankshaft**



## 1. composition

The cheapest material to manufacture crankshafts in large numbers, is cast iron. All types of iron that are being used for crankshaft manufacturing are however alloys. The most common and therefore most important part of these alloys is carbon. Therefore these alloys are commonly called carbon-steel alloys, all stock VW flat four crankshafts are made from this material.

Other elements that are commonly used to enhance the so dearly wanted 'toughness', are chrome and molybdenum. Crankshafts with these additions in the steel are then called 'Chro-Mo(ly)' cranks. The material specification of chro-mo cranks are usually designated as 4130 or 4340 (4340 being the stronger and slightly more expensive alloy).

## 2. manufacturing

The way a crankshaft is manufactured is the second defining property. There are cast crankshafts and forged crankshafts, and some mixed manufacturing processes.

### *Cast crankshaft*

The hot liquid (carbon) steel is poured in a mold at environmental pressure. The mold is a little larger then it needs to be so the crankshaft needs machining of the journals (turning, polishing and hardening) afterwards and then the new crank is ready for action!

*The crankshaft is the most charged piece of equipment in a combustion engine. It needs to follow strict specifications concerning strength and elasticity. The force the pistons develop via the connecting rods can go up to thousand ton and more. A forged crankshaft (picture on the right side) can resist these forces much easier than the cast crankshafts (picture on the left side).*



## *Forged crankshaft*

With forged cranks however, the hot liquid steel is formed/ pushed into a cylinder shaped mold, after which the true forging process takes place; several tons of pressure put an enormous force onto the mold. You need to realize that (chro-mo) steel molecules are not perfectly round, but stretched. The huge pressure will force the hot steel to align according to the shape of the mold. During the next step, the raw piece of forged steel cools off and gets its final machining and surface hardening done.
You understand now that forged crankshafts are more expensive to manufacture because of the more complex manufacturing process en the expensive manufacturing equipment needed.

There are additional ways to manufacture a crankshaft, processes that you may describe as a mix of forged and cast: the 'billet' crankshafts and the original Volkswagen crankshaft!

## *Billet Chro-Mo crankshaft*

A 'billet' Chro-Mo crankshaft is made from a forged piece of metal (Chro-Mo alloys are used most of the time, the alloy strength is receives a number depending on the strength of the alloy, the higher the number the stronger, e.g. 4140 of 4340), the forged piece will not be shaped under pressure. The billet crankshaft is forged in a cylindrical shape and then get fully machined to the final shape using (automated) CNC equipment.

## *Surface hardening*

One of the (extra) manufacturing processes known to build a crankshaft is surface hardening. the genuine Volkswagen crankshaft received this type of treatment. It is interesting to know that when you have your crankshaft grinded for a second time, to the next undersize, you need to harden your crankshaft so to have the same hardness and strength Volkswagen intended to give your engine, nitriding surface hardening is very common. Surface hardening will improve the lifetime of your engine (less wear). You will understand the concept that a very small piece of hard but fragile metal will strengthen once it receives a very hard outer layer after surface hardening. This surface hardening explains, for a part at least, the longevity and legendary reliability of our Volkswagen Beetle I guess.



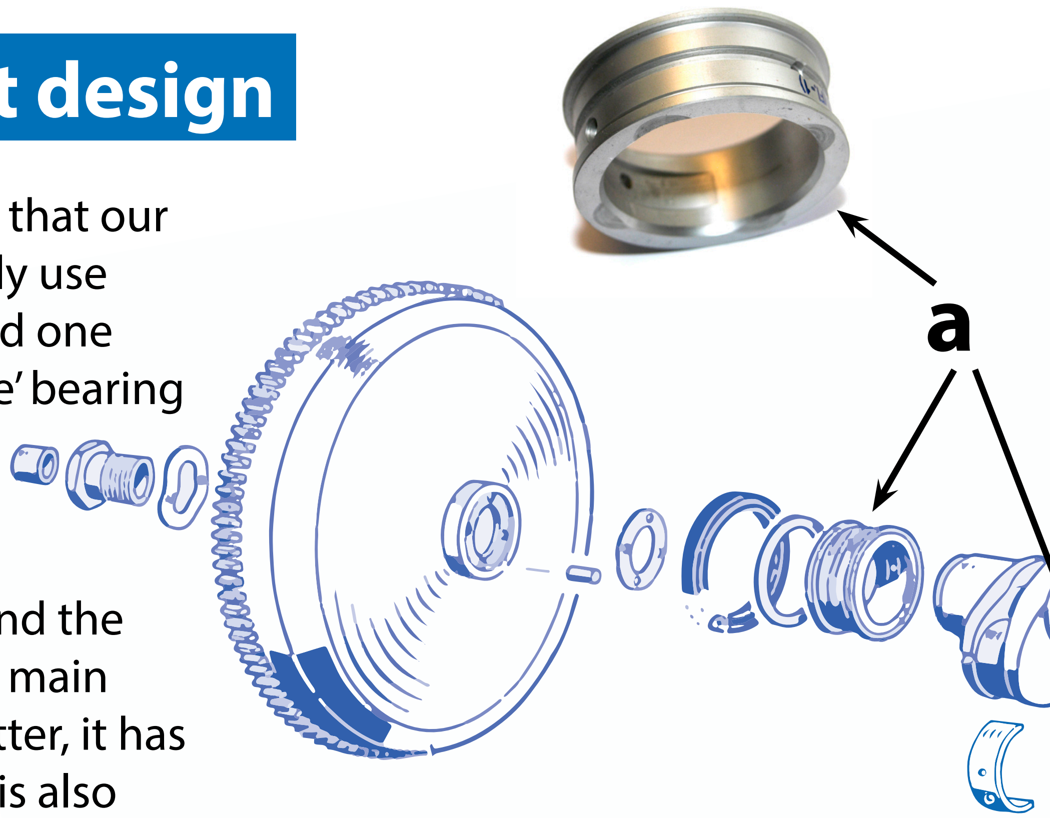
## *The Volkswagen crankshaft*

The Volkswagen crankshaft is a special case anyway. One will call it a cast crankshaft, another will call it forged. Both are right really; the original Volkswagen crankshafts are manufactured using a rather basic cast iron piece of material, which is easy to melt. This basic cast iron is forged under pressure though, the chro-mo forged crankshaft are forged under low pressure which makes it a more affordable process.

You could call the Volkswagen crankshaft a “low pressure forged cast crankshaft. But, we all now that what was produced in  the Volkswagen factory was of a high standard. The genuine Volkswagen crankshaft was built to last, we all experienced that.

Below, you see an original crankshaft for the Volkswagen Polo from 1982 through 1994, the VW number or O.E.M. number is 031105021AC.

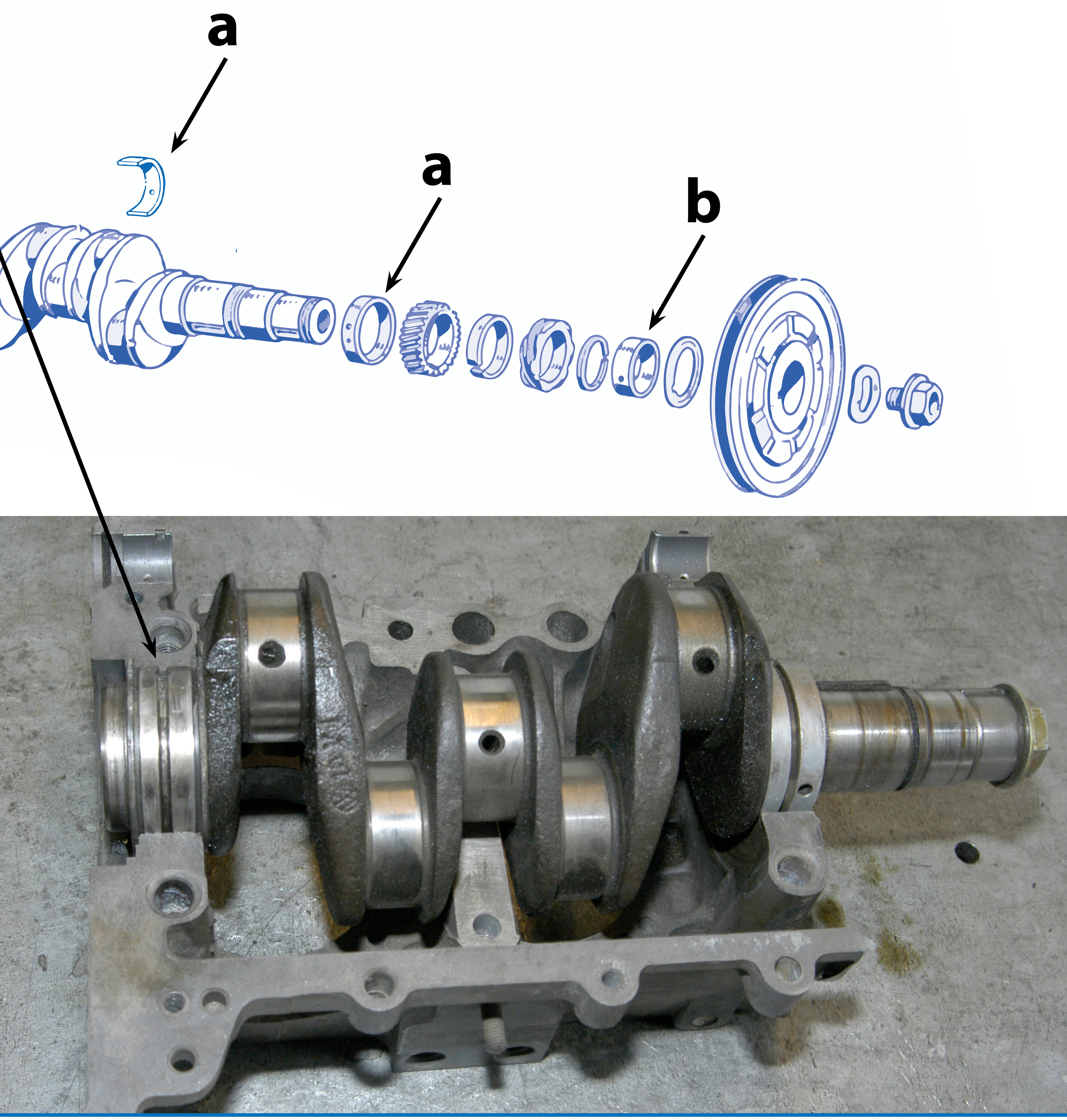
## 3. crankshaft design




It is pretty well known that our VW flat four cranks only use 3 main bearings (a) and one smaller diameter 'nose' bearing (b) to support the forces that act on the front pulley which drives the fan and the generator. Although 5 main bearings would be better, it has been proven that this is also possible in the same amount of space (e.g. Subaru). In the 1930's, when the VW engine was designed, other realities needed to be taken into account such as available bearing quality and machining costs. In those days a wider bearing surface (feasible when you only have 3 main bearings) gave better service live as the forces are more spread out because the contact surface is wider. As our VW engines know moderate rpm's, a simple crank with only 3 main bearings was the right design.

At higher rpm's and bigger loads (more stroke and/or larger bore with bigger engines), the torsional stress is of course higher with a 3 main bearing crank over a crank with 5 mains, where each connecting rod is supported by a main bearing left and right. To make matters even worse for our original VW crank, its crank throws don't have extra mass on the opposite side to counter the weight of the rod and piston. We discuss counterweighting later on.



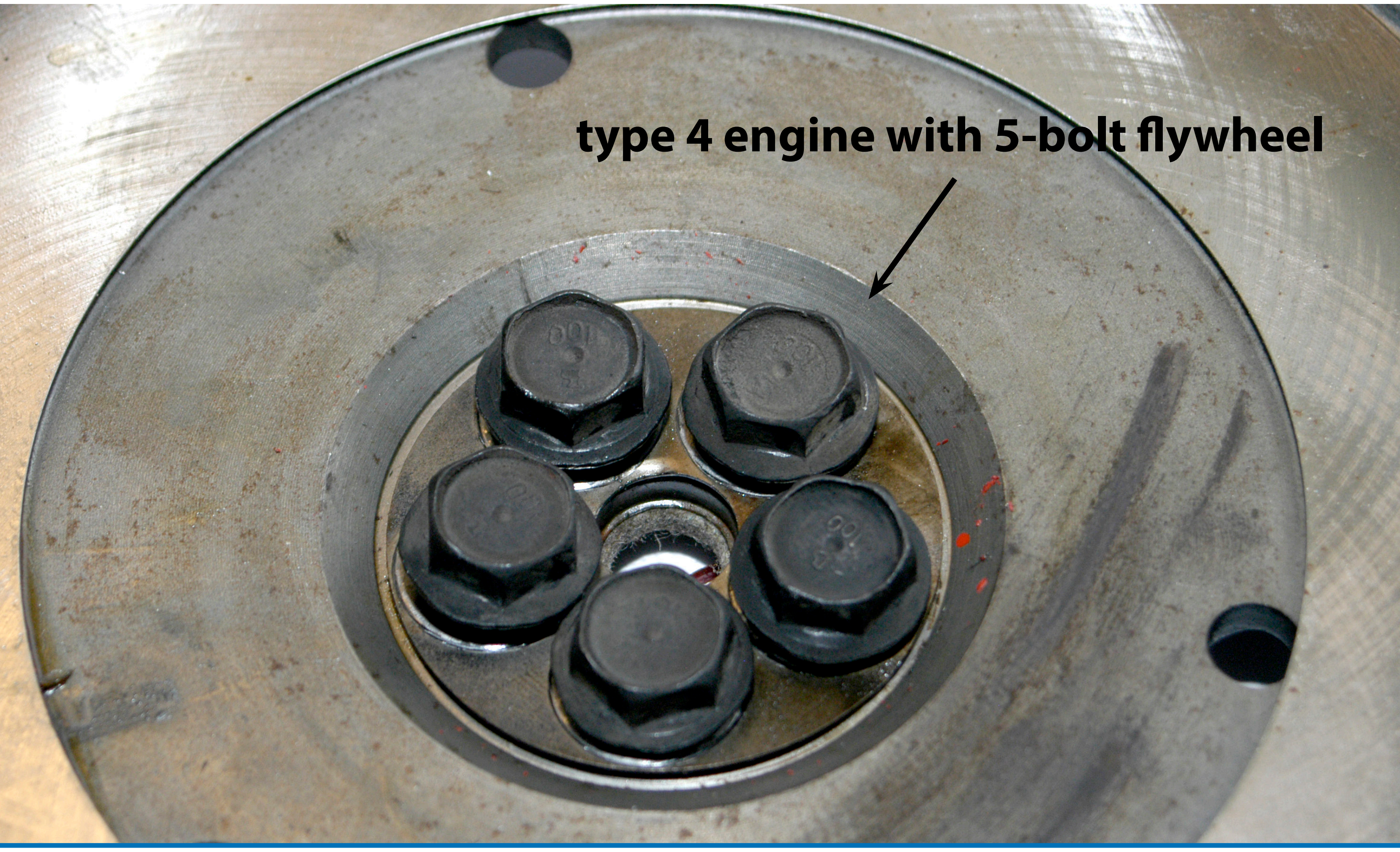

a
a
b

## *Bearing diameter, stroke and stiffness*

The history of VW 4 cylinder boxer engine design can be categorized into three evolutionary design stages. The crankcases or cylinder heads are distinct for the three stages of evolution, the development of the crankshaft also makes a clear statement on how VW responded to the engines getting bigger, stronger while reliability was improving:

**1. 30 hp 'type 1'**
**2. 34-40-44-50 hp 'type 1-3'**
**3. 66-100 hp 'type 4'**

There was also a mixture due to the introduction of the water-cooled engines at VW. Because of the water-cooling engines introduction, the larger space between the cylinders of the type 4 engine (for extra





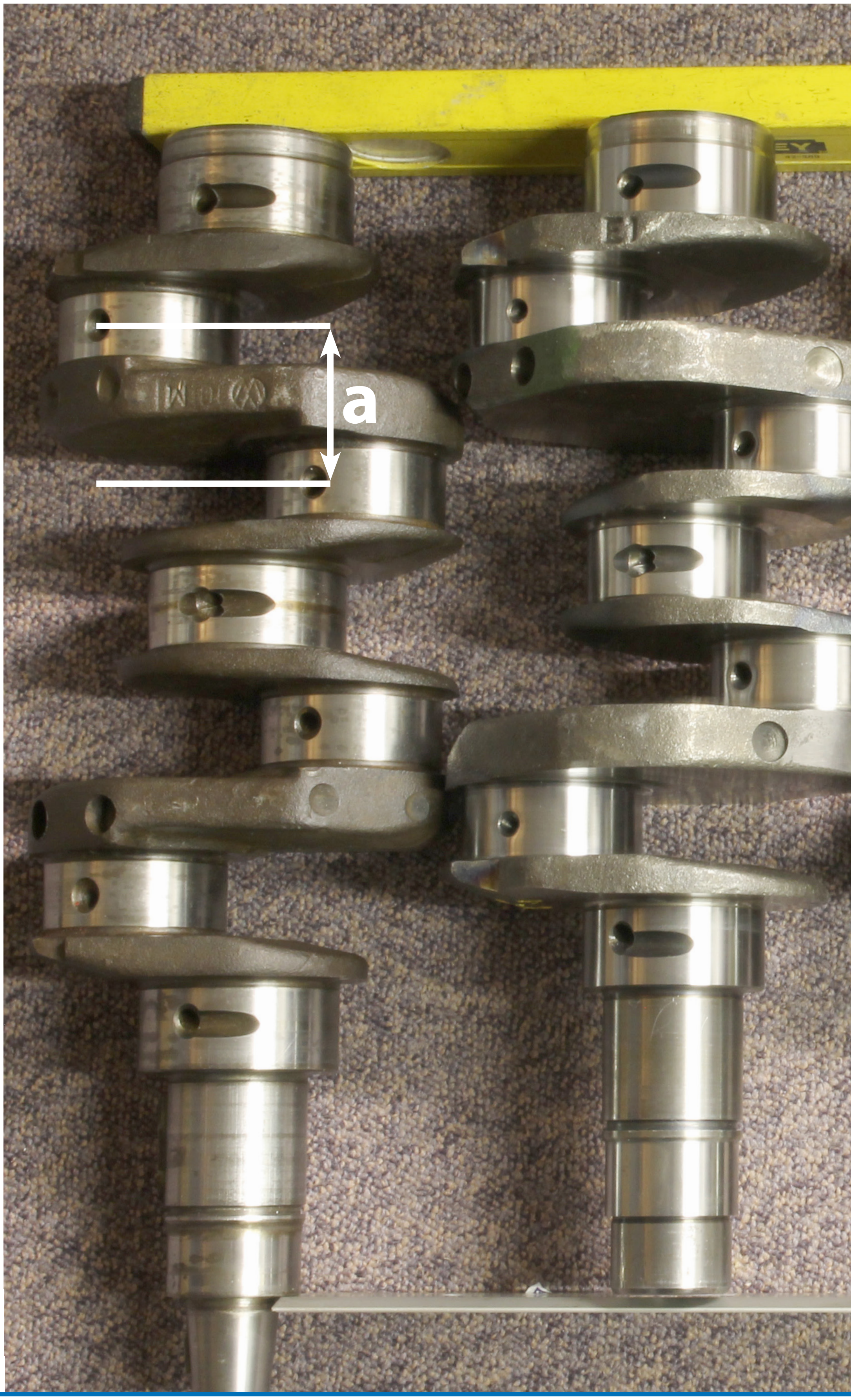

air-cooling) wasn't necessary anymore, the shorter cylinder spacing distance of the type 1 was sufficient again, even with a larger stock bore (94 mm).The waterboxer did retain the larger diameter main bearing journals of the type 4 engine however, so the stronger 5-bolt flywheel (picture bottom left, below you see the typical 1-bolt flywheel) could also be kept. The result was the "Wasserboxer", or water-cooled boxer engine:

**4. 68-112pk Wasserboxer (WBX)**

You'll read about the engine types and codes in this edition, article #4 talks about all VW engine types including the "Wasserboxer" WBX.

# #06 Engine

The market required stronger engines, engine size grew, partly by increasing stroke and partly by increasing the bore size. A bigger bore made it eventually necessary that the cylinder center lines increased, so enough cooling air could flow between the cylinders on each cylinder bank. A larger cylinder center line also increased the crankshaft length (a). The evolutionary steps become clear when you study the crankshaft used in each period. You can see these increased crankshaft lengths clearly in the picture on the right.







from left to right: type 4 1700 cc - WBX 2100 cc - 1600 cc - 1200 cc - 30 hp

The table below shows how the main journal diameter and the rod journal diameters are linked to the crankshaft stroke of the existing Volkswagen and Porsche 4-cylinder boxer push rod engines, the WBX crankshaft and a few example of tuning cranks.

We start our comparison with the start of the 'evolution' of the VW engine; the 30/36 hp crank. The diameter of the main bearing diameter as well as the rod journals is just 50 mm. These cranks were snapping in half now and then, the first Volkswagen professionals were used to see broken crankshafts in their workshop.

| Crankshafts | Engine type | Stroke [mm] | Main bearing diameter [mm] | Connecting rod diameter [mm] |
|---|---|---|---|---|
| original-VW | 30 hp | 64 | 50 | 50 |
| original-VW | 1200 type 1 | 64 | 55 | 55 |
| original-VW | 1.3-1.6 type 1 | 69 | 55 | 55 |
| original-VW | 1700 type 4 | 66 | 60 | 55 |
| original-VW | 2000 type 4 | 71 | 60 | 50 |
| original-VW | 1.9 WBX | 69 | 60 | 55 |
| original-VW | 2.1 WBX | 76 | 60 | 55 |
| original-Porsche | Porsche 356 A/B | 74 | 50 | 53 |
| original-Porsche | Porsche 356 C | 74 | 55 | 53 |
| tuning | Tuning 30 hp Okrasa | 69.5 | 50 | 50 |
| tuning | Tuning type 1 | 84 | 55 | 50.8 |
| tuning | Tuning T1, T4 mains | 84 | 60 | 50.8 |



# crankshaft basics

Volkswagen engineers must have been aware of this issue, the later 1200 cc engines as of 1960 were given a crankshaft with 55 mm main bearing diameter and rod journal diameter with equal 64 mm stroke. This resulted in an enormous jump in main-rod journal overlap (as can be seen in the table below) and crank breakages were greatly reduced. The confidence in the larger journals was so big, that some years later, an increase in stroke (to 69 mm) was introduced using the same 55 mm journals. Even with the increased stroke, the overlap was still bigger then it was on the 30/36 hp crankshaft.

| Overlap [mm] | Connecting rod bearing width (on crankshaft) | additional information/ securing crankshaft-flywheel |
|---|---|---|
| 18 | 22 mm | 1x central bolt M27, 4x 6mm pins/dowels |
| 23 | 24 mm | 1x central bolt M27, 4x 8mm pins/dowels |
| 20.5 | 23 mm | 1x central bolt M27, 4x 8mm pins/dowels |
| 24.5 | 26 mm | 5x M12 bolts, no dowels |
| 19.5 | 26 mm | 5x M12 bolts, no dowels |
| 23 | 23 mm | 5x M12 bolts, no dowels |
| 19.5 | 23 mm | 5x M12 bolts, no dowels |
| 14.5 | 22 mm | 1x central bolt M27, 8x 6mm pins/dowels |
| 17 | 22 mm | 1x central bolt M27, 8x 6mm pins/dowels |
| 15.25 | 22 mm | Chro-mo forged/billet, 8x 6 mm dowels |
| 10.9 | 23 mm | Chro-mo forged/billet, 8x 8 mm dowels |
| 13.4 | 23 mm | Chro-mo forged/billet, 8x 8 mm dowels |

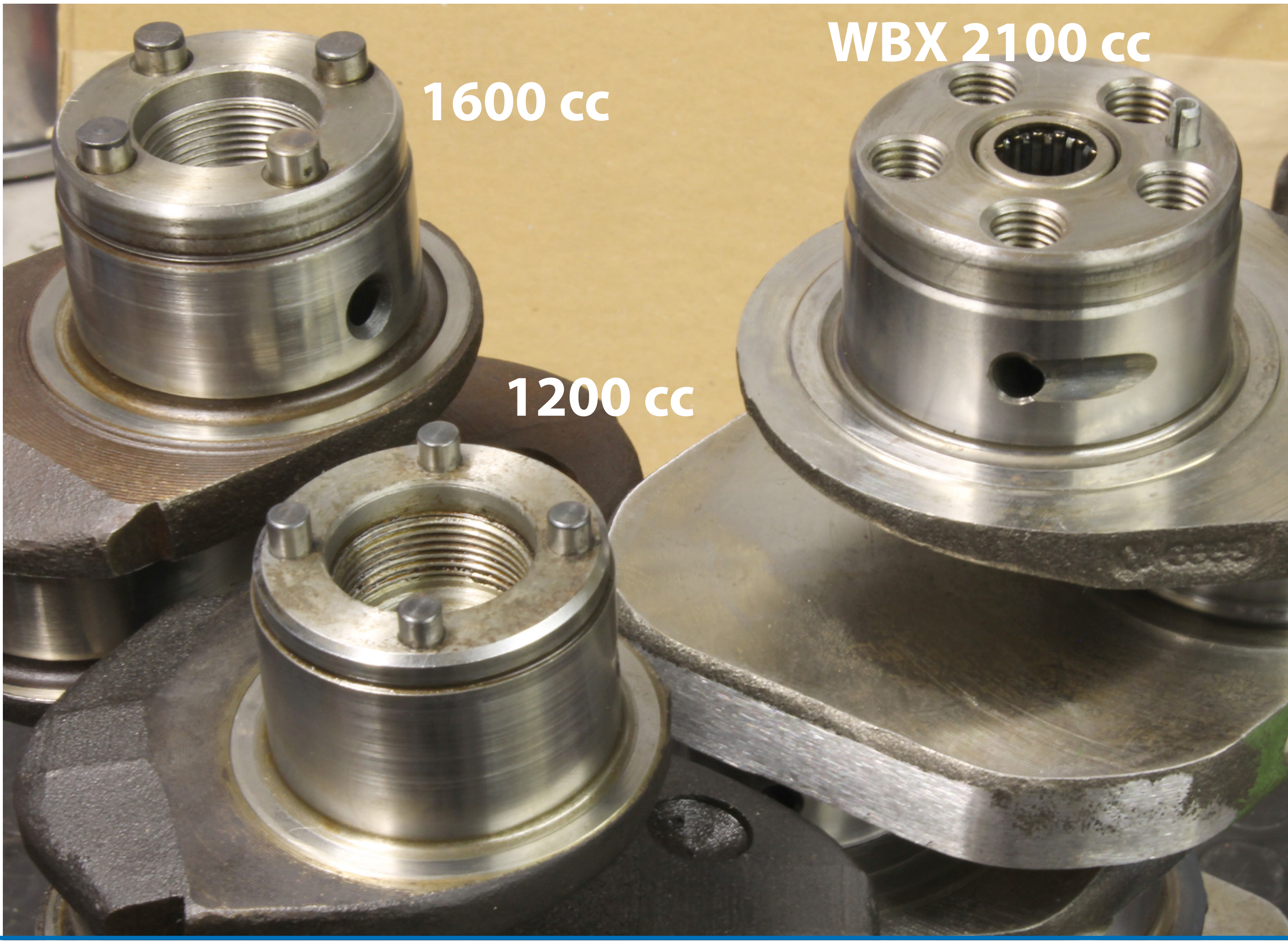

The 64 mm 1200 cc 34 hp crank-shafts had a tendency to break, not so often though as early cranks.  With the experience that Volkswagen had during the sixties, harmonic vibrations at low rpm were thought to be the root cause of this problem. To avoid these vibrations the crank shaft “cheek width” was increased (picture on the left), this resulted in the new 69 mm stroke cranks (no more tapered cheeks on the 69 mm crankshafts).

Another advantage of the later larger 55 mm main bearing diameter compared to the older 30/36 hp 50 mm journal size is the extra space this provided for stronger 8 mm dowels over the smaller 6 mm dowels of the older 30/36 hp 1200 crankshafts. In the picture on the right you can see these differences clearly .



Also visible in the picture below is the even larger (60 mm) diameter main bearing size of the type 4 and WBX crankshafts. 5 special M12 bolts are used now to secure the flywheel to the crank. The single dowel in the type 4/WBX crank is now used for orientation purposes only.

**Top: WBX 2100 cc flywheel side with needle roller bearing for the transmission.**
**Bottom: The difference in main journal diameters and flywheel to crank attachments with the 30/36 hp (below), 1600 type 1 (top left) and WBX 2100 cc (right) cranks.**

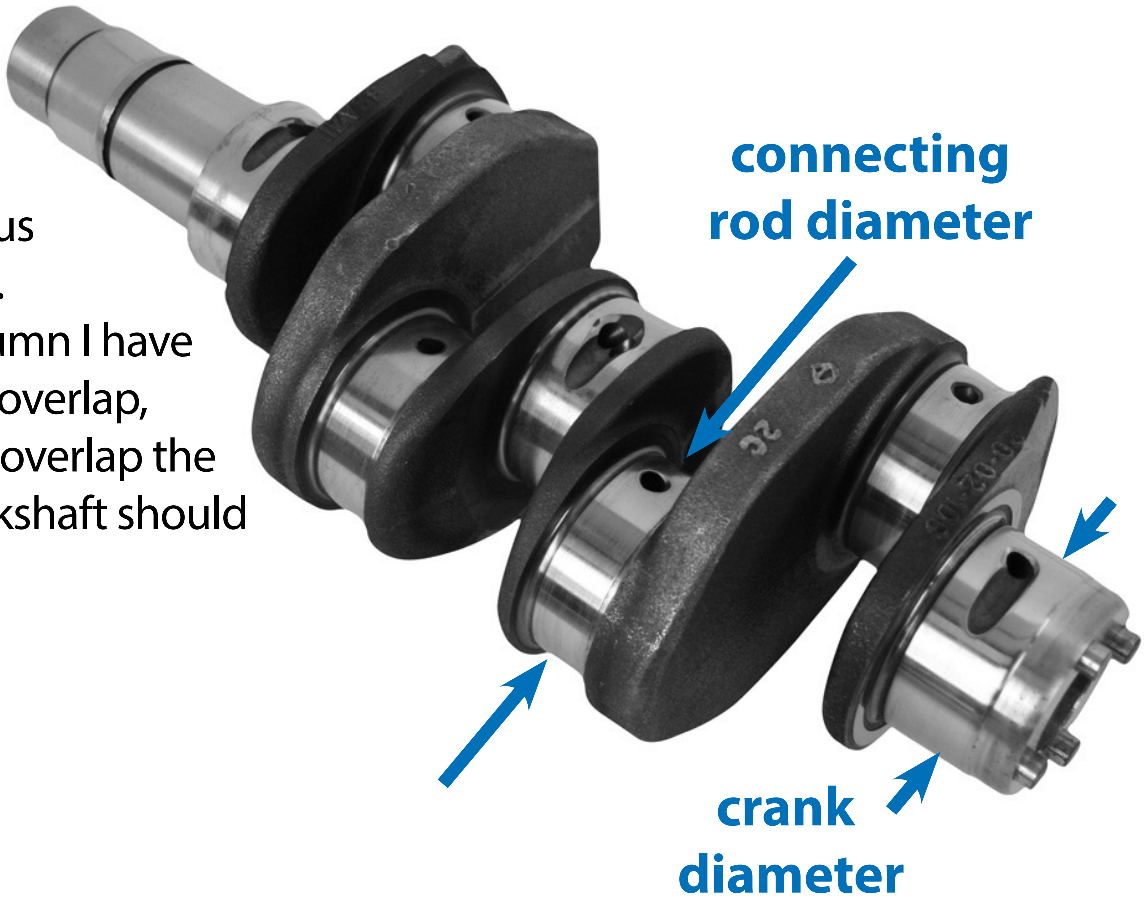


Most interesting in the listing of the crankshaft table is that Porsche basically made the same design choice as Volkswagen to meet the demand of ever increasing horsepower: the stronger and later Porsche 356C cranks also received 55 mm mains over the older 50 mm mains of the 356A (and some B models), using the same stroke!

The result was more overlap, hence a stiffer and thus stronger crank.
In the fifth column I have calculated the overlap, the higher the overlap the stiffer the crankshaft should behave.

## *Counterweights*

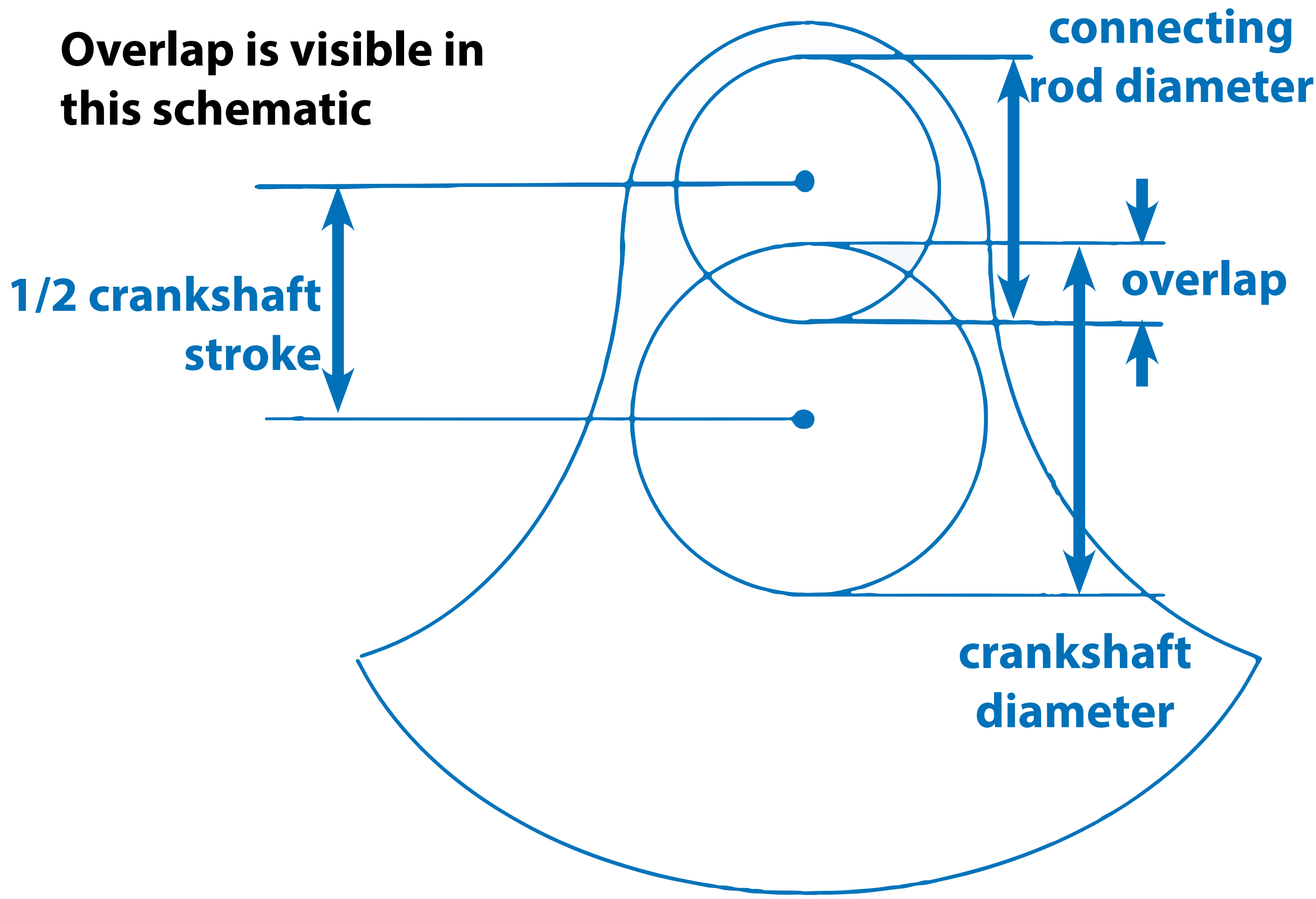
Engineers have added counterweights to the crankshaft to eliminate the torsion resulting from the lack of balance. These counterweights have become a very important design element to improve the performance of the engine. More about this later.



The biggest overlap in the table is the 1700/1800 cc crankshaft of the type 4 engine, but that was somewhat expected because of the very short stroke and large bearing sizes. Unexpected however (also to me) was the fact that the 1200 cc 34 hp crank is a close second place(!) together with the 1900 cc WBX crank (which was expected).

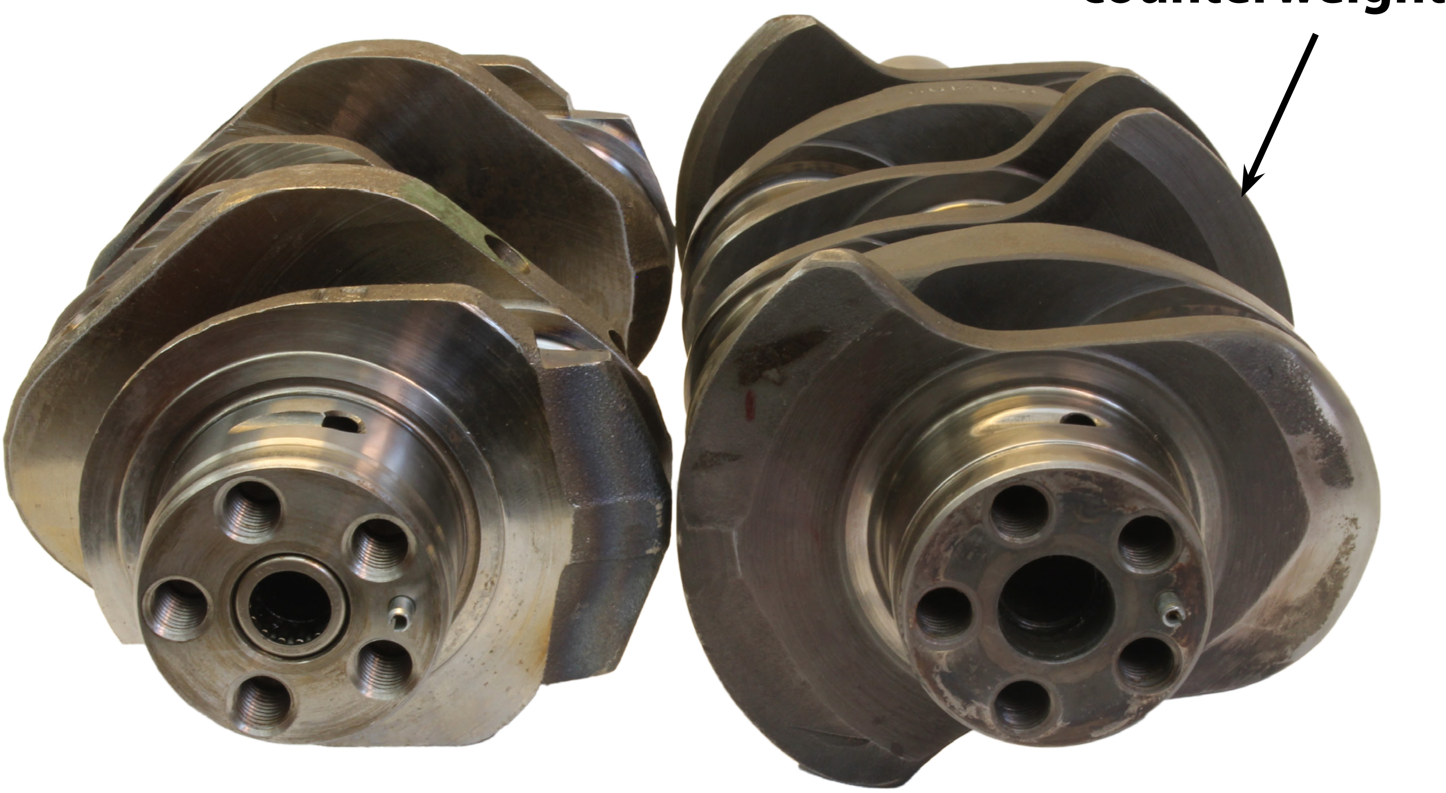
In the picture on the following page is another interesting design feature visible on the 2100 cc WBX crank (left one in the picture): additional material perpendicular to the stroke as a sort of counterweighting. VW found out by experience that this made the engine rotate and run more smoothly by eliminating harmonic vibrations.

**Overlap is visible in this schematic**



Why is stiffness so important? The crankshaft uses plain bearings for support. The lubrication oil film between the crank surface and the bearing is just a few hundreds of a millimeter or just a few thousands of an inch thick. If the crank twists just a tiny bit, the result is an immediate reduction of the oil film. Any crank will twist and bend a little, but between 'a little' and 'too much' is a fine line.

Crank stiffness is therefore very important to good bearing (and thus engine) life. Another problem that 'a little more than desired' twisting of the crank can cause is the fact that the piston will not be perfectly perpendicular to the cylinder bore anymore: this will result in a lesser sealing ability of the piston rings. Compression will then suffer under high stress, which is at higher loads/torque and/or rpm.




**exceptional location for the counter/balance weights on the stock 2100 cc WBX crank**

**more traditionally located counterweights on an Oettinger type 4 crank.**



The latter is not something you can measure, only stationary compression at cranking speed can be measured.

In other words: a crankshaft that is stiffer will result in a longer life span. Or from a tuning point of view: a stiffer crank will be able to endure more torque and mor horsepower. An extra advantage of a crank with larger main bearing diameter is the opportunity to use a stronger crank to flywheel connection: more contact area and more room for larger/more bolts and more or bigger dowels.

*author: Walter de Vette*

## conclusion

The conclusion should be pretty obvious by now: besides the sort or type of crankshaft material and manufacturing process (forging or not, type of hardening), both Porsche and Volkswagen thought that crank overlap is an important design criterium for a stronger crankshaft.

To sum up, the larger the overlap, the stronger the resulting crankshaft. Increasing main and rod diameter and keeping stroke low or moderate both help to keep cranks and (tuned) engine alive.

I hope this article provided some insight in the design and development of the air-cooled factory crankshafts and that this will help you make the right choices for your project.

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