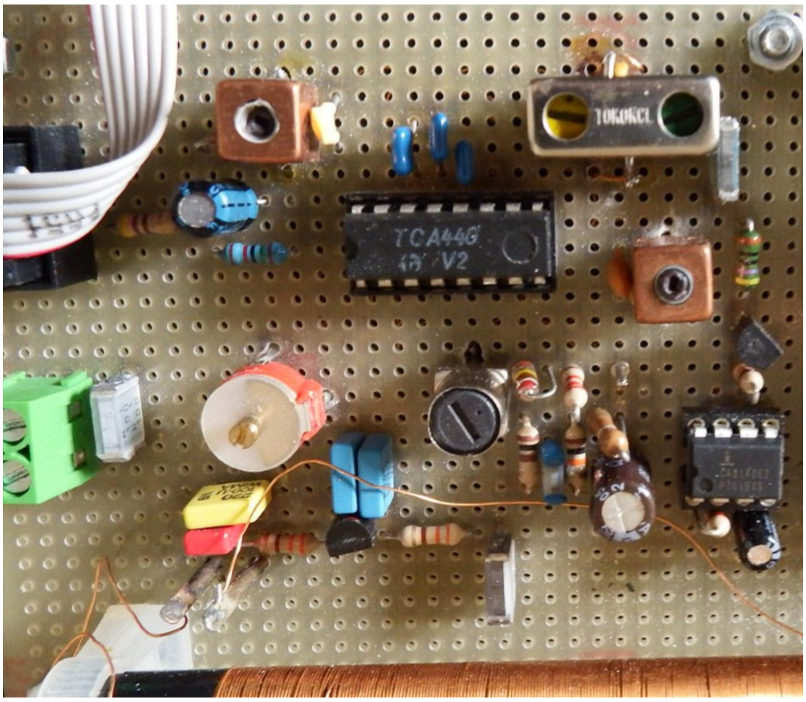
Applications of
AVR Single chip controllers AT90S, ATtiny, ATmega and ATxmega
**DCF77 clock with ATmega16**


# A DCF77 AM Superhet Receiver

## 1 What is DCF77?



DCF77 is a transmitter in the VLW band with a frequency of 77.5 kHz at 50 kW, see Wikipedia for more details. It is located at Mainflingen in mid-west Germany (near Hanau and Frankfurt) and transmits the "official" time in Germany by

- reducing its amplitude down to 15% at the start of each second for a duration of either 100 or 200 milliseconds, by that encoding zeros and ones bits,
- a missing 59th bit that signals the end of a minute and the start of the next amplitude reduction as the begin of the next minute,
- encoding time and date information as well as several parity bits in those 59 bits.

With that information a clock can be synchronized to display exact time and date.

## 2 Why a home-brewed receiver for DCF77?

Besides that it is fun to build an own receiver for those Very-Long-Wave signals there are some rational reasons to do that:

1. Contrary to commercially available DCF77 receiver modules this receiver has a very high amplification of the signal and so can receive the signal over a very large distance, beyond the 2,000 km limit that DCF77 has been designed for. Two amplification regulators reduce the amplification level in the near-field so that it works well in my 30 km distance to DCF77 (with very small amplification) as well as in the far-field (at a very high amplification level). Even enclosed within an iron cookie box the AM receiver still works fine.
2. Several LC resonators and a ceramic filter increase the immunity to noise. Noise in this frequency range comes from switching regulators (e.g. power supply devices, switched lamps, etc.) that can have very large amplitudes and can tamp any receiver that has less selectivity. E. g. my energy-saving lamp in my shag or the power supply of my laptop produces so much noise that any commercially available DCF receiver module in less than 2 m distance is overwhelmed and produces nothing.
3. Just because you can do it by yourself: receiving VLW waves via a ferrite rod anten-

na, decoupling of this already very selective LC resonator with an FET, preamplifying this signal in a regulated HF amplifier, mixing the HF with a (77.5+455) = 532.5 kHz oscillator, selecting the 455 kHz mixer result with a High-Performance IF filter, feeding this into a high-gain regulated amplifier, rectification of the resulting IF and to filter the amplitude in an RC filter to detect the duration of the second's amplitude reduction can be done within a single chip and some external components.

But why use such an old IC TCA440 instead of more later ones?

- Because more modern IC combine AM and FM in one chip, but the FM part is useless here. The same with audio amplifiers on board: useless for a DCF77 receiver.
- Because more modern ICs only offer a very small part of the overall amplification of a TCA440, they are designed to cover only very large signal strengths with that low amplification factors.
- Other commercially available DCF77 receivers are of the direct amplification type and filtering resonators (of the ceramic or crystal type) for 77.5 kHz are rarely available, if at all. By mixing the signal High-Performance IF filters can be used to increase the selectivity. And the TCA440 has anything on board that is necessary for that.
- To increase the selectivity of more modern AM receiver ICs a large number of external components would be necessary. The TCA440 has anything on board for that.

# 2 Schematic of the receiver

On the next page is the electrical scheme of the receiver.

The VLW signals are received with a 10 cm ferrite rod with enameled copper wire. The capacitors are to be selected for the measured impedance of the rod (see below) and a trim capacitor of 90 pF allows for adjusting the antenna resonator for a maximum signal.

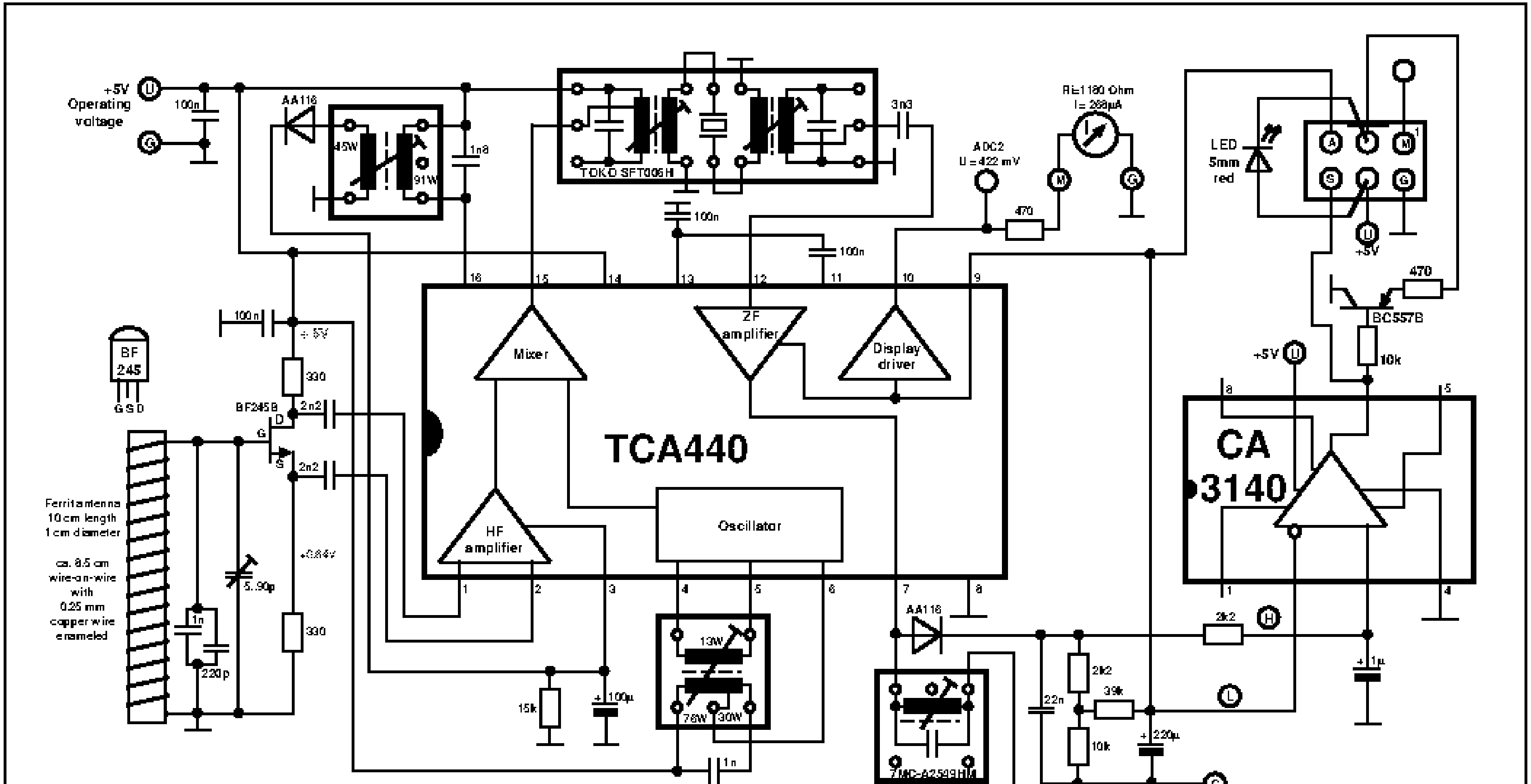
The N channel FET BF245 (any other N channel type can be used) decouples the resonator and generates a symmetrical (differential) signal for the HF input of the TCA440, which is coupled to the input with two capacitors.

The HF amplifier of the TCA440 is connected with pin 16, where an LC filter with a Germanium diode and a 15 k resistor and a 100 µF electrolytic capacitor produces a regulator voltage for the gain of the HF amplifier. This regulator voltage controls the HF amplification in the near-field. The LC filter is self-made on a Neosid coil body 05 9539 00 (9.5 µH).

The LC resonator on pins 4, 5 and 6 of the TCA440 generates an oscillator signal of 532.5 kHz to be fed to the mixer. This LC coil is also self-made and produces a stable oscillator signal.

The output of the mixer on pin 15 is fed into a commercial SFT006H IF filter consisting of a combination of two LC resonators and a 455 kHz ceramic resonator. The filtered signal enters the IF amplifier on pin 12 of the TCA440.

IF amplifier output on pin 7 of the TCA440 is filtered with a commercially available 455 kHz resonator and rectified with a germanium diode. A RC filter network filters the fast seconds pulses, to be fed to the positive input of the CA3140 FET opamp, and averages those very slowly to be fed to the negative input pin of CA3140. The slow average voltage is also fed to the IF regulator voltage input on pin 9 of the TCA440 and to the display driver input. The display driver output voltage drives a 288 µV instrument and can be read on an AD converter input pin of the controller.



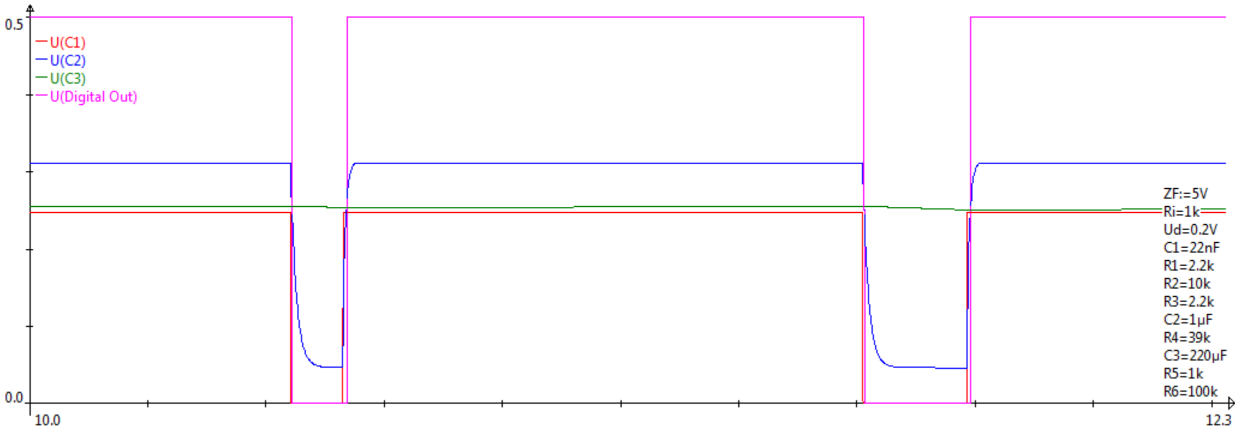

**DCF77-Superhet-Receiver**
**(C) 2018 by DG4FAC**

The output of the opamp CA3140 drives a transistorized-driven LED and provides the seconds pulses for the controller readout and DCF77 signal analysis. The output signal follows the amplitude of DCF77: high amplitude = high, low amplitude = low. A good controller software should be able to detect the signal no matter if it is high- or low-active (like the one described here).

All external components, including the power supply of 5 V, are tied to a 6-pin connector.

### Simulation of the voltages

These are the voltages that occur on the capacitors of the RC network when a logical zero and one occur in the DCF77 signal by decreasing the amplitude to 15%.




The voltage on the first capacitor, after rectification of the IF, decreases and increases very fast. Its small capacity of 1 µF has no relevant influence and just smoothes down the 455&nbps;kHz peaks from the rectifier diode.

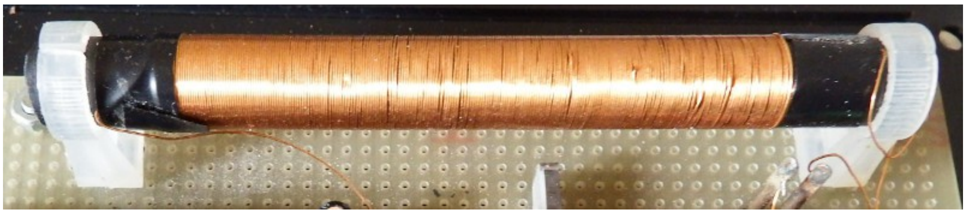
The voltage on the fast integrator with R3 (2k2) and C2 (1µF) decreases relatively fast with the reduced amplitude. It just buffers the signal during the time when the rectifier does not load the capacitor.

The voltage on the slow integrator with R4 (39k) and C3 (220µF) remains uninfluenced by the second's amplitude reduction (very small decrease). It takes many seconds until the voltage reaches its average value.

The digital output signal on the CA3140 is very stable, but very short spikes can occur from the 455 kHz rectified signal. Those can easily be filtered by the controller's software.

# 3 Mounting

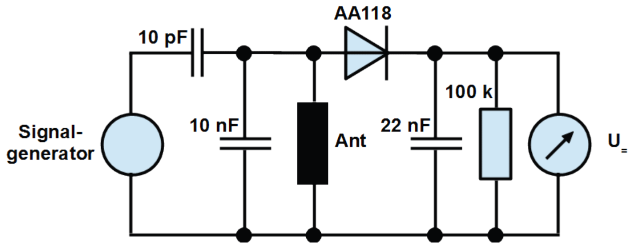
## 3.1 Mounting the antenna



The VLW receiver antenna is build on a ferrite rod, where a 0.25 mm copper wire is wounded on. Litz wire is not necessary due to the low frequency.

On both ends the coil is fixed with tape. The antenna is mounted in two plastic holders onto the PCB.

To determine the inductance of the antenna coil a capacitor of 10 nF is added to form a resonator and a signal generator (can be a digital one, such as described [here](here)) feeds its signal over a small capacitor such as 10 pF into that resonator. Either the signal on the resonator is viewed with an oscilloscope or the shown rectifier produces a DC voltage from that, which can be measured by a usual voltage meter. By that the resonance can be identified.




From the resonance frequency $f_{res}$ the inductance of the coil can be calculated:

$$L(H) = 1 / 4 / \Pi^2 / f^2 / C.$$

The inductance shall be approximately 3.5 mH.

From the measured inductance the capacitor C, which is necessary for a resonance frequency of 77.5 kHz, can be calculated:

$$C(F) = 1 / 4 / \Pi^2 / 77500^2 / L$$

## 3.2 Mounting the LC filters

The LC filters are mounted as follows.

### 3.2.1 HF preamplifier circuit

Primary coil 91 windings, secondary 45 windings, 0.1 mm enameled copper wire on Neosid coil body 05 9539 00 (9.5 µH).

### 3.2.2 Oscillator circuit

Primary coil 30 plus 76 windings, secondary 13 windings, 0.1 mm enameled copper wire on the same Neosid coil body.

### 3.2.3 IF filter

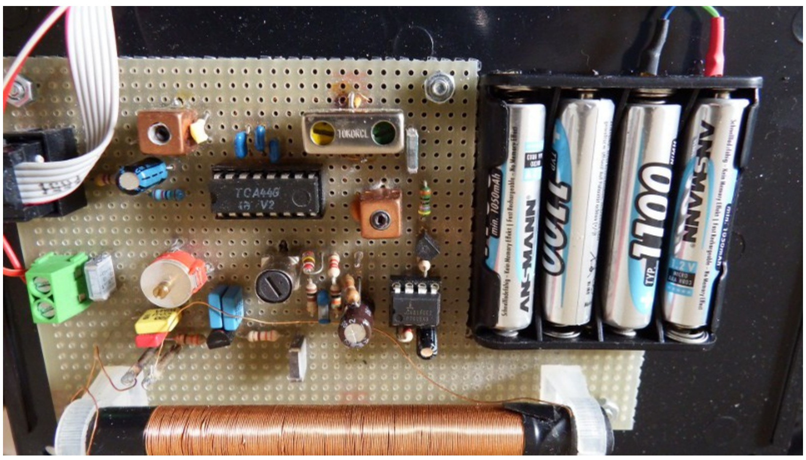
This filter is a commercially available TOKO SFT006H.

### 3.2.4 IF output filter

The output filter is a commercially available filter 7MC-A2549HM.

## 3.3 Mounting the PCB

The receiver can be build on a small PCB and wired with 0.25 mm solder-able enameled copper wire. The TOKO filter does not fit into the 2.54 mm pattern and larger holes have to be made to fit that into.



## 3.4 Adjustment

When adjusting the receiver's circuits the ferrite rod should be directed to Mainflingen and this direction is not to be changed during adjustment (because it has a strong influence on signal strength's).

Note that adjusting is easy because none of the adjustments affects other adjustments as well. So bringing all to a maximum is easy. But also note that the temperature also has a strong influence on the result, so do not be disappointed if an evening adjustment yields other result than an afternoon adjustment.

If you have an oscilloscope start with it connected to the source of the BF245. If not, connect a voltmeter to pin 5 of the 6-pin connector. You can also use a field strength instrument, if you have one attached.

First adjust the trim capacitor parallel to the antenna coil to a maximum signal strength. If you are very far away from Mainflingen you might not be able to see the signal yet on your oscilloscope. In that case use the voltage measurement or the signal strength indicator instead. If that does not work either come back to this step later on, when the rest of the filters has been adjusted.

If you own a frequency counter, such as the one described here, you can first adjust the oscillator frequency to 532.5 kHz on pin 6 of the TCA440. If not, adjust to maximum.

Adjusting the other resonators goes all around and in direction of the maximum.

# 4 Operation

The signal strength is varying mainly due to the sensitivity of the ferrite rod antenna to directional changes. When changing direction it might takes rather long until the signal level stabilizes due to the slow averaging. The LED can be used to identify a successful direction change: a flickering signal on that shows unsuccessful changes. But in any case leave enough time for averaging.

Good luck with receiving DCF77.

Praise, error reports, scolding and spam please via the comment page to me.