Reading a digital vernier calliper

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1. Objectives

Modern electronics does not spare traditional mechanical constructions. You certainly know digital vernier callipers, at least by sight. The advantages of such devices are obvious: They display values as an exact number, you can leave out a more or less arduous location on the calliper, it converts millimetres into inches and vice versa via at the touch of a button and it usually allows to define the zero position arbitrarily, so that variances from the nominal value are easily detected. Specific callipers are even able to calculate tolerances and mean values. But much more interesting for us is the often hardly noticed data output which also exist in many callipers. Dealers sometimes offer the required connection wires, PC adapters, PC software and other analyzing devices for branded products. Those are, however, very expensive and usually hard to adapt to the given problem. There against we totally control our BASIC-Tiger and can convert and collect incoming data at will. Wouldn't it be excellent to be able to read data from a digital calliper with BASIC-Tiger? If you are interested in this problem and in an unconventional solution – just go ahead reading!

2. The inner life of a digital vernier calliper

A digital calliper is a precision device and not quite cheap. In order to prevent you from dismantling the device out of pure curiosity and risk damaging it, the author has done it for you. You can see interesting details on the following pictures. Although we do not need to know the exact functionality of such a digital calliper, some information won't hurt.

Length measurement is based on a capacitive principle. The special IC on a circuit board installed on a movable slider sends out a comparatively high-frequency signal to a large "capacitor board", which is also placed on this circuit board. This oscillation is coupled to another integral capacitor board which is placed below the scale. Also on the movable circuit board there are many small capacitor boards (stripes in figure 4), which launches the signal distributed throughout the structure of the integrated circuit board. Depending on which segments receive which signal, the analysis of the movement and therefore the position is done by the IC. Here the vernier principle from the mechanical calliper is used again to measure even very small changes in position. Things get simpler in the further data processing. The IC counts position steps forwards and backwards from a freely defined zero position and also remembers them through a switching off (automatically or manually) of the display until the next movement or keystroke (mm/inch) if necessary. At the same time the IC displays the measured value in active condition and transmits it via the data interface.

Fig. 1 typical digital vernier calliper

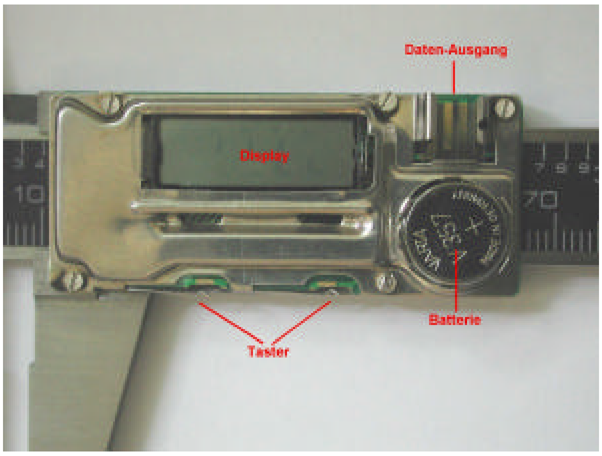


Fig. 2 electronic assembly after dismantling the plastic casing

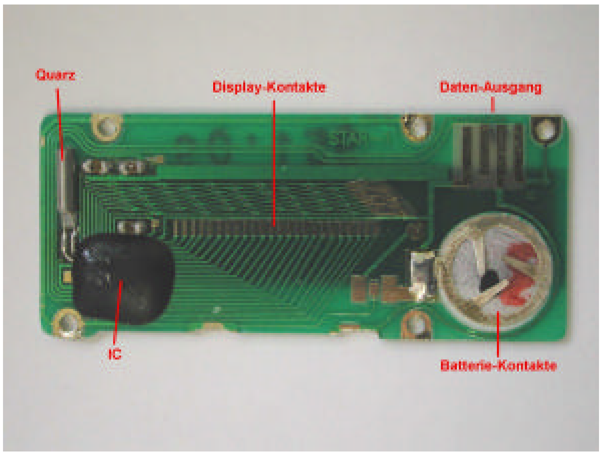


Fig. 3 taking off the sheet metal casing and the display reveals the equipped circuit board.

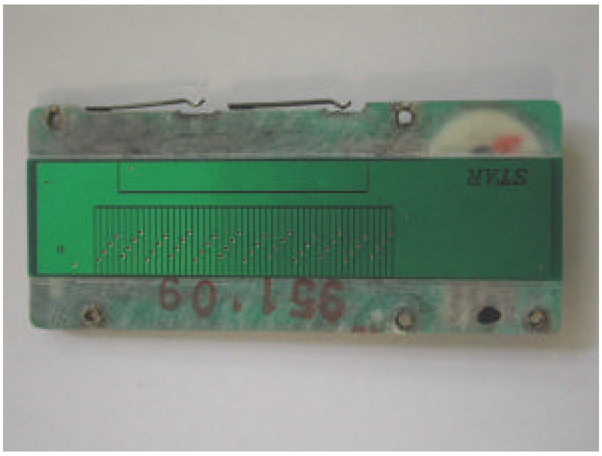


Fig. 4 the actual capacitive measuring sensors on the backside

Fig. 5 Display with rubber connector

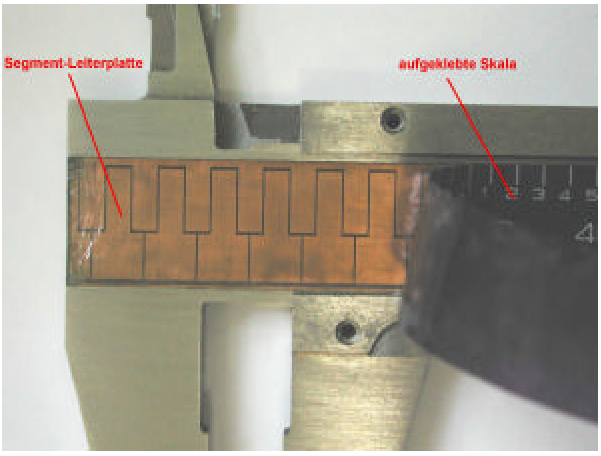


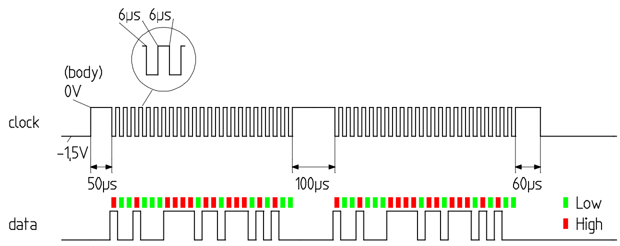
Fig. 6 the "secret" of the travel sensor, a thin circuit board with single isolated copper surfaces glued beneath the scale

3. The physical format of data output

Data formats vary of course depending on the calliper's producer. First of all be careful with designations for data interfaces which often occur in manuals. They often use terms like "RS232", "Opto-RS232", "RS232C" and "printer port" indiscriminately. Compatibility with "real" RS232 or printer interfaces hardly exists. There are, however, expensive products which even communicate directly with "real" RS232.

Nevertheless comparatively cheap products from the Far East (mostly China) with which we will work here, are in a way standardised. Their parameters are described in the following paragraph. A synchronous serial signal is outputted. Synchronous means that in opposite to the V24 or RS232 interface, which we know from our PC or BASIC-Tiger, a clock pulse is transmitted in addition. The data code is a 24 bit binary code. Every measured value is transmitted twice in a modified way. The usual transmission cycle takes 300 ms. The mere data transmitting time is 0.5 ms. The clock pulse amounts 70 kHz, data is transmitted while the clock is low. The configuration of the interface connection looks as follows (figure 7).

1. Negative battery pole (-)
2. Data (D)
3. Clock Pulse (CP)
4. Positive battery pole (+)



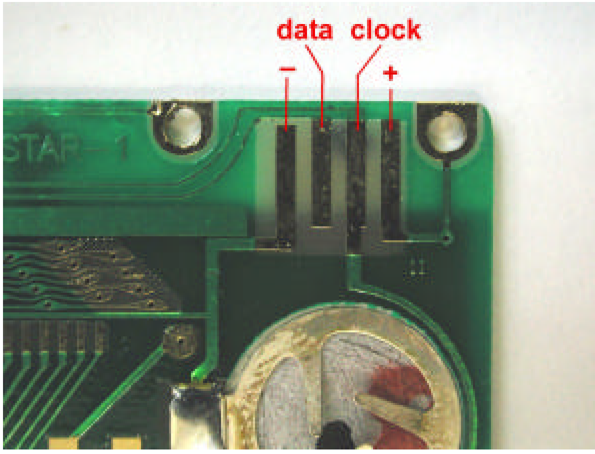


Fig 7 Data output; left: Designation of pins; right: geometrical configuration; below left: Pulse scheme

Clock and data line have the same voltage level as the battery poles. Please note that the battery plus pole may be connected to the housing (like the author's device). This gets important when the metallic mechanical system of the calliper is put on or even assembled to a device, where the housing has a negative ground.

The callipers which mostly origin from China look quite different from the outside, they are comparatively cheap, but still dependable and exact. Although many of them contain a data output, the search for finished data acquisition solutions will be unsuccessful in most cases. You hardly find a tool manufacturing shop or DIY store which will be able to offer you a data cable, software or other kind of finished solutions. That's why we will develop our own solutions from the first.

4. The mechanical problem of the data output

Unfortunately mechanical contacting these digital vernier callipers is rather difficult. There is no matching plug-in system apart from the specifically built data cable – which is expensive. To avoid this solution we have to build something ourselves. It is difficult to manufacture such a plug yourself, but easier to solder something standard on the contact area. The first way has the advantage that the device stays useful for professional attachable devices and warranty remains valid. Still, you will have to design a plug with absolutely non-standard contact spacing (a bit less than 2 mm) and a high mechanical severity (bevels at the sides, very limited space etc.). One possibility is to find a piece of circuit board with a path spacing of 2 mm. A few spring clips from a plug are bent for a direct circuit board connection and are soldered onto the circuit board. A thin but stable isolating layer is glued on it, since otherwise the guiding metal brackets of the calliper would cause a short circuit at the top. Like this you can produce a cable to the interface which is cheap and still does not change shape and functionality of the calliper.

The second way is more suitable for your own experiments und makes the interface more accessible for the future. If you chose soldering, pay careful attention to the rules for irritable electronic components (electrostatics, heat, short circuits!). Use low voltage soldering irons (12 V) if possible or disconnect the soldering iron from the power supply system as a precaution. You probably know standard headers which you find on every circuit board. Jumpers, female connectors etc. are plugged into it. Those plug systems also exist (unfortunately in small amounts) with a 2 mm pitch which exactly matches our problem (figure 8). To make a contact system, get yourself a header and a female connector and cut off a block of four. The socket is soldered to the circuit board after bending it several times (figures 9 and 10). The plug is best soldered to a piece of circuit board with 2 mm pitch circuit paths. Finally a fitting cable is soldered – finished (figures 11 and 12). With a bit of luck you will manage to make the mechanics invisible to an outside observer.

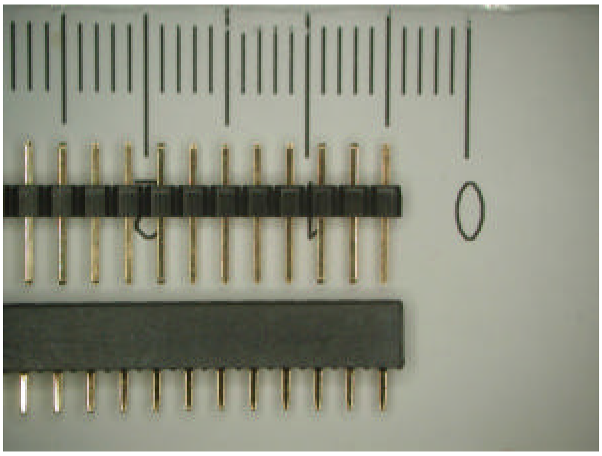


Fig. 8 Header and socket (2mm pitch)

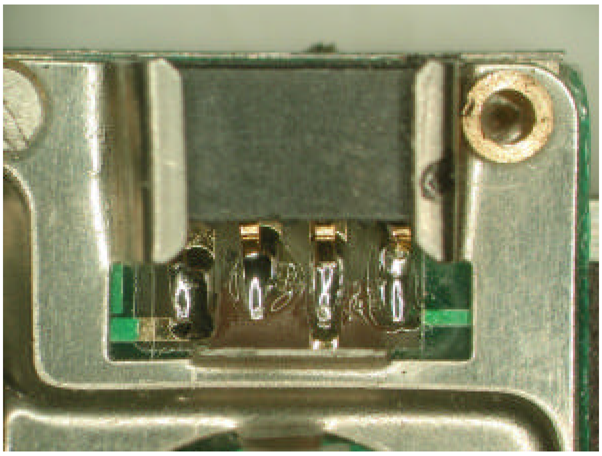


Fig. 9 soldered socket

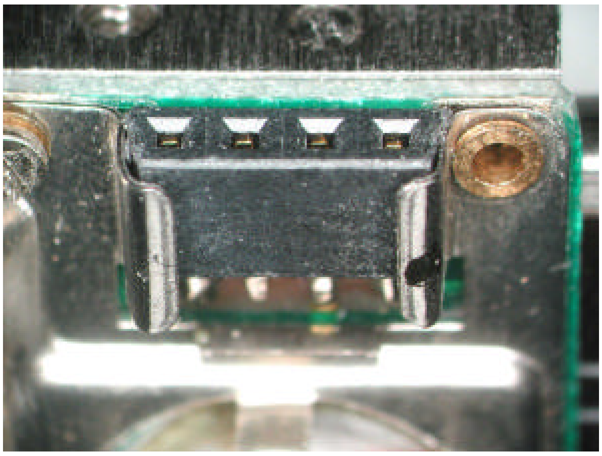


Fig. 10 from another perspective

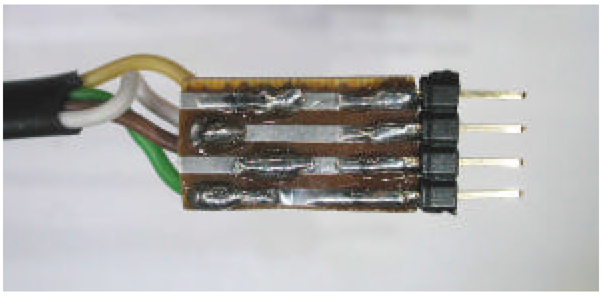


Fig. 11 DIY plug

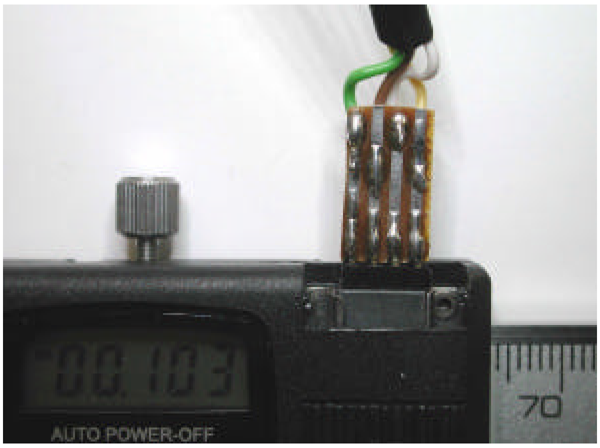


Fig. 12 calliper with plugged-in cable

5. The circuitry

With this inside knowledge everything seems to be quite simple – a level converter raises the voltage level of clock and data line to TTL (CMOS) level – BASIC-Tiger will surely know a command to serially read in 24 respectively 48 bits...

But again the problem lies in the detail. We notice soon that converting levels is not that easy because of high resistance outputs of the calliper (in order to save electricity). Besides it is not possible to serially transmit data to BASIC-Tiger on the given frequency synchronous (yet!). Commercial or DIY solutions usually use an own microcontroller (PIC) for conversion into a standard RS232 protocol. An impressive solution by Kevin Timmerman can be found on

http://www.pcmx.net/gauge/

There, however, you will be dependent on a programmed PIC. We will try to make it with a standard logic unit. The intelligence will be within Basic-Tiger.

The concept is as follows:

On the first level a six-fold CMOS inverter CD4049 serves as an AC-coupled linear amplifier which doubles voltage levels of clock and data. Unfortunately this first level only works properly until an operating voltage of about 3.5 V. This operating voltage is implemented by a 1.5 kΩ and an 820 Ω potential divider as well as an Elko. For a better level adoption we use a HCT7400 at 5 V, which generates sufficiently high and clear signals from the 3.5 V levels for the following ICs and which can negate data signals in addition. With these two circuits we get the signals clock 1 and data to "normal" level. But how do we transmit them to BASIC-Tiger? We have the following solution for this problem:

With the fast clock 1 of the calliper we transmit the data to a shift register in first instance, in order to output and read them with a slow clock 2 (given by BASIG-Tiger) during the long "transmission break". Clock 2 is generated by command SHIFT_IN at L81 and with it data is read in at L80. With this trick we become independent from the clock pulse too fast for BASIC-Tiger and can simply reach a synchronisation at the same time.

This solution requires a unit which surely detects the calliper's interrupts. We do it with a single-trip multivibrator CD4538 which is activated immediately with the first L/H transition of the original clock signal. Every further impulse triggers the single-trip multivibrator. Not before the last L/H transition the actual single-trip multivibrator pulse time, defined by R and C, starts. It switches back long enough after the impulse package. This signal now switches the route for both clocks. The change over switch for both is an analog switch CD4066. When impulses arrive from the vernier calliper they are let through. When impulses stop coming, after a certain time clock 2 of the BASIC-Tiger takes over the further shifting of data. The shift signal from the single-trip multivibrator is monitored on L82. When L82 is low BASIC-Tiger starts reading data from the shift register. We use a HCF4571 as a shift register with which bit lengths of 16, 32, 48 or 64 can be realised. The calliper's 48 clock pulses shift in its data and further clock pulses of BASIC-Tiger, this time with different timing parameters, shift it out again at the end. We can realise a complete depleting of the whole shift register by a suitable number of BASIC-Tiger clock pulses (we chose 100) while respectively after reading it.

The calliper can be supplied externally (1.55 V) by a further potential divider similar to the first amplifier IC voltage supply. This makes sense for applications in which the calliper is permanently connected to BASIC-Tiger. In the case of permanent voltage supply we advice you to take out the battery.

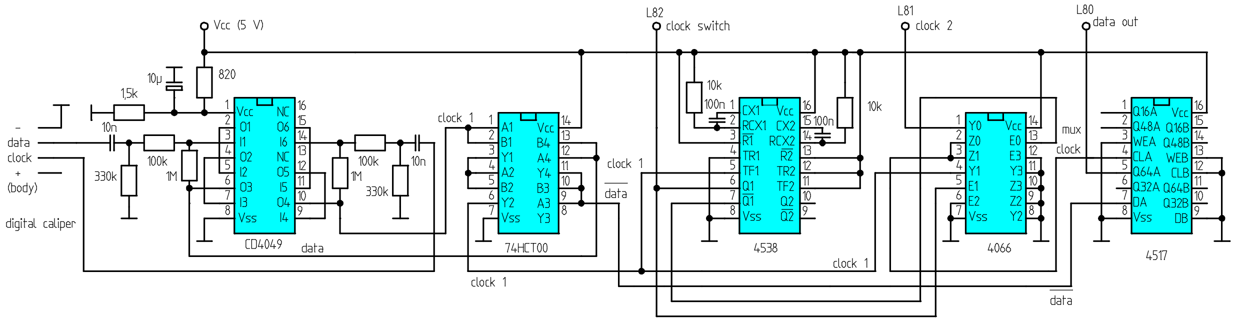


Fig. 13 Circuit for reading a digital vernier calliper

6. A simple reading software

The last part of our project is the BASIC-Tiger software CALLIPER_01.TIG which shifts bits out of the shift register using a SHIFT_IN instruction and collects them within a variable. The software implements the correctly timed control of both clocks 1 and 2 as well as evaluation of the read data (e.g. conversion to mm or inches – L83 high or low) by scanning the level at L82. You can display measured values on the (as usual connected) LC display or the serial interface SER1 using a terminal program on your computer. The software is commented in detail and widely self-explaining, so that we can leave out detailed explanations here.

After finishing and connecting everything the question remains, what advantages our system offers. After all, the calliper can display everything itself, output measured values in mm or inches etc. The following possibilities should encourage you to try out simple software modifications:

- Measured data can now be printed or saved
- Time information can be recorded for timing diagrams
- Maximum, minimum, mean values, variation and other statistical data can be determined in a simple way (just rotate an elliptical object slowly between the jaws while pressing them together with light pressure and you will automatically receive maximum and minimum…)
- What about using digital vernier callipers as travel sensors (for example at your home lathe)?
- Output of measured values in any unit
- Acoustic signals when limits are exceeded (Good / bad recognition without watching!), even a spoken output of measured values is possible...

The author is anxious to see completely new applications for a vernier calliper – good luck!