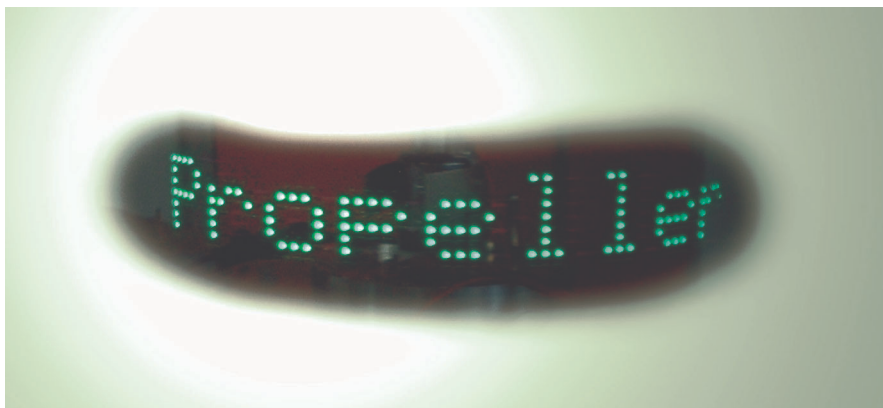


Propeller Display

Renesas H8 Design Contest 2003
Entry H3210



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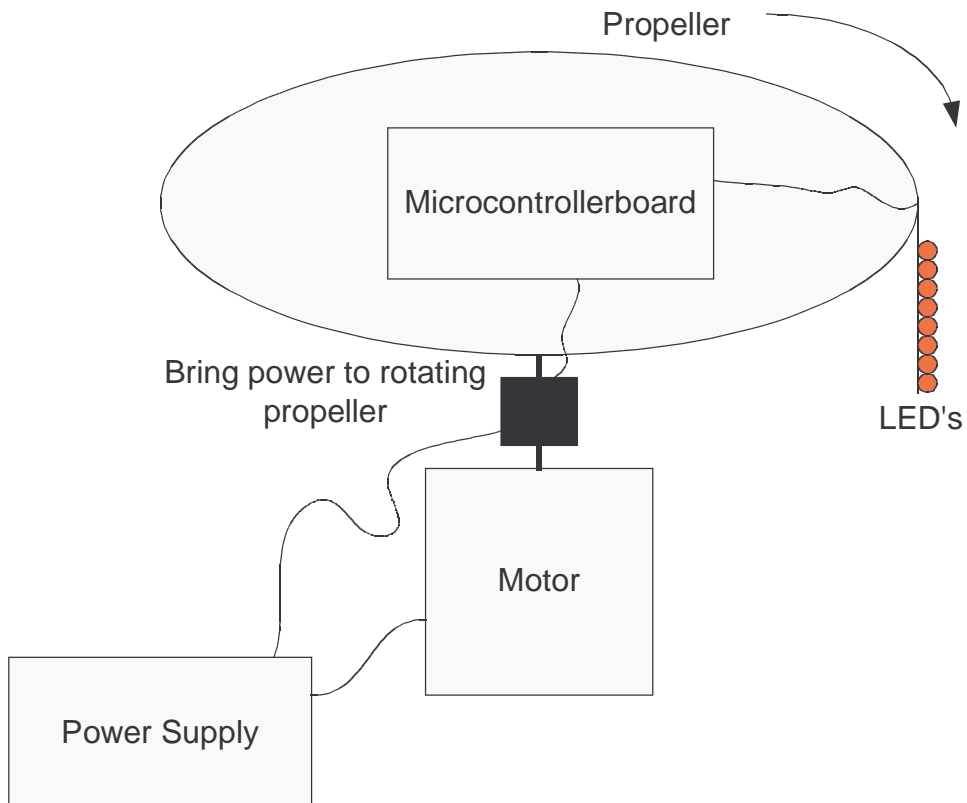
1 Planning

1.1 Short Description

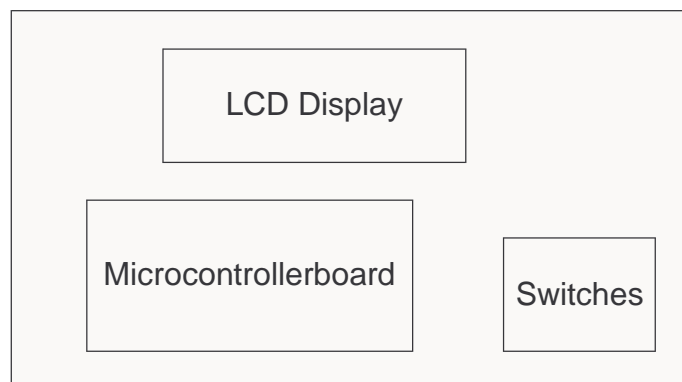
1.1.1 Abstract

The following drawing shows the basic components of the project.

Propeller Display



Terminal



1.2 Functional Specification

1.2.2 Requirements

<i>Description</i>	<i>Must</i>	<i>Nice</i>	<i>Priority</i>
Display Text	✓		1
Display Pictures	✓		1
Show predefined strings	✓		1
Wireless text and power transfer to the propeller	✓		1
Terminal to enter a user defineable text		✓	2
Integrated power supply (230V)		✓	2
Display of a real time clock and the date		✓	2
Receiving of a sms and show it		✓	3
Display of the current temperature		✓	3
Adjustable LED-Current		✓	3

1.2.3 Functions and Properties

1.2.3.1 Power Up

After the power up, a little demo is started and shows all graphical features of the propeller display. The demo is repeated until the user enters a text or the display is powered down.

1.2.3.2 Enter a text

It should be easy without reading a thick manual to enter a text on the terminal. If the text is entered it should be fast and safe transferred to the display. It would be nice if this happens wireless.

After the reception of the text, it is displayed immediately on the propeller display until a new text is received.

1.2.3.3 Display

Texts and pictures should be easy readable with as less flickering as possible.

1.3 Additives

1.3.1 Required tools

- GNU-Tools for programming/Software
- Power Supplies
- Multimeter
- KO
- PC/Laptop
- Handy
- Signal generator
- Soldering Iron / Solder
- PCB prototyping machine
- PCB and schematics drawing tool
- OpenOffice.org for documentation
- Consumable Material (LED's, resistors, condensators, microcontroller...)

1.4 Calculations

1.4.1 Speed of the LED's (Framerate)

The rotational speed of the LED's affects directly how many pictures can be displayed in a second. This corresponds to the framerate.

On a modern TV, the framerate is 100Hz. The more framerate, the less flickering of the picture.

Because on the Propeller Display the picture is scanned mechanically, it is not easy to achieve high framerates. For me it isn't possible to mechanics that can rotate the LED's 100 times a second.

The propeller has to be very well balanced to keep vibrations as low as possible and keep the speed of the rotating LED's as high as possible.

How fast are the LED's when a picture is displayed with a framerate of 25Hz?

Here is the Calculation.

Acceptance: $f = 25\text{Hz}$ (Framerate)

$r = 20\text{cm}$ (Radius from centre of rotation to the LED's)

$$u = 2 \cdot r \cdot \pi = 2 \cdot 0.2\text{m} \cdot 3.141 = 1.256\text{m}$$

$$v = f \cdot u \cdot 3600 = 25 \cdot 1.256\text{m} \cdot 3600 = 113'040 \frac{\text{m}}{\text{h}} = 113.04 \frac{\text{km}}{\text{h}}$$

Acceptance: $f = 25\text{Hz}$ (Framerate)

$r = 15\text{cm}$ (Radius from centre of rotation to the LED's)

$$u = 2 \cdot r \cdot \pi = 2 \cdot 0.15\text{m} \cdot 3.141 = 0.942\text{m}$$

$$v = f \cdot u \cdot 3600 = 25 \cdot 0.942\text{m} \cdot 3600 = 84'807 \frac{\text{m}}{\text{h}} = 84.807 \frac{\text{km}}{\text{h}}$$

We see that already a slow framerate of 25Hz generates very high speeds on the LED's. The bigger the radius of the display, the bigger is the speed and more vibrations occur.

1.4.2 Required reaction time of the microcontroller

Depending of the rotational speed of the LED's and the resolution of the display the microcontroller has to be quick enough to switch the LED's on and off in an acceptable time.

Here is a calculation of the minimum the, the microcontroller has to react.

Acceptance: $f = 25\text{Hz}$ (25 frames in a second)

$$r = 15\text{cm} \Rightarrow u = 0.942\text{m}$$

$$l_{\text{LED}} = 5\text{mm} \text{ (Vertical distance between the LED's)}$$

In order that a nice clean picture is originated, the horizontal and vertical distance from pixel to pixel or LED to LED should be the same.

We calculate the number of displayable pixels on the horizontal axis.

$$\text{PixelCount}_{\text{Horizontal}} = \frac{u}{l_{\text{LED}}} = \frac{0.942\text{m}}{0.005\text{m}} = 188.4 = 188$$

The most speed of the microcontroller is needed when a LED is toggled every time. This corresponds to a bit pattern of 101010101... When this bit pattern can be displayed, every other bit pattern/picture can be displayed without problems.

The microcontroller must be fast enough to toggle the LED's 188 times in a second. Whit 25 frames in a second:

$$\text{PixelClock} = f \cdot \text{PixelCount}_{\text{Horizontal}} = 25\text{Hz} \cdot 188 = 4.7\text{kHz}$$

$$\text{ReactionTime} = \frac{1}{\text{PixelClock}} = \frac{1}{4.7\text{kHz}} = 212.766\mu\text{s}$$

When a bright area is displayed and the LED's remain ON the whole time, we see a lot of horizontal lines and not a picture with single dot's.

To avoid this, the LED's only flashes shortly on a position and then moves a bit to the next pixel position and flashes shortly again.

For this better display method a shorter reaction time of the microcontroller to switch the LED's is necessary.

In the hardwaremanual of the microcontroller is the maximal number of cycles which a IRQ-Routine needs to execute the first instruction.

This time is specified on page 113 in the hardwaremanual and is max 33 clock cycles.

With a clock (microcontroller) of 18.432MHz we get the following time:

$$\text{IRQDelay}_{\text{Max}} = \frac{1}{f_{\text{Clock}}} \cdot 33\text{Cycles} = \frac{1}{18.432\text{MHz}} \cdot 33\text{Cycles} = 1.79\mu\text{s}$$

We see that the delay time to enter the IRQ-Routine is fast enough for the needs of the propeller display. (To leave the irq routine we also need max. 1.79μs)

2 Analysis

2.1 *Microcontrollerboard*

The microcontrollerboard should be designed universally that the Terminal and Propeller Display can be realized with the same board.

2.1.1 Requirements

Propeller Display

- Per LED a digital output
- A digital input for synchronization of the displayed picture and the propeller position
- Interface to the Terminal (wireless, serial)

Terminal

- Interface to the Propeller Display (wireless, serial)
- Interface to a LCD-Display

Combined (plus reserve and „nice to have“)

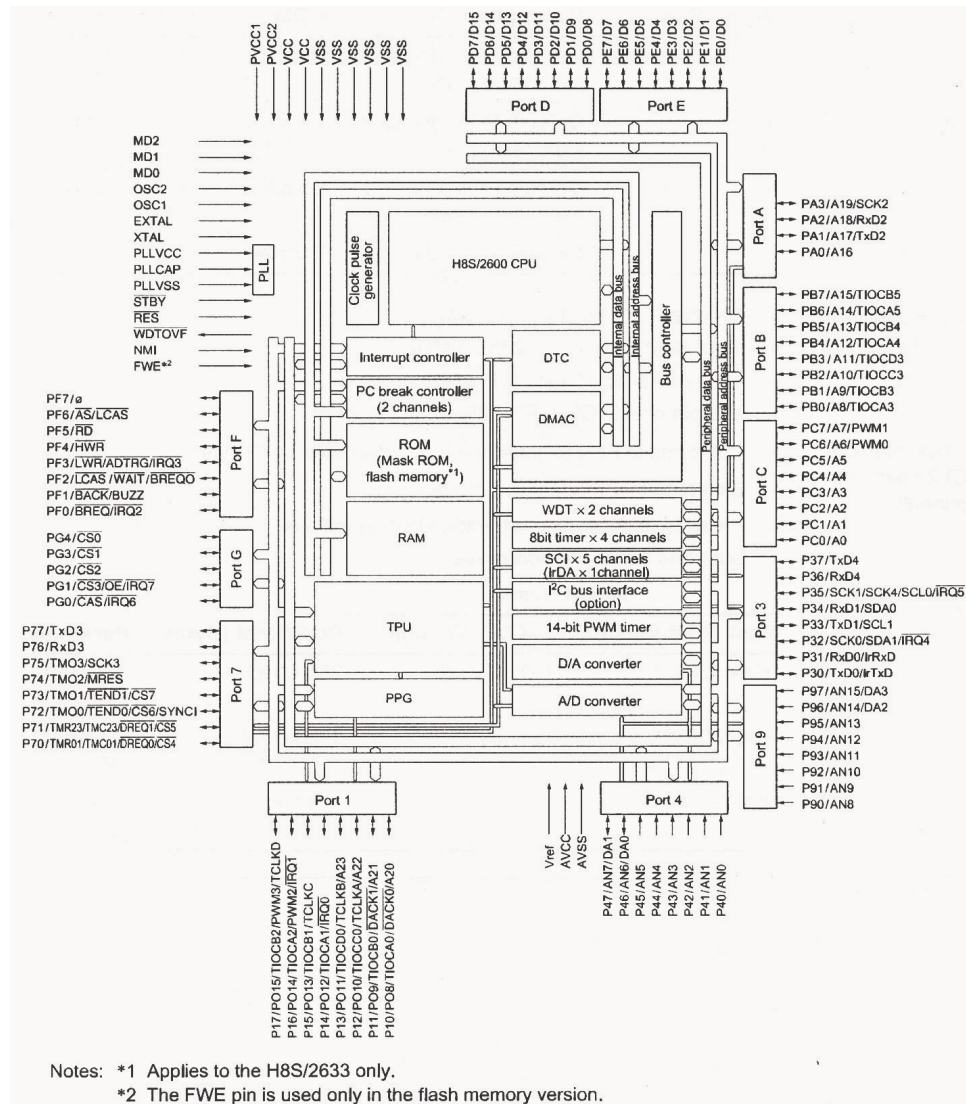
- 20 I/O's on a connector plus 8 I/O's to connect a LCD-Display
- 2 async serial interfaces
- 3 PWM-Outputs to control the brightness of the LED's
- 4 Analog Inputs to measure voltages
- External IRQ-Input

2.1.2 Choice of the Microcontrollers

Because the price and electrical requirement isn't critical in this project i take a controller with many IO's, much Flash and RAM and many peripherals.

My choice was the **H8S/2633** in single chip mode.

H8S/2633 Overview



Features

What	How many
Flashsmemory	256kB
RAM	16kB
Clock	25MHz
Timer	6ch 16-Bit Timer with 16 IC/OC plus 8-Bit Timer
DMAC (Direct Memory Access Con.)	Yes
DTC (Data Transfer Controller)	Yes
SCI (serial Interface)	5 (One of them with IrDA)
ADC (AD-Converter)	16ch 10-Bit
DAC (DA-Converter)	4ch 8-Bit
Various	PPG (16ch Pulse Pattern Generator), 32kHz Subclock

2.2 LED PCB

On the LED PCB the LED's are located, which converts the electrical signals from the microcontroller to optical signals for the human eyes and the necessary electrical drivers.

2.2.1 Requirements

- Min.7 LED's in vertically direction (to display a 7x5 standart font)
- Very bright LED's
- LED's with large angle
- Light mechanical assembly to reduce vibrations

Nice to have

To show pictures it's nicer to have more LED's so i take 16 LED's instead of only 7.

LED Current

On the LED PBC has to be drivers to drive the LED's because the microcontroller cannot provide enough current.

From Hardware Manual Page 890:

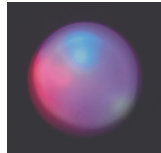
I_{low} per Pin:	10mA
I_{high} per Pin:	2mA
I_{low} all Pins:	120mA
I_{high} all Pins:	40mA

I drive the LED's with the highest possible current to achieve brightest possible picture. A minimum of 20mA is necessary.

2.2.2 Evaluation of the LED's

On the market there are various LED's. Very nice ones have a Red, Green and Blue chip. With this RGB-LED's the colors can be mixed together and it's possible to create many many different colors.

I found only one type wich was available in small quantities.



RGB-LED from Conrad Electronics

As you can see on the picture this LED is very bad. It's impossible to obtain a homogene white color by mixing red, green and blue together. The green chip is nearly not visible though the current was bigger than on the other colors.

Better RGB-LED's like the ones used for big screens are only available in quantities above 1000 pieces, so i looked for single LED's.

The brightest ones that were avaylable for me were these:

Sloan

<i>Type</i>	<i>Color</i>	<i>Brightness [mcd]</i>	<i>Angle [°]</i>
G01N	Green	150	120
B01N	Blue	45	120

Stanley

<i>Type</i>	<i>Color</i>	<i>Brightness [mcd]</i>	<i>Angle [°]</i>
HBR1105W	Red	52	40
HPG1105W	Green	38	40
HEB1105W	Blue	30	40

Brightness and a big angle are the importantest properties for the Propeller Display, so i tooked the LED's from Sloan. Unfortunately there exist no red LED's from the series 01N, so i take a red one from another supplyer with similar datas.

2.2.3 Driver

To drive the LED's there are two simple possibilities. It can be done with discrete transistors or with an integrated circuit like the ULN2803 darlington driver.

Because it's easier with the darlington driver and costs are not important in this project, i take the ULN2803 driver.

2.3 Wireless Data Transfer

To bring text to the propeller it's necessary to have a wireless communication between the terminal and the propeller.

I evaluated 3 possibilities.

<i>Variant</i>	<i>Description</i>
IrDA	Data is transferred optically like in Laptops, Palm, Handy...
Inductively	The text can be transferred from a stationary coil to the rotating coil which is mounted on the propeller and rotateing with it.
Radio	Text is transferred by a redio channel.

Decisionmatrix Points 0 (bad) to 10 (good)

	<i>IrDA</i>	<i>Inductively</i>	<i>Radio</i>
<i>Criteria</i>	<i>Points</i>	<i>Points</i>	<i>Points</i>
Safe transmission	3	8	10
Long range	4	1	10
Low power	5	8	3
High speed	8	5	10
Buyable ready to use with an easy interface	10	0	10
Price	10	0	5
<i>Sum</i>	40	22	48
<i>Rank</i>	2	3	1

Data transfer by radio is the best for this project, so i buy a radio module to do the communication between terminal and propeller.

2.4 Propeller Supply

Because the propeller rotates it's not too easy to bring power to it for driving the microcontrollerboard, LED's and radio module.

2.4.1 Requirements

- V_{Out} min. 7V, therewith for the 5V regulator
- I_{Out} min. 500mA (16 LED's à 20mA = 320mA plus Microcontroller...)

2.4.2 Variants

<i>Variant</i>	<i>Description</i>
Sliding Contact	Sliding contact like in motors.
Generator	A generator on the propeller generates power from the rotation.
Transformer	The primary coil of the transformer is mounted fix and the secondary coil on the propeller which is rotating.

Decisionmatrix Points 0 (bad) to 10 (good)

	<i>Sliding C.</i>	<i>Generator</i>	<i>Transf.</i>
<i>Criteria</i>	<i>Points</i>	<i>Points</i>	<i>Points</i>
Operates on rotation	10	10	10
Operates without rotation (e.g. softwareupdate)	10	0	10
Little weight	10	2	4
For high current (>300mA)	7	5	10
Non sensitive for dirt	3	10	10
High rotation speed possible	8	10	10
Little outlay	10	4	5
<i>Sum</i>	58	41	59
<i>Rank</i>	2	3	1

The best variant is the transformer. But i think that it's not too easy to realize it, so i take the variant with the sliding contact.

2.5 Terminal

The terminal is the interface between a human or computer and the propeller display. Text is entered and edited on the terminal and then transferred to the propeller display.

2.5.1 Requirements

- Easy and efficient enterint of the text (e.g. Keyboard)
- Display for a preview of the entered text
- Interface to the Propeller Display
- Option: Interface to PC (serial)

2.5.2 Variants for entering text

<i>Variant</i>	<i>Description</i>
Keyboard	Entering text like on a PC.
Rotary switch	Rotate a switch to select a character.
Touch Screen	A fingerdip on the display selects a character.

Decisionmatrix Points 0 (bad) to 10 (good)

	<i>Keyboard</i>	<i>Rotary switch</i>	<i>Touch Screen</i>
<i>Criteria</i>	<i>Points</i>	<i>Points</i>	<i>Points</i>
Fast entering of text	10	5	8
Not sensitive to dust	5	7	10
Easy to realize	5	10	3
Not sensitive for a slap	7	6	2
Lifetime	8	6	10
Cheap	8	10	0
<i>Sum</i>	43	44	33
<i>Rank</i>	2	1	3

Winner of the ranking is the rotary switch.

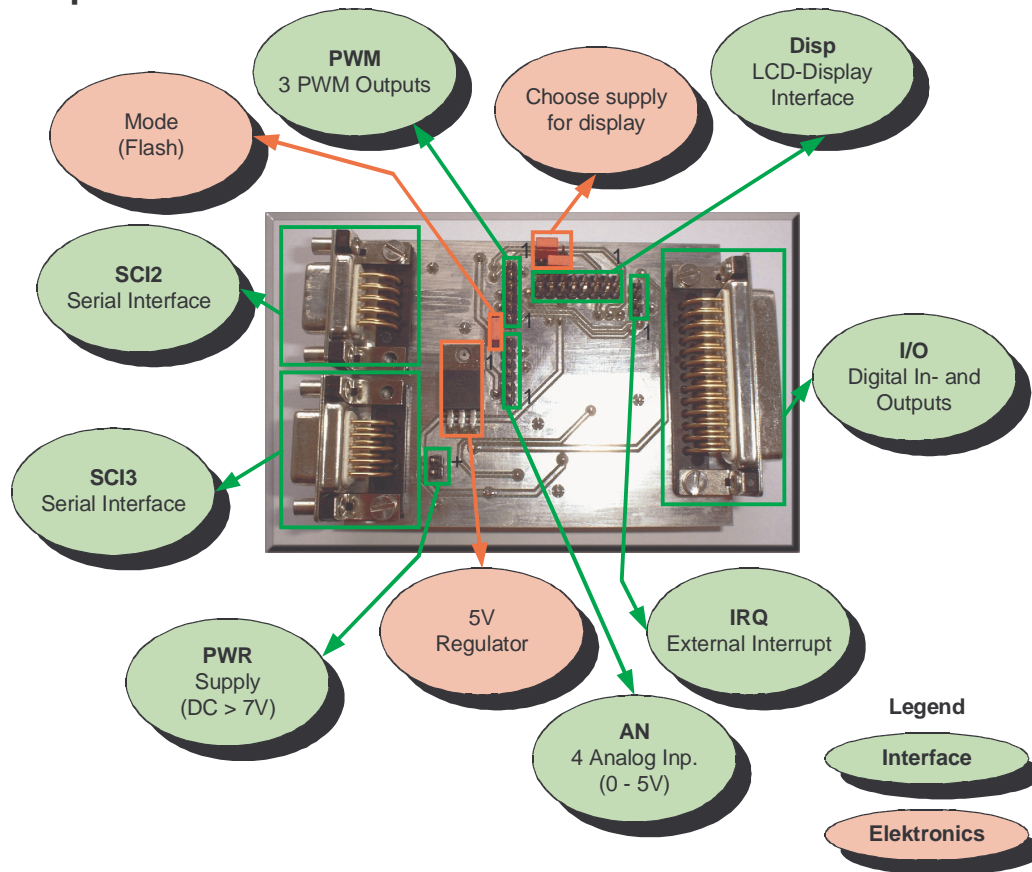
3 Realization

3.1 Microcontrollerboard

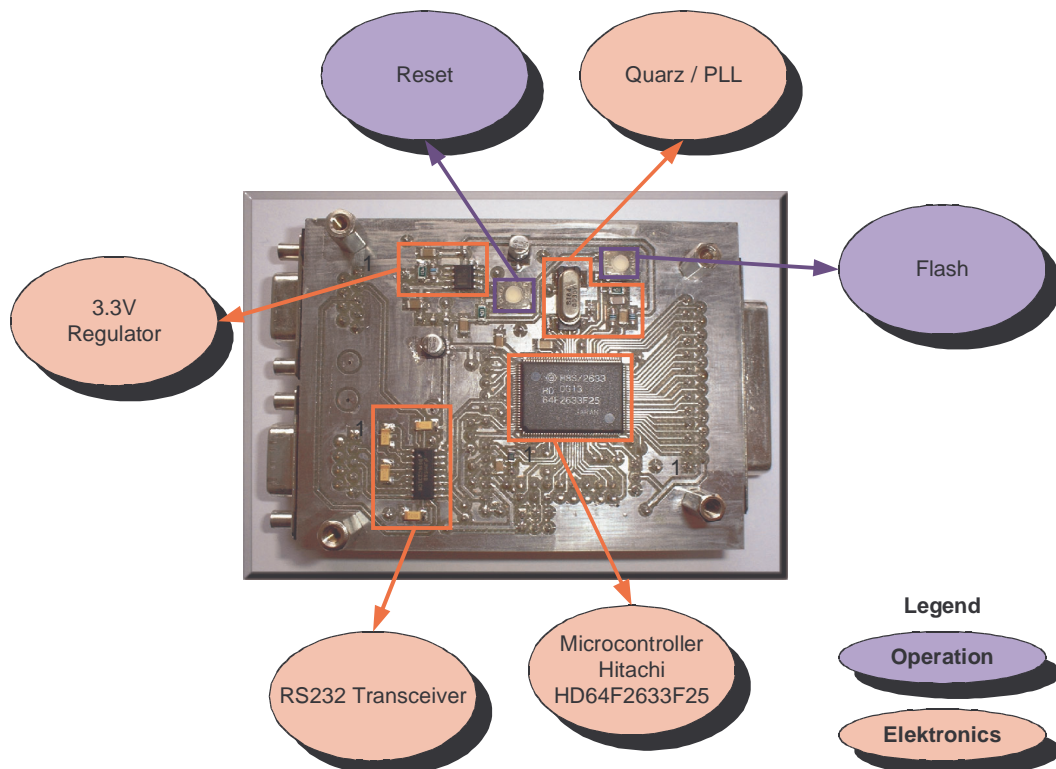
3.1.1 Important pages in the Hardwaremanual (H8S/2633)

<i>What</i>	<i>Page</i>	<i>Description</i>
Quarz	848	Clock
Supply	887	Electric requirements
Mode	74	Different modes
On Board Programming	802	Flash Memory
Memory	76	Memory and addresses
PWM Outputs	547	14-Bit PWM Outputs
SCI	583	Serial Interfaces
TMR	521	8-Bit Timer
Electrical requirements	883	Voltages, Currents, Frequencies...
IRQ	91	Interrupt Controller
I/O Ports	327	Ports (Digital in- and outputs)

3.1.2 Top View



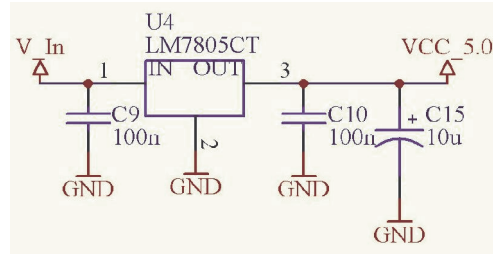
3.1.3 Bottom View



3.1.4 5V Regulator

For the 5V supply i took a LM7805 fixed 5V regulator. Beside the regulator itself some capacitors at the input and output are required. The values of the capacitors are taken from the datasheet.

Maximal output current is 1A.



3.1.5 3.3V Regulator

The 3.3V are made with a LP2951 voltage regulator. It's output voltage can be set with an external potention divider. For stabilization there are required also capacitors like with the LM7805 regulator.

Maximal output current is 100mA.

$$U_{Out} = U_{Ref} \cdot \left(1 + \frac{R_7}{R_6} \right)$$

The reference voltage is given by the datasheet. For R_6 a value of $100k\Omega$ isn't too bad.

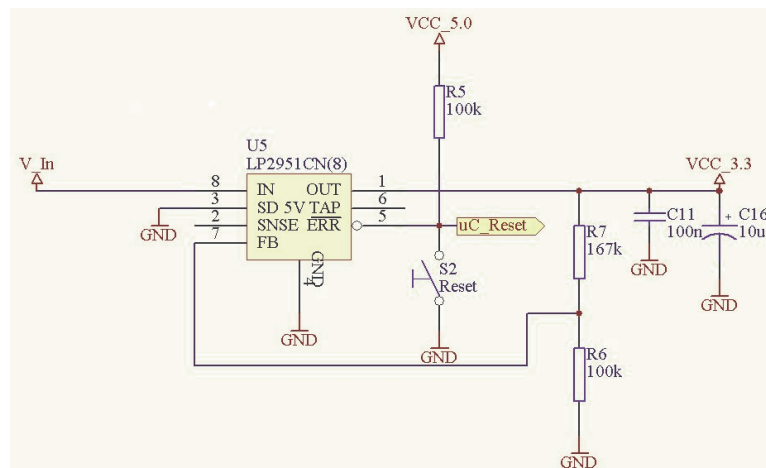
$$U_{Ref} = 1.235V$$

$$R_6 = 100k\Omega$$

The required voltage U_{out} is 3.3V. Now we can calculate the value of R_7 :

$$R_7 = R_6 \cdot \left(\frac{U_{Out}}{U_{Ref}} - 1 \right) = 100k\Omega \cdot \left(\frac{3.3V}{1.235V} - 1 \right) = 167k\Omega$$

For R_7 we take the calculated $167k\Omega$ resistor.



3.1.6 Reset

The microcontroller needs a reset device to start up reliable after powering it on.

On the LP2951 voltage regulator a reset device is integrated. It has an open drain output, so the 5V can be switched with it. This is required because the ports of the microcontroller are powered with 5V.

Have a look at the scheme on item 3.1.5.

3.1.7 Quarz / PLL

A clock frequency between 2MHz and 25MHz is required by the CPU. This can be generated with a quartz/resonator. It's possible to double or quadruplicate the frequency of the quartz by using the integrated PLL of the microcontroller. The ratio can be set in a register of the microcontroller.

After a power on reset the PLL is working with a ratio of 1:1.

For easy generation of frequencies required by the UART (serial interface) it's best to use a quartz with a frequency which is a multiple of the baudrate. 18.432MHz is such a frequency.

A disadvantage of such a high frequency is the high current consumption of the microcontroller, but for this project this isn't relevant.

In the hardware manual page 848 is described that at frequencies above 12MHz no series resistor R_d is required. For the capacitors C_{L1} and C_{L2} we take values of 10pF. They can be between 10pF and 22pF.

On the PLL there are connected the recommended components (hardware manual page 850).

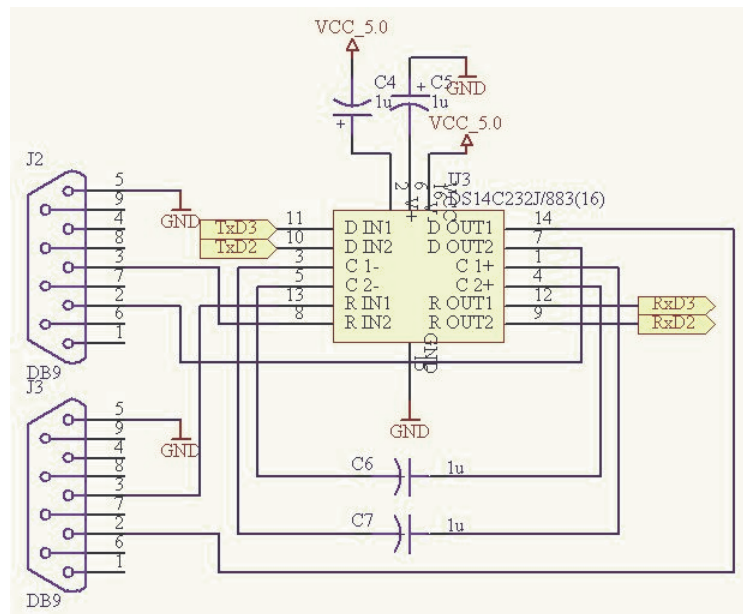
3.1.8 Serial Transceiver

A standart RS232 interface is working with voltages of about 24V. Because the microcontroller only works with 5V on the ports, a serial transceiver chip is required which converts the 5V signal to a signal with 24V.

On the other side it converts the 24V from the RS232 side to 5V for the microcontroller.

The DS14C232 from National Semiconductor is such a serial transceiver. Only some capacitors are required by the chip. It generates the higher voltages by itself.

Recommendet values for the capacitors in the datasheet are 1 μ F.



One transceiver chip is required for two serial interfaces with Rx and Tx.

3.1.9 LCD Interface

A standart textdisplay requires following connections to the microcontroller:

<i>Designator</i>	<i>Description</i>
V_{SS}	Ground
V_{DD}	5V Supply
V_{LCD}	Supply for the LCD-Driver 0-5V (Contrast)
RS	Register Select
R/W	Read (1) or Write (0)
E	Enable
DB ₀ *	Databit 0 (I/O)
DB ₁ *	Databit 1 (I/O)
DB ₂ *	Databit 2 (I/O)
DB ₃ *	Databit 3 (I/O)
DB ₄	Databit 4 (I/O)
DB ₅	Databit 5 (I/O)
DB ₆	Databit 6 (I/O)
DB ₇	Databit 7 (I/O)
E2	Enable for 2nd controller (only on large displays)

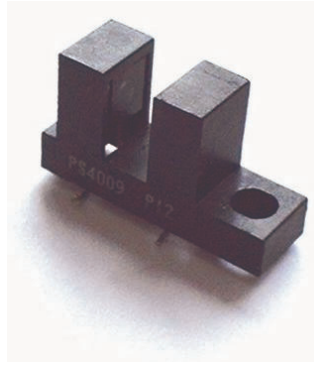
*Optional; not connected on 4-Bit Mode

Beside the supply, 8 digital outputs of the microcontroller are required to connect a standart LCD display.

Because one port with it's 8 bits is sufficient to drive a LCD in 4-Bit mode, i connect only these required signals together.

To adjust the contrast by software, for the signal V_{LCD} a PWM-Signal is taken, wich is filtered by a RC. By vary the PWM signal, different contrasts can be set. A potentiometer isn't longer required.

3.2 Photo Interrupter

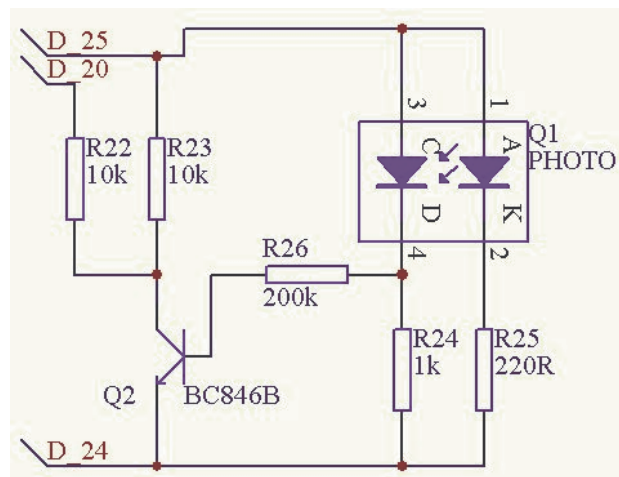


3.2.1 Description

On the rotating part of the propeller there is mounted a photo interrupter. It is required by the software for synchronize the picture with the propeller position.

The photo interrupter is connected to an IRQ-Input of the microcontroller. IRQ-Inputs can be configured to fire up at rising or falling edge of a signal.

3.2.2 Electronics & Dimensioning



Connections

D_25 = 5V, D_24 = GND, D_20 = Output signal (low on interruption)

R_{25}

R_{25} is dimensioned that on the sender a current of about 15mA flows.

$$R_{25} = \frac{5V - U_{LED}}{I_{LED}} = \frac{5V - 1.6V}{15mA} = 227\Omega$$

An available value is 220Ω.

R₂₄

By testing different values i discovered an optimal value of 1kΩ.

R₂₃, R₂₆

R₂₆ limits the basis current of the transistors. R₂₃ sets the output current which this circuit can deliver. On the microcontroller the input resistance of a pin is very high, i take a value of 10kΩ.

Now we can calculate the collector current.

$$I_C = \frac{5V}{R_{23}} = \frac{5V}{10k\Omega} = 500\mu A$$

The gain of the transistor BC846 with a collector current of 500μA is about 200.

We can calculate the required basis current now..

$$I_B = \frac{I_C}{\beta} = \frac{500\mu A}{200} = 2.5\mu A$$

Basis resistor R₂₆:

$$R_B = \frac{5V}{I_B} = \frac{5V}{2.5\mu A} = 2M\Omega$$

To bring the transistor to saturation for R₂₆ i take a value of **200kΩ**.

R₂₂

To protect the transistor, the current can be limited with resistor R₂₂.

Max output current of the circuit

Max output current against 5V:

$$I_{maxLo} = \frac{5V}{10k\Omega} = 500\mu A$$

Against ground we have the additional R₂₃:

$$I_{maxHi} = \frac{5V}{10k\Omega + 10k\Omega} = 250\mu A$$

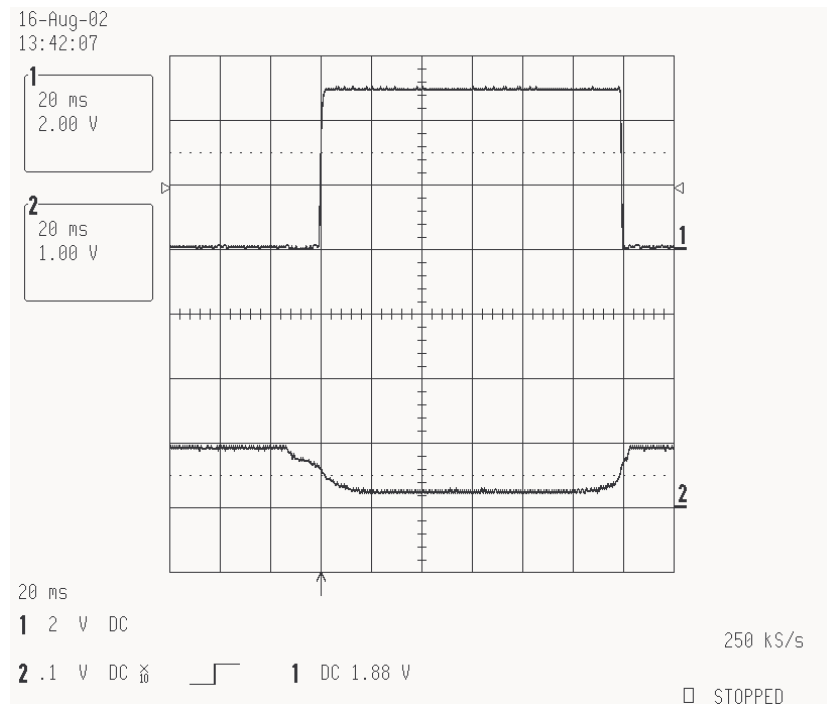
3.2.3 Measurement

Now i test the circuit.

Channel 1 Output signal D_20

Channel 2 Knot R₂₄, R₂₆, Phototransistor

For a short time a cardboard is pushed in the photo interrupter.



Without the cardboard, the voltage over the phototransistor (CH2) is 0.95V. The output signal of the circuit (CH1) is low.

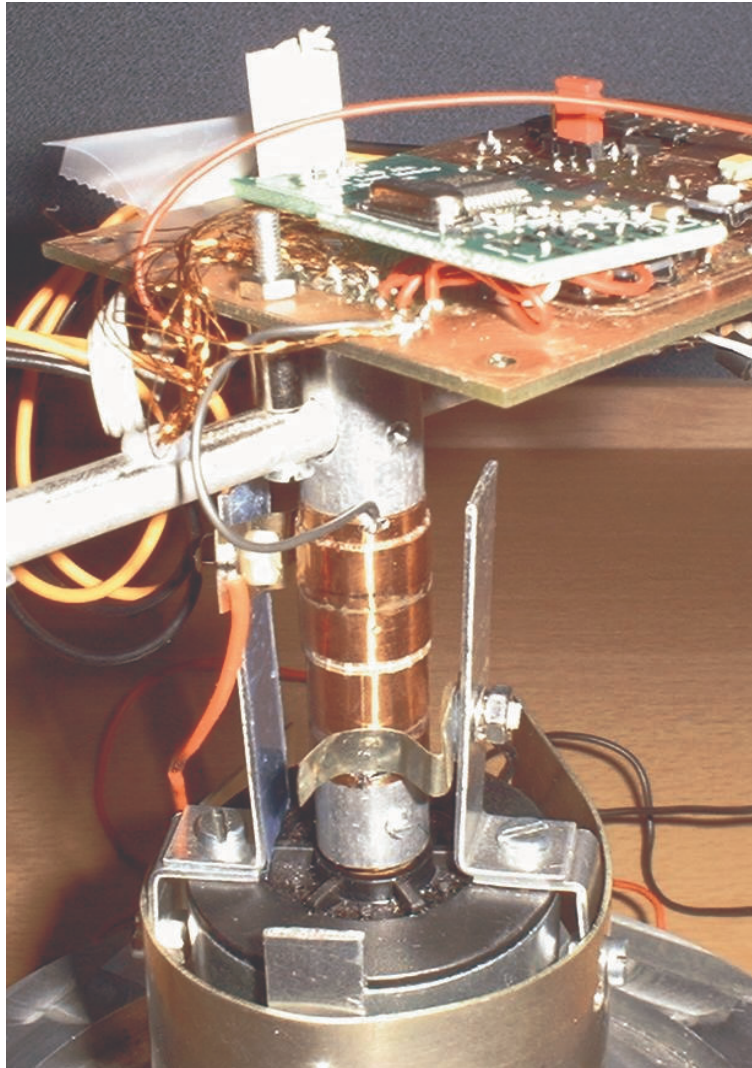
At the same time the cardboard is between the LED and the phototransistor, the voltage over the phototransistor drops to 0.6V. This inhibits the transistor and the output voltage rises to 5V.

Conclusion

The circuit is working properly.

3.3 Supply transfer

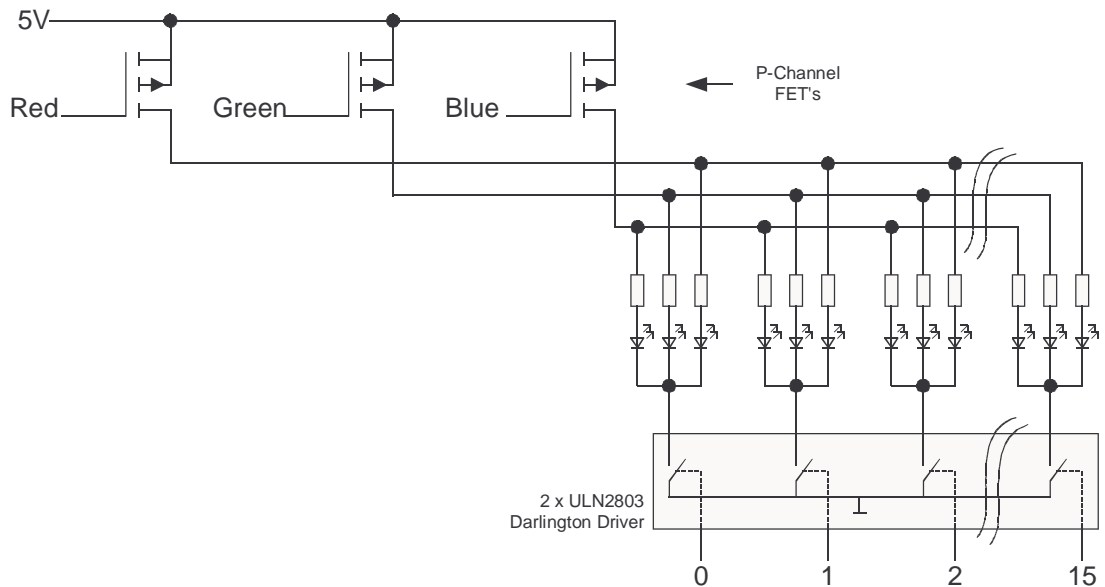
This is a self constructed sliding contact which brings the supply to the rotating propeller.



3.4 LED Driver

I realize a High-End variant with 16 pixel in the height. Every pixel can be red green or blue, so 16x3 LED's are required.

3.4.1 Scheme



3.4.2 Description

A pixel can be switched completely on or off by a switch of the darlington driver. The color can be selected when a single FET is switched on. It's possible to mix the colors when more than one FET is switched on or when they're driven with PWM-Signals.

3.4.3 Dimensioning

Known Values

FET	$R_{DS(on)} = 0.8\Omega$
ULN2803	$V_{CE(Sat)} @ 20mA = \text{ca. } 0.6V$
LED Green	$V_{AK} = 3.5V$
LED Blue	$V_{AK} = 3.6V$
LED Red	$V_{AK} = 1.75V$
All LED's	$I_{LED(Max)} = 20mA$

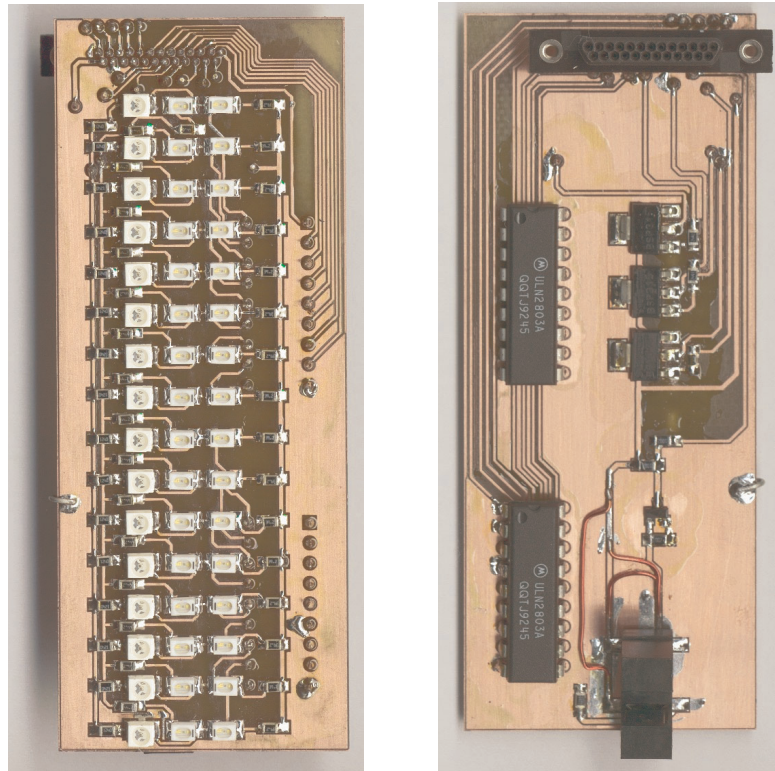
Calculation of LED series resistor

$$R_{Gre} = \frac{V_{Supply} - V_{AK} - V_{CE(Sat)}}{I_{LED}} - R_{DS(on)} = \frac{5V - 3.5V - 0.6V}{20mA} - 0.8\Omega = 44.2\Omega$$

$$R_{Blu} = \frac{V_{Supply} - V_{AK} - V_{CE(Sat)}}{I_{LED}} - R_{DS(on)} = \frac{5V - 3.6V - 0.6V}{20mA} - 0.8\Omega = 39.2\Omega$$

$$R_{Rd} = \frac{V_{Supply} - V_{AK} - V_{CE(Sat)}}{I_{LED}} - R_{DS(on)} = \frac{5V - 1.75V - 0.6V}{20mA} - 0.8\Omega = 124\Omega$$

3.4.4 Photo of the LED-PCB



3.4.5 Remarks

FET's

Normally the gate of a FET has a very high resistance to the other connections. But it has a parasitary capacitance (BSP315, $C_{iss_max} = 400\text{pF}$). When the gate is switched with a fast PWM signal, very high currents may appear. Because the microcontroller can deliver only 2mA i protect it's output with a resistor.

$$R_{SeriesResistance} = \frac{U}{I} = \frac{5V}{2mA} = 2.5k\Omega$$

Now even with a short circuit the current in or out to a port can't exceed 2mA.

Photo Interrupter

The photo interrupter is also located on the LED-PCB.

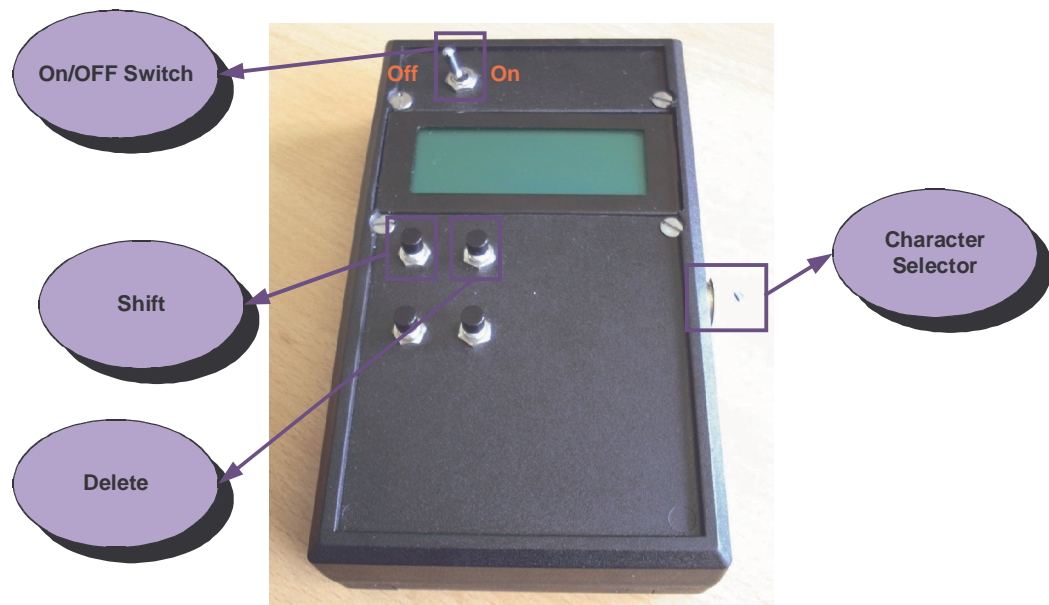
3.5 Terminal

3.5.1 Constituents

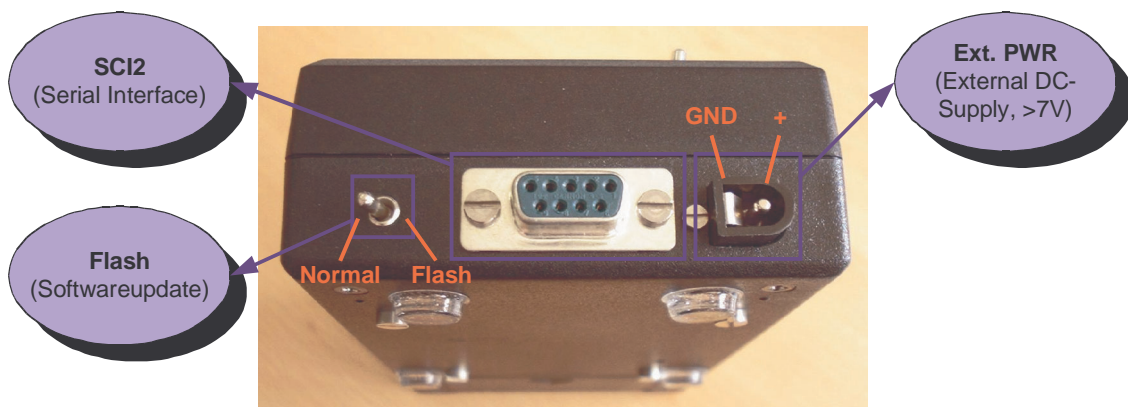
The terminal consists of the following parts:

<i>Component</i>	<i>Self made</i>
Microcontroller PCB	✓
LCD-Display	
Radio PCB	
Housing	
Software	✓
Expendable items (switches, battery, connectors, screws...)	

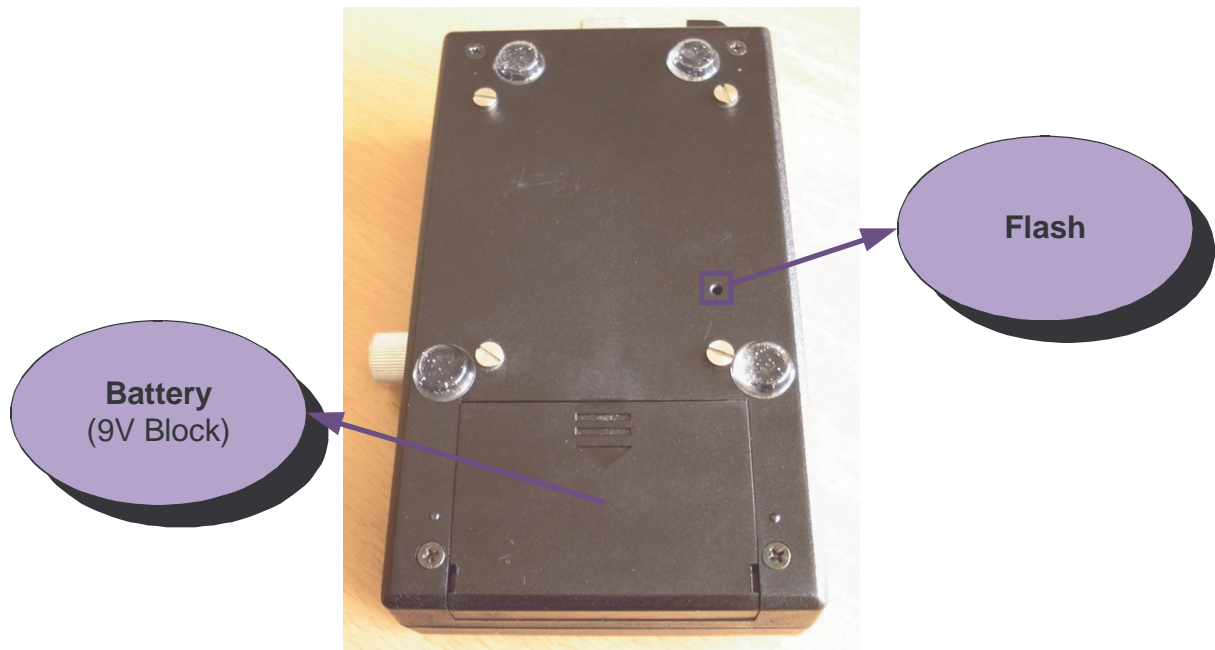
3.5.2 Front



3.5.3 Connectors



3.5.4 Backside



3.5.5 Electrical Connections

Switches/Incremental switch

The H8S/2633 microcontroller on some ports has internal pull-up resistors. So it's possible to connect switches directly to a port and the other side to ground.

<i>What</i>	<i>Connection/Pin on μC-Board</i>	<i>Microcontroller</i>
Shift Switch	25-Pin. D-Sub / 16	PE3
Delete Switch	25-Pin. D-Sub / 4	PE4
Incremental switch A	25-Pin. D-Sub / 15	PE1
Incremental switch B	25-Pin. D-Sub / 3	PE2
Incremental switch Push	25-Pin. D-Sub / 2	PE0

Radio PCB

<i>What</i>	<i>Connection/Pin on μC-Board</i>	<i>Microcontroller</i>
TXEN	25-Pin. D-Sub / 25	PG2
CS	25-Pin. D-Sub / 12	PG1
PWR_UP	25-Pin. D-Sub / 24	PG0
DOUT	25-Pin. D-Sub / 23	RxD0
DIN	25-Pin. D-Sub / 10	TxD0

LCD-Display

The LCD-Display is connected on it's own connector on the microcontroller PCB.

For the pin assignment have a look at the file „Pins_p04.pdf“.

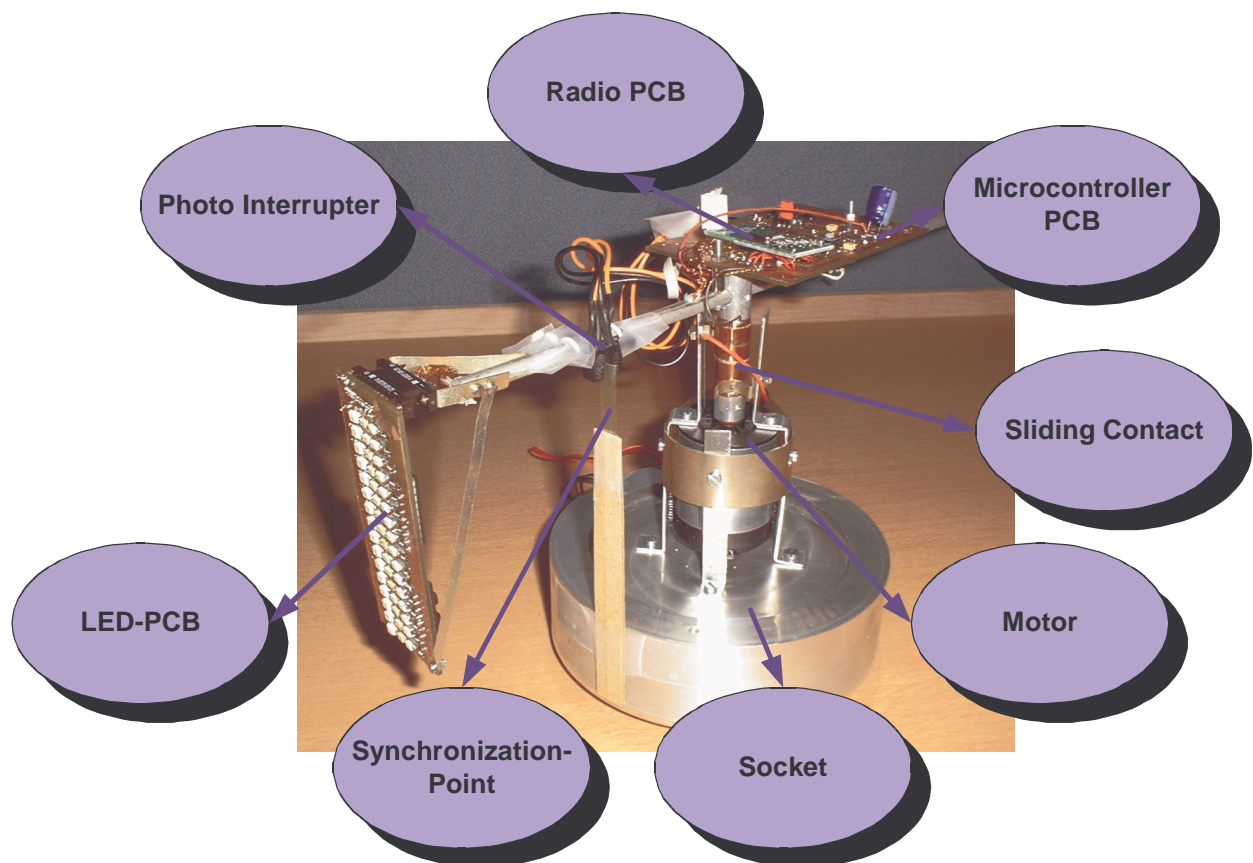
3.6 Propeller

3.6.1 Constituents

The propeller consists of the following parts:

<i>Component</i>	<i>Self made</i>
Microcontroller PCB	✓
LED-PCB	✓
Radio PCB	
Motor	
Supply transfer to the propeller	✓
Mechanicals	✓
Software	✓
Expendable items (photo interrupter, connectors...)	

3.6.2 Photo of the second prototype



3.6.3 Modification

The photo interrupter on the LED-PCB didn't work well, so I mounted it on the propeller arm. For high speeds the LED-PCB was too flexible.

3.6.4 Electrical Connections

Radio PCB

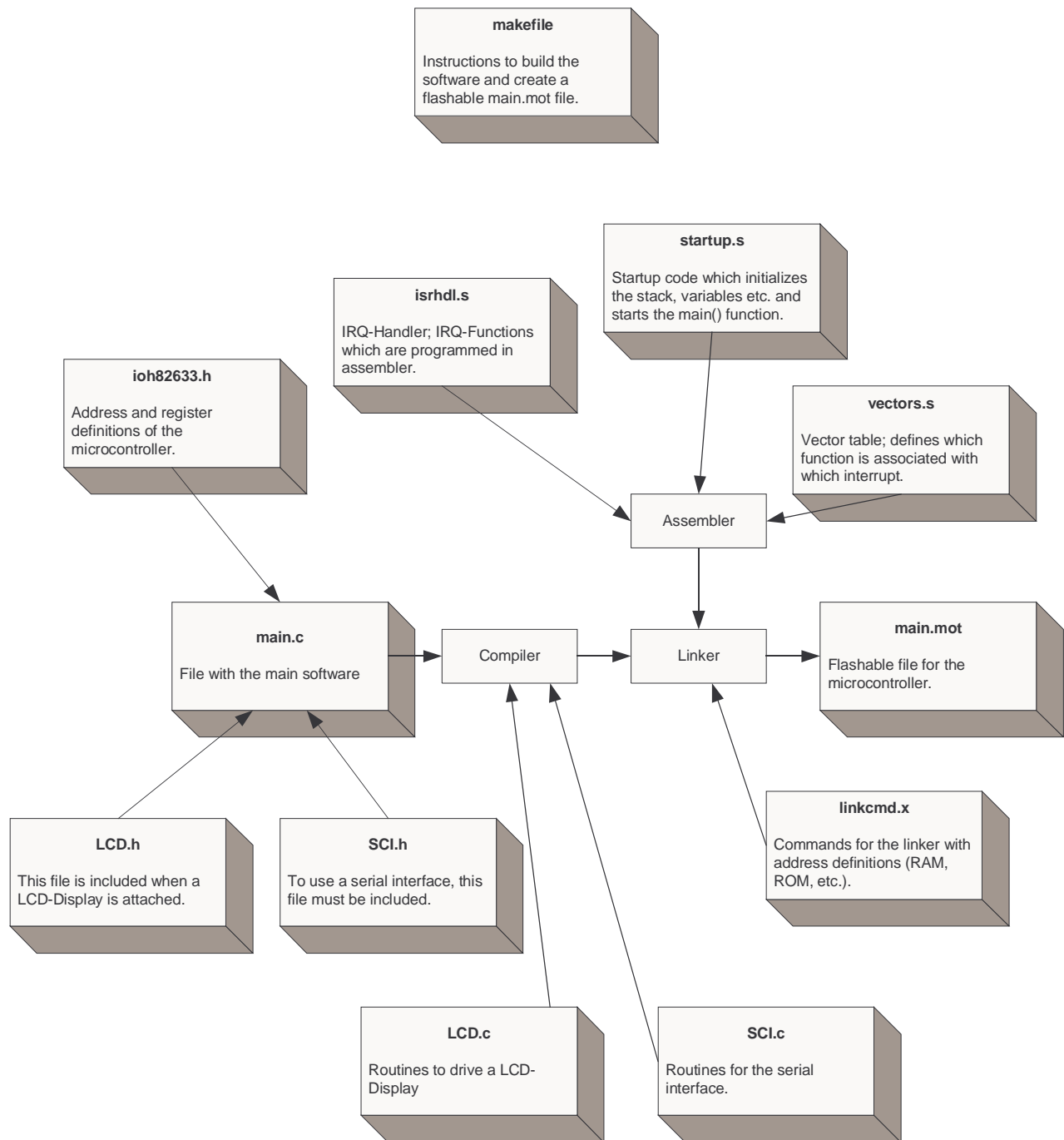
<i>What</i>	<i>Connection/Pin on μC-Board</i>	<i>Microcontroller</i>
TXEN (Pin 1)	25-Pin. D-Sub / 25	PG2
CS (Pin 4)	25-Pin. D-Sub / 12	PG1
PWR_UP (Pin 2)	25-Pin. D-Sub / 24	PG0
DOUT (Pin 8)	25-Pin. D-Sub / 23	RxD0
DIN (Pin 6)	25-Pin. D-Sub / 10	TxD0

LED-PCB

<i>What</i>	<i>Connection/Pin on μC-Board</i>	<i>Microcontroller</i>
ROW1 (Pin 17) Blue	JP4 / 3	PWM3
ROW2 (Pin 18) Green	JP4 / 2	PWM2
ROW3 (Pin 19) Red	JP4 / 1	PWM1
Photo interrupter (Pin 20)	JP3 / 2	IRQ0
5V (Pin 25)	25-Pin. D-Sub / 14	-
GND (Pin 24)	25-Pin. D-Sub / 1	-
LED D1 (Pin 1)	25-Pin. D-Sub / 22	PD7
LED D2 (Pin 2)	25-Pin. D-Sub / 9	PD6
LED D3 (Pin 3)	25-Pin. D-Sub / 21	PD5
LED D4 (Pin 4)	25-Pin. D-Sub / 8	PD4
LED D5 (Pin 5)	25-Pin. D-Sub / 20	PD3
LED D6 (Pin 6)	25-Pin. D-Sub / 7	PD2
LED D7 (Pin 7)	25-Pin. D-Sub / 19	PD1
LED D8 (Pin 8)	25-Pin. D-Sub / 6	PD0
LED D9 (Pin 9)	25-Pin. D-Sub / 18	PE7
LED D10 (Pin 10)	25-Pin. D-Sub / 5	PE6
LED D11 (Pin 11)	25-Pin. D-Sub / 17	PE5
LED D12 (Pin 12)	25-Pin. D-Sub / 4	PE4
LED D13 (Pin 13)	25-Pin. D-Sub / 16	PE3
LED D14 (Pin 14)	25-Pin. D-Sub / 3	PE2
LED D15 (Pin 15)	25-Pin. D-Sub / 15	PE1
LED D16 (Pin 16)	25-Pin. D-Sub / 2	PE0

3.7 Software

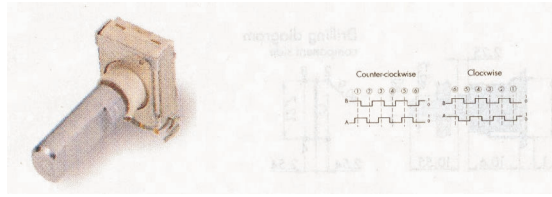
3.7.1 Different Files



3.7.2 Build and flash the software

After programming the software, the batchfile „compile.bat“ can be startet. This run's the GNU-Compiler which compiles the C-Files. After that the assembler assembles the assembler files. Compiler and assembler creates objectfiles which are compound to a single file by the linker. With special commands the linker can create directly a flashable .mot file.

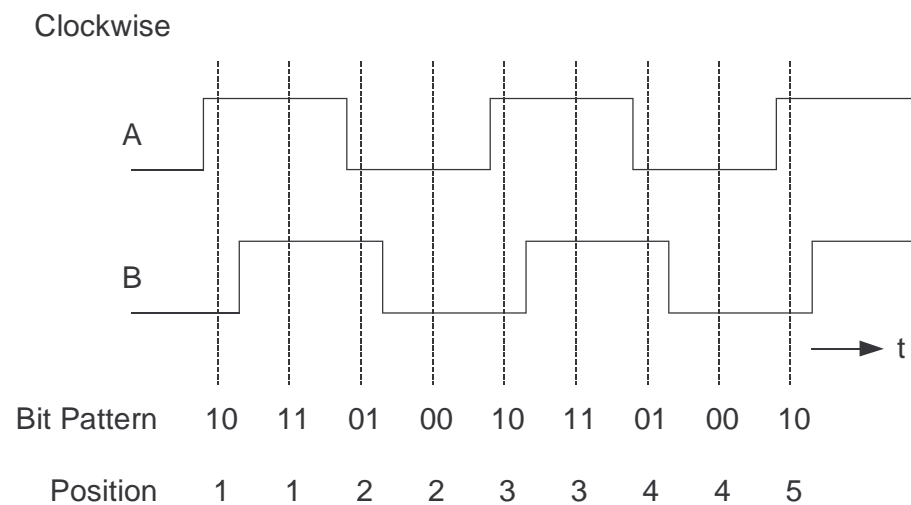
3.7.3 Rotation Switch



3.7.3.1 Introduction

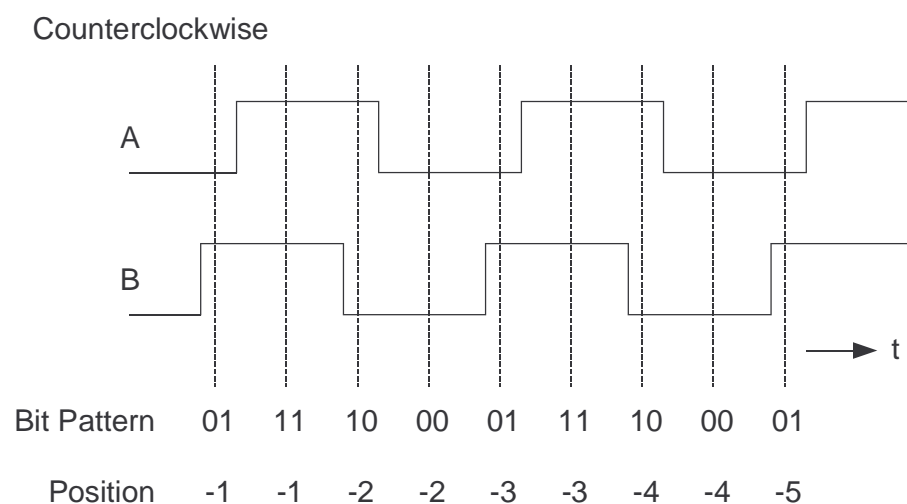
This switch outputs three signals. One signal represents the push function. The other two signals show the steps and direction of the rotation.

Following signals appear when the switch is rotated clockwise:



In resting state the signals A and B are both either low or high. Only if a step happens, first signal A changes it's state and after a short time also signal B.

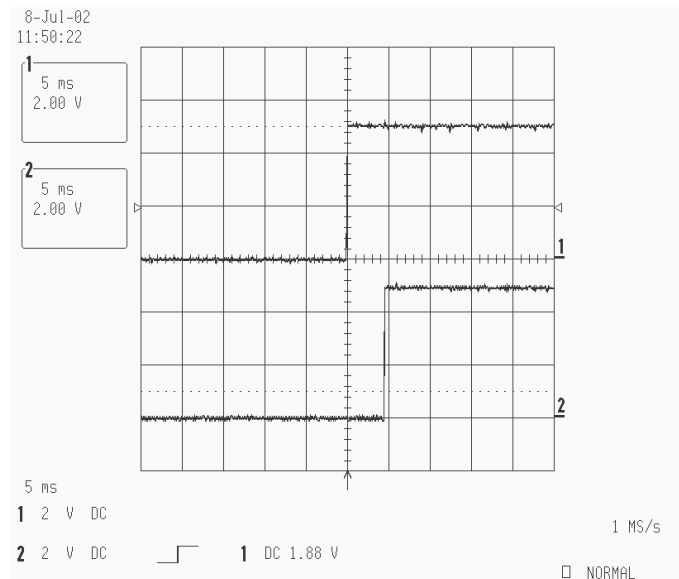
Following signals appear when the switch is rotated counterclockwise:



Here firstly signal B changes on a step and then signal A.

3.7.3.2 Measurements

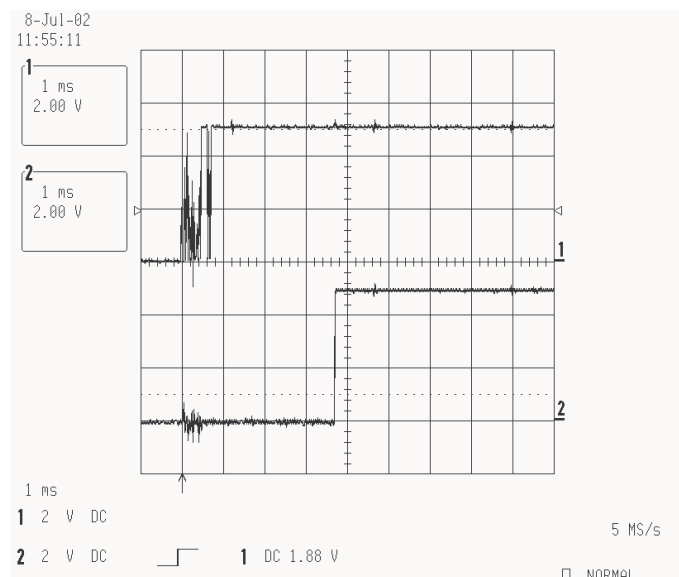
Sequencing is a measurement of the signals to show how the timings of the switch are. After that we see how fast the microcontroller has to react to these signals.



If the switch is rotated slowly, the time between the two signals is about 5ms. If it is rotated very fast, this time is about 2ms.

To not lose any steps it's necessary to poll the signals twice as fast as they appear. This time is about a millisecond.

Sometimes the signals bounce a bit. How long does the signal bounce?



The bouncing time can be up to one millisecond long. In this phase the state of the switch is undefined. It has to be filtered away.

3.7.3.3 Solution with Interrupts

An elegantly way to react to the signals of the rotation switch is to fire an interrupt when a step appears. It's necessary to setup the IRQ's that these are reacting to the rising and falling flanks of the signals.

If a step appears let's say interrupt A is fired firstly and when a step to the other side appears, interrupt B is fired firstly and after some time also the other interrupt.

Because of the bouncing of the signals when they change it's necessary to disable the interrupts in this time – about one millisecond.

I implemented this variant, but it has some problems:

Problem 1 (slow rotation)

If the rotation switch is rotated very slowly, the first interrupt appears and the software opines that one step has happened. After that (the interrupts are enabled after the bouncing time), the other interrupt appears and the software opines that a step on the other side appeared. But this isn't true.

Problem 2 (fast rotation)

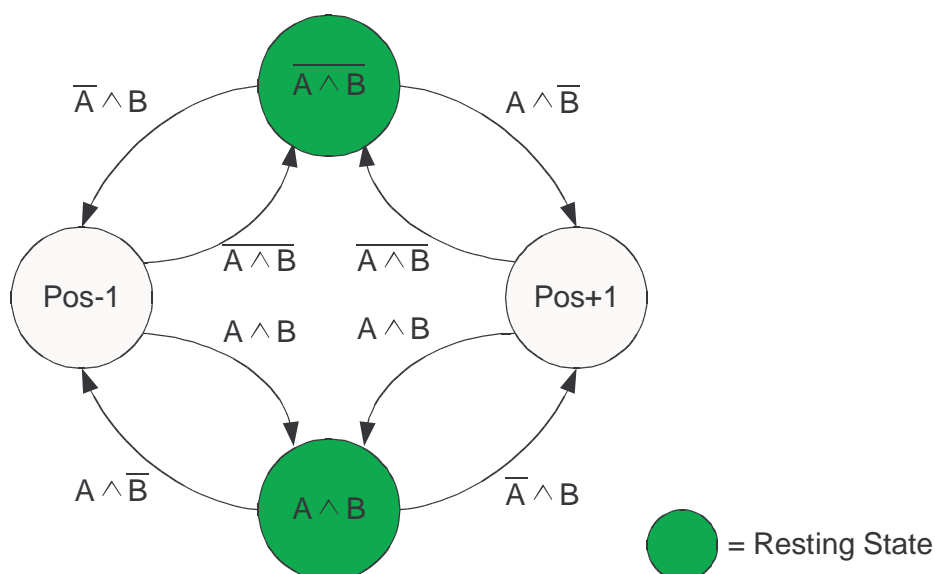
If the switch is rotated very fast it seems that the software is generating random numbers. This appears because after the bouncing time is over and the interrupts are enabled, it's not defined which interrupt is fired next time.

Conclusion

This solutions with the interrupts isn't a good solution. It works only if the user rotates the switch with an average speed. Not too fast and not too slow.

3.7.3.4 Solution with a State Machine

My second solution is one with a state machine. The signals A and B of the rotation switch are polled periodically and then given to a state machine.



This state machine was quite easy to implement:

```
void RotationSwitch_Read(void)
{
    unsigned char SwitchState;
    static unsigned int SwitchState_before = 0;

    SwitchState = PORTE & 6;          // Take bits 1 and 2 from port E
    SwitchState = SwitchState >> 1;

    if (SwitchState != SwitchState_before) // If state changed
    {
        switch (SwitchState)
        {
            // On a step
            case 1: if (SwitchState_before == 3) // If switch was idle (11)
                    {
                        RotationSwitch_counter++; // One step to the right
                        UserInput = 1;           // Signalisation for main-program
                    }
                    else
                    {
                        RotationSwitch_counter--; // One step to the left
                        UserInput = 1;           // Signalisation for main-program
                    }
                    break;

            // On a step
            case 2: if (SwitchState_before == 0) // If switch was idle (00)
                    {
                        RotationSwitch_counter++; // One step to the right
                        UserInput = 1;           // Signalisation for main-program
                    }
                    else
                    {
                        RotationSwitch_counter--; // One step to the left
                        UserInput = 1;           // Signalisation for main-program
                    }
                    break;
        }
    }

    SwitchState_before = SwitchState;
}
```

Description of the code

The function „RotationSwitch_Read“ is called periodically by a timer interrupt every millisecond.

In the variable „SwitchState“ is the current position of the switch. Only if something changed to the last poll, the next instructions are executed.

Only if the signals are different (case 1 or case 2) a step happend.

If the current SwitchState is 01 (dez 1) and before it was 11 (dez 3), then a step to the right appeared.

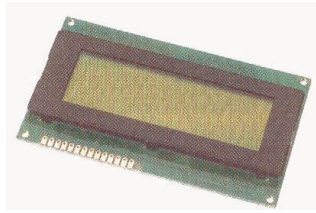
If the current SwitchState is 01 (dez 1) and before it was 00 (dez 0), then a step to the left appeared.

Test / Result

In contrast with the interrupt driven variant described before, this variant with the state machine is working very well. Even if the switch is rotated very fast or very slow the results are great.

It is working best when the polling interval is about 2ms.

3.7.4 LCD Driver



3.7.4.1 Introduction

Standard character based LCD-Displays use a HD44780 or compatible controller by Hitachi. It has a built in font and drives the LCD itself with the necessary voltages.

It's simple to use such a display; firstly it has to be initialized and after that the text can be transferred to the RAM of the display controller. The controller then shows this text on the lcd.

To save some pins on the microcontroller, i drive the display in the 4-Bit mode. Data is transferred in a high- and low-nibble.

All LCD related functions i put in a separately C-File (lcd.c, lcd.h).

3.7.4.2 Function Overview

<i>Name</i>	<i>Description</i>
LCD_Wait_Time	The display controller is very slow, so this function waits until the display controller is ready for the next command.
LCD_Wait *	Reads the busy-flag of the display controller and returns if the display is ready for the next commands (only works after initialization of the display).
LCD_Init *	Initializes the display. Sets 4 or 8-Bit mode, cursor on/off, blinking of the cursor ect.
LCD_WriteInstr *	Sends an instruction to the display
LCD_Clear	Clears the display
LCD_Control	Sets display active/passive, cursor on/off/blinking
LCD_SetCursor	Puts the cursor to a specific line and character position
LCD_WriteChar *	Puts a single character to the actual cursor position
LCD_WriteStr	Writes a string (array of unsigned char) to the display until the zero character is reached (ASCII-Character 0).
LCD_WriteInt *	Writes an integer value (signed 16-Bit) as text to the display.

*These functions are explained below

3.7.4.3 LCD_Wait

```
void LCD_Wait(unsigned char Enable)
{
    unsigned char busy;

    PBDDR = 8 | 4 | 2 | 1; // Set all pins on port B as outputs, except D4 to D7
    do
    {
        PBDR = 4;           // Read from Display
        PBDR = Enable | 4;  // Read and Enable (High Nibble)
        busy = PORTB & 128; // Read Busy Flag
        PBDR = 4;           // Enable low
        PBDR = Enable | 4;  // Read and Enable (Low Nibble)
        PBDR = 4;           // Enable low
    }
    while (busy);           // Repeat until Busy-Flag is reset
    PBDR = 0;              // Disable / Write
    PBDDR = 255;           // All pins as outputs
}
```

Firstly, all pins which are connected to the display except the data-bus (D4...D7) are defined as outputs.

Then the signal R/W (Read/Write) is set to high, now we can read from the display.

If the enable signal is given to the display, it puts it's data on the bus and the microcontroller can read it. First the high nibble of the data (upper 4 Bits) and on the next time the enable signal is given, it outputs the low nibble (lower 4 Bits).

On large displays with 4 lines and 40 characters there are 2 controller chips. One is controlling the upper 2 lines and the other the lower 2 lines. The controller is selected by give the right bit as parameter to the function.

Reading of the busy flag is repeated until it is reset and the display is ready to receive new command or data.

When the display is ready, all pins of port B are set to outputs.

3.7.4.4 LCD_Init

```

void LCD_Init(unsigned char DisplayType)
{
    unsigned char enable;

    enable = 9;          // Init both display controllers (bit 0 and bit 3)

    PBDDR = 255;         // Pord B as output

    LCD_Wait_Time(15);   // Wait min. 15ms
    PBDR = enable;       // Enable1, Enable2
    PBDR = enable | 48;  // Enable1, Enable2, Data (3), Init
    PBDR = 48;           // Data (3)
    LCD_Wait_Time(5);    // Wait min. 5ms
    PBDR = enable;       // Enable1, Enable2
    PBDR = enable | 48;  // Enable1, Enable2, Data (3), Init
    PBDR = 48;           // Data (3)
    LCD_Wait_Time(1);    // Wait min. 160us
    PBDR = enable;       // Enable1, Enable2
    PBDR = enable | 48;  // Enable1, Enable2, Data (3), Init
    PBDR = 48;           // Data (3)
    LCD_Wait_Time(1);    // Wait min. 160us
    PBDR = enable;       // Enable1, Enable2
    PBDR = enable | 32;  // Enable1, Enable2, Data (2), 4-Bit Mode
    PBDR = 32;           // Data (2)
    LCD_Wait_Time(1);    // Wait min. 160us

    // From now, 2 Nibbles required
    LCD_WriteInstr(3, 40); // DataLength 4-Bit, 2 Lines, 5x8Dots Font
    LCD_Clear();          // Clear Display
    LCD_Control(3, 1, 0, 0); // Display On, Cursor Off, Blink Off
    LCD_WriteInstr(3, 128 | 0); // Set DDRAM Addr. 0

    LCD_Wait_Time(1);     // Wait

    // Set variables for different display types
    switch (DisplayType)
    {
        // Display with 4 lines and 40 chracters
        case 0: DDRAM_Offset_Line_1 = 0;
                DDRAM_Offset_Line_2 = 64;
                DDRAM_Offset_Line_3 = 0;
                DDRAM_Offset_Line_4 = 64;
                ControllerCount = 2;
                break;

        // Display with 4 lines and 20 chracters
        case 1: DDRAM_Offset_Line_1 = 0;
                DDRAM_Offset_Line_2 = 64;
                DDRAM_Offset_Line_3 = 20;
                DDRAM_Offset_Line_4 = 84;
                ControllerCount = 1;

    }
}

```

The initializing of the display is done according to the description in the datasheet of the HD44780 page 46.

After the initialization the DDRAM-Offset's are set equal to the display type which is connected.

Possible values for the parameter DisplayType:

<i>DisplayType</i>	<i>Description</i>
0	For display with 4 lines and 40 characters per line
1	For display with 4 lines and 20 characters per line For display with 2 lines and 20 characters per line

3.7.4.5 LCD_WriteInstr

```
void LCD_WriteInstr(unsigned char LCD_Controller, unsigned char Instr)
{
    unsigned char enable;

    switch (LCD_Controller)
    {
        case 1: enable = 8; // Activates first LCD_Controller on the display
                break;

        case 2: enable = 1; // Activates second LCD_Controller on the display (on large displays)
                break;

        case 3: enable = 9; // Activates both LCD_Controller
                break;

        default: enable = 8;
    }

    // Send High Nibble
    PBDR = enable; // Enable1, Enable2
    PBDR = enable | (240 & Instr); // Enable and HighNibble from Instr
    PBDR = 240 & Instr; // HighNibble from Instr
    LCD_Wait(enable); // wait 37us (?)

    // Send Low Nibble
    Instr = Instr << 4;
    PBDR = enable; // Enable1, Enable2
    PBDR = enable | Instr; // Enable and LowNibble from Instr
    PBDR = Instr; // LowNibble from Instr
    LCD_Wait(enable); // wait 37us (?)
}
```

Possible values for the parameter LCD_Controller:

<i>LCD_Controller</i>	<i>Description</i>
1	Selects first controller
2	Selects second controller
3	Sends the command to both controllers simultaneous

Firstly the HighNibble of the instruction is sent to the display; The enable signal is going to high, after that additionally the upper 4 bits of the instructions are put on the bus. When the enable is going to low and the data is still on the bus, the displays inputs this data.

Now the busy flag is read and when the display is ready, the same happens to the lower 4 bits of the instruction.

When the busy flag is low, the instruction has been executed by the display and it is ready for the next instruction.

3.7.4.6 *LCD_WriteChar*

Example

```
LCD_WriteChar(8, 'C');
```

Enables display controller 1 and writes a C to the current cursor position.

3.7.4.7 *LCD_WriteInt*

Example

```
LCD_WriteInt(1, 5, -232);
```

Writes -232 on line 1 of the display on cursor position 5.

3.7.5 Serial Interface

3.7.5.1 Introduction

The H8S/2633 microcontroller has 5 serial interfaces built in. Other microcontrollers can be connected to it, a PC or other peripherals.

Every serial interface (SCI) can be synchronous, asynchronous, has it's own baudrate and data format (or 8 databits, parity, number of stopbits).

One SCI has the possibility to drive an IrDA transceiver chip directly.

All SCI based functions are collected together in the files sci.c and sci.h. In a project simply the sci.h can be included and then a serial interface can be used.

3.7.5.2 Function Overview

<i>Name</i>	<i>Function</i>
SCI_Init *	Initializes the serial interface. Sets the baudrate, activates the interface, enables the required interrupts etc.
SCI_WriteChar *	Writes a character to the send-buffer. If the interface is ready, it sends out this character and deletes it from the buffer.
SCI_WriteStr	Sends a whole string to the serial interface until the zero-character is reached. (Uses SCI_WriteChar)
SCI_WriteLn	Same as SCI_WriteStr, but adds a CR (Carriage Return) and LF (Line Feed) to the string.
SCI_WriteCRLF	Sends a Carriage Return and Line Feed
SCI_WriteInt	Converts a 16-bit integer value to a string and sends it to the serial interface.
SCI_GetRecBufferCount	Returns the number of characters in the receivebuffer.
SCI_GetSenBufferCount	Returns the number of characters in the sendbuffer.
SCI_GetRecBufferChar *	Gets a character from the receivebuffer and deletes it from the buffer.
SCI_IRQRecChar *	Interrupt funktion which receives a character and puts it on the receivebuffer.

*These functions are explained below

3.7.5.3 SCI_Init

```
void SCI0_Init(void) // Like example in hardware manual page 621
{
    unsigned int index;
    unsigned int wait;
    unsigned char Clock;

    SCI0_RecBuf_CharCount = 0;
    SCI0_SenBuf_CharCount = 0;

    // Initialize receivebuffer
    for (index=0; index<SCI0_RecBuf_Length; index++)
    {
        SCI0_RecBuf[index] = '\0';
    }

    // Initialize sendbuffer
    for (index=0; index<SCI0_SenBuf_Length; index++)
    {
        SCI0_SenBuf[index] = '\0';
    }

    Clock = 0; // SCI Clock = Internal (Asynchronous Mode)

    MSTPCRB = MSTPCRB & 127; // SCI0 Start (Bit 7 => 0)
    SCR0 = SCR0 & 207; // Reset TE- and RE-Bits
    SCR0 = (SCR0 & 207) | Clock; // Set Clock
    SMR0 = 0; // Asynch, 8-Bit, No Parity, Even Parity, 1 Stop Bit, No
    Multiproc., Clock = Phi
    SCMR0 = 0; // Normal SCI Operation (No Smart Card)
    BRR0 = 29; // 19200 Baud => n = 0, N = 29
    for (wait=0; wait<2000; wait++); // Wait min. a 1-Bit-Interval
    SCR0 = 64 | 32 | 16; // Receive IRQ, Rx/Tx Enabled, Asynch. Clock
}
```

We take a look at the initializing of SCI0, the first serial interface of the H8S/2633 microcontroller.

Firstly the variables SCI_RecBuf_CharCount and SCI_SenBuf_CharCount are set to 0. In this variables is stored, how many characters are in the buffers. These buffers are realized in software.

Now both buffers are initialized, therefore they are filled with null characters in a for-loop.

The Variable Clock defines if the clock for the serial interface is generated internally or is connected externally. In synchronous mode, the clock is coming from outside when data is received.

In the „Module Stop Control Register B“ the serial interface can be started.

Now the parameters for the dataformat can be set. I take a european quasi standart; 8-Bit data, no parity, one stopbit and a baudrate of 19200.

The value for the baudrateregister „BRR2“ has to be calculated.

$$N_{BRR2} = \frac{\phi}{64 \cdot 2^{2n-1} \cdot B} \cdot 10^6 - 1 = \frac{18.432}{64 \cdot 2^{2 \cdot 0 - 1} \cdot 19200} 10^6 - 1 = 29$$

Φ = Main-Clock in MHz, n = Baudratengenerator Clock, B = Baudrate

After waiting a bit and setting SCR0 again, the interface is ready to communicate.

3.7.5.4 SCI_WriteChar

```
void SCI0_WriteChar(unsigned char Data)
{
    while ((SSR0 & 128) != 128); // Waits until last character is sent
    TDR0 = Data;                // Write Data to the send register
    dummy = SSR0;                // Dummy read
    SSR0 = SSR0 & 127;           // Data is ready, start sending
}
```

The top located bit in the register SSR0 signalizes if the last character already was transferred. If this is not the case we have to wait until the last character is sent.

Now we can write our character to the send register TDR0 and tell the microcontroller with reset bit 7 of the register SSR0 that the character is ready to send.

Before register SSR0 is writable, a dummy read is necessary (described in hardware manual).

3.7.5.5 SCI_GetRecBufferChar

```
char SCI0_GetRecBufferChar(void)
{
    char zeichen;

    zeichen = '\0';

    if (SCI0_RecBuf_CharCount > 0)
    {
        zeichen = SCI0_RecBuf[SCI0_RecBuf_ReadPos];
        SCI2_RecBuf_ReadPos++;
        SCI2_RecBuf_ReadPos = SCI0_RecBuf_ReadPos % SCI0_RecBuf_Length;
        SCI2_RecBuf_CharCount--;
    }

    return(zeichen);
}
```

If there aren't any characters inside the receivebuffer ($\text{SCI0_RecBuf_CharCount} < 1$) then this function returns a null.

In the other case, if there is one or more characters inside the buffer the function returns the next character from the buffer and then point to the next automatically. It's working on the principle of a FIFO-Buffer (first in, first out).

When the end of the buffer is reached, the modulo-division takes the ReadPosition back to the beginning of the buffer.

If a character was read from the buffer, the variable `SCI0_RecBuf_CharCount` is decremented.

Now the readed character is returned by the function.

3.7.5.6 *SCI_IRQRecChar*

```
#pragma interrupt
void SCI0_IRQRecChar(void)
{
    // Write a character to the buffy when it isn't full
    if (SCI0_RecBuf_CharCount < SCI0_RecBuf_Length)
    {
        SCI0_RecBuf[SCI0_RecBuf_WritePos] = RDR0;
        SCI0_RecBuf_WritePos++;
        SCI0_RecBuf_WritePos = SCI0_RecBuf_WritePos % SCI0_RecBuf_Length; // Go back to the
        beginning of the buffer
        SCI0_RecBuf_CharCount++;
    }
    dummy = SSR0;
    SSR0 = SSR0 & 191; // RDRF (Receive Data Register Full) reset flag
}
```

This function cannot be used directly.

If the microcontroller received a character, it fires an interrupt and then this function is called.

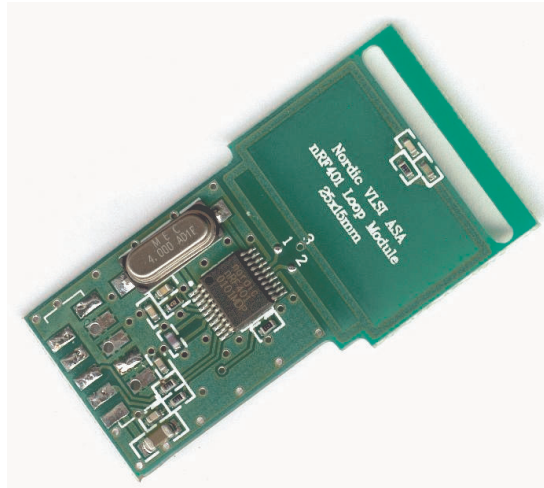
It stores the received character in the receive buffer and increments the variable `SCI0_RecBuf_CharCount` which shows the main program how many characters are currently in the buffer.

When the end of the buffer is reached and it isn't full, the modulo division takes the `SCI0_RecBuf_WritePos` variable to the beginning of the buffer.

If the buffer is full and no more characters can be received because the main program doesn't empties the buffer, the received characters are deleted.

Last but not least the interrupt flag has to be reset. If not, the interrupt is fired again but no new character was received and we get an endless loop.

3.7.6 Wireless data transfer



3.7.6.1 Introduction

For the wireless data transfer between terminal and propeller display i take a „nRF401 Loop Module“ from Nordic. It can be connected to a serial interface of the microcontroller.

Beside the serial interface, three signals which controls the radio module has to be connected:

<i>Signal</i>	<i>Description</i>
TXEN	Transmit enable (0 = Receive, 1 = Send)
PWR_UP	Power On/Off (0 = Standby, 1 = On)
CS	Channel Selection (0 = CH1 433.92MHz, 1 = CH2 434.33MHz)

These signals are connected to port G of the microcontroller and can be controlled by software.

For the data transfer between the radio module and the microcontroller i take SCI0. Both serial interfaces are working with 5V, so they can be connected directly together. The receive and transmit signals has to be crossed out between these two devices.

The receiver on the radio module has a built in PLL which synchronizes the clock with the clock of the sender. To give the receiver a chance to do this synchronization it's necessary to send this bitpattern some times: „10101010“. This correspondents to the decimal value 170.

After this, to synchronize der UART's it's recommended to send this bitpattern: „11111111“.

Now the UART of the receiver can receive the startbit of the following byte correctly.

When there is no sender near the receiver, the receiver is receiving only noise. So the microcontroller has to filter out the data of the noise. For this a simple protocoll is introduced. The microcontroller scans the data stream and looks for a predefined start-sequence. After this it receives all characters until the final-sequence appears.

3.7.6.2 Protocol

Synchronization	Startsequence	Data	Finalsequence
-----------------	---------------	------	---------------

Synchronization

Byte 0:	170	PLL Synchronisation
Byte 1:	255	UART Synchronisation

Startsequence

Bytesequency: „StarT“

Data

Any desired lenght of any bytes except CR and LF.

Finalsequence

Byte 0:	13	Carriage Return (CR)
Byte 1:	10	Line Feed (LF)

Remarks

In the application-note of the loop module „nAN400-07rev1_1.pdf“ is a remark, that the data packets should be as short as possible. Because there may be other senders in the 433MHz band like wireless headphones or toys...

It is also necessary to do some error checking and retransmit the data if something was wrong. Maybe i implement this later if it's necessary.

3.7.6.3 RF_SendStr

This function takes the string from the user, puts it inside the described protocol and sends it through the air.

```
void RF_SendStr(unsigned char *str)
{
    unsigned int index;

    PGDR = 4 | 1;                // Send Mode, Channel 0, PWR_Up

    WaitTime(5);                 // Wait 5ms to start up the loop module

    SCIO_WriteChar(170);          // PLL synchronization with 10101010
    SCIO_WriteChar(170);          // PLL synchronization with 10101010
    SCIO_WriteChar(255);          // UART synchronization
    SCIO_WriteStr(StartString);   // Send startsequence
    SCIO_WriteStr(str);           // Send userstring

    // Send stoppsequency some times
    for (index=0; index<10; index++)
    {
        SCIO_WriteChar(13);
        SCIO_WriteChar(10);
    }

    WaitTime(100);               // Wait some time

    PGDR = 0;                    // Receive Mode, Channel 0, PWR_Down
}
```

Firstly the loop module is activated and switched to send mode.

After this we have to wait min. 3ms to let it start up correctly.

The PLL synchronization and UART synchronization bytes are sent and after that the string. Now the stoppsequency is written to the sendbuffer and. We wait until everything is sent outside.

Sometimes the stoppsequency was not received correctly and then the receive buffer of the receiver was filled with noise after the sender was powered down. So i send the stoppsequence more than once.

3.7.7 Moving Message Display

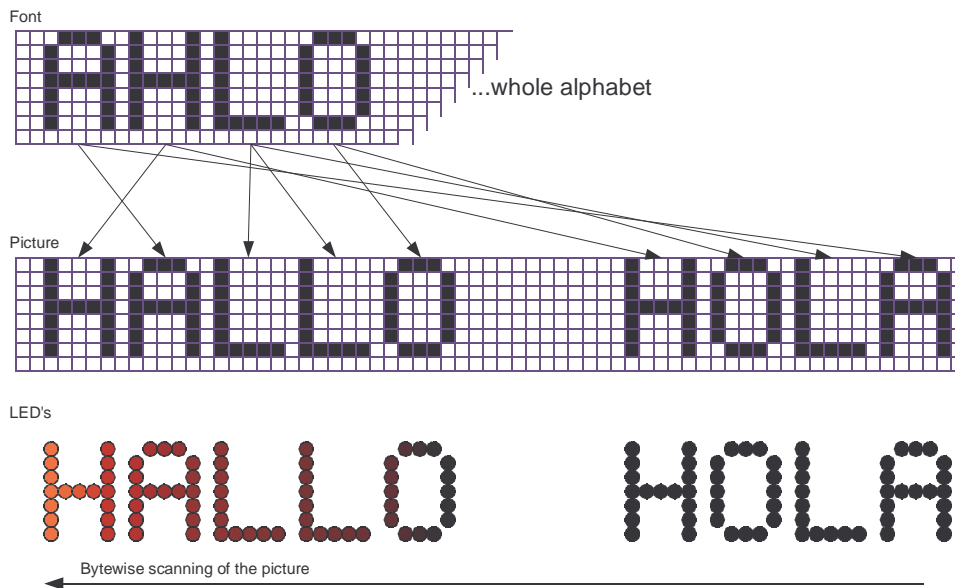
3.7.7.1 Introduction & Principle

Before the text can be displayed, it has to be converted to a bitmap and stored in an array. Because the H8S/2633 has a lot of RAM, i store the whole text as a bitmap in it.

After the conversion, the bitmap can simply transferred periodically to the LED's which displays the picture column by column.

The eye of the visitor puts these columns together to the complete picture.

To convert a string to a bitmap it's necessary to have a font. Every possible character is stored in the flash. A little routine copies the single characters together to obtain a whole string.



Have a look to this principle:

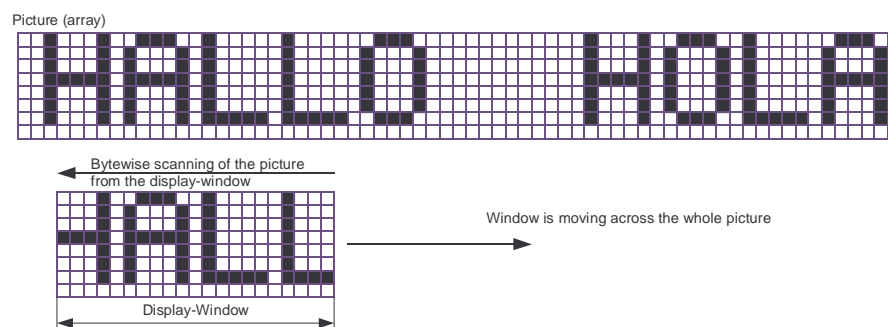
Because the motor of the propeller turns clockwise, the microcontroller has to output the picture from the right side to the left. If the direction would be wrong, the text appears mirrored.

3.7.7.2 Scrolling

Scrolling is relatively easy to implement too. A window which complies to the pixelcount of one round of the propeller is moved over the picture.

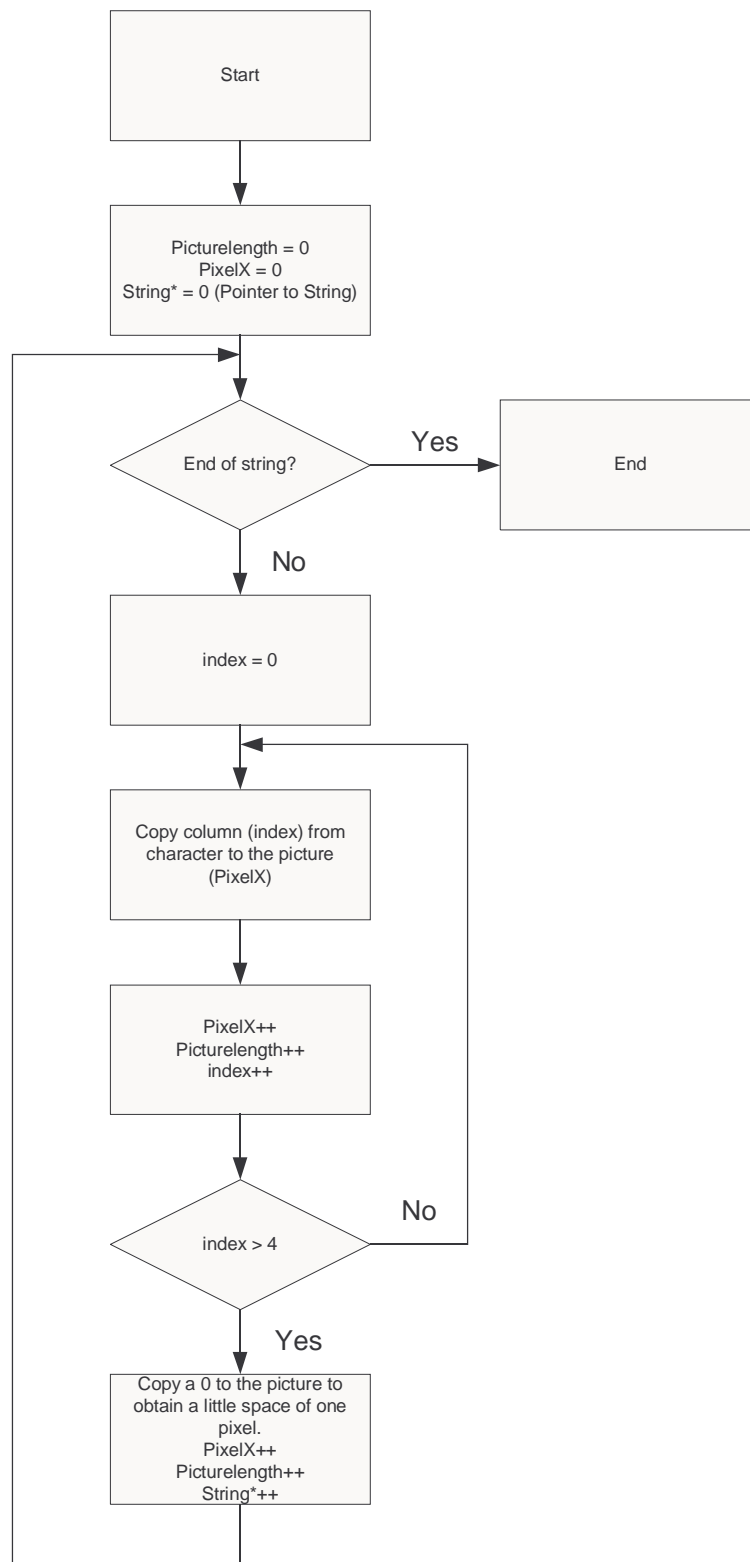
Only the pixels in this window are putted out by the LED's.

When this window moves, also the displayed text moves and it looks like scrolling.



3.7.7.3 Creating the bitmap (function: *InsertText*)

This sequence copies the characters of the font to the bitmap (picture) until the end of the string is reached.



After the process of create the bitmap in the variable „PictureLength“ the horizontal pixelcount is available. The function to scroll the picture needs this information.

Here is the implementation of the picture creation:

```
void InsertText(unsigned char *str)
{
    char NoPicture;
    int index;
    int color;

    while (*str != '\0')
    {
        // If it is a picture and not a character insert it
        NoPicture = 1;
        switch (*str)
        {
            case 177: InsertPicture(0); // TSU-Logo
                     NoPicture = 0;
                     break;

            case 178: InsertPicture(1); // Colortest
                     NoPicture = 0;
                     break;

            case 179: InsertPicture(2); // Smiley
                     NoPicture = 0;
                     break;

            ...<snip>

            case 186: for (index=0; index<32; index++)
                       {
                           InsertPicture(9); // Animation: Running man
                       }
                     ScrollSteps = 16;
                     NoPicture = 0;
                     break;

            case 187: for (index=0; index<9; index++)
                       {
                           InsertPicture(10); // Animation: Coin
                       }
                     ScrollSteps = 16;
                     NoPicture = 0;
                     break;

        }

        // If it isn't a picture, it's a character
        if (NoPicture)
        {
            for (index=0; index<5; index++)
            {
                for (color=0; color<3; color++)
                {
                    Picture[PictureLength][color] = font[*str][index];
                }

                // Update Picture-Length
                if (PictureLength < PictureLengthMax)
                {
                    PictureLength++;
                }
            }
            for (color=0; color<3; color++)
            {
                Picture[PictureLength][color] = 0; // Space between the characters
            }

            // Update Picture-Length
            if (PictureLength < PictureLengthMax)
            {
                PictureLength++;
            }
        }

        str++; // Next character
    }

    DisplayPosition = 0 - DisplayLength;
}
```

When this function is called and given a pointer to it which points to a string (character array), it converts the string into a bitmap.

It copies all characters to the bitmap until the end of the string (zero) is reached.

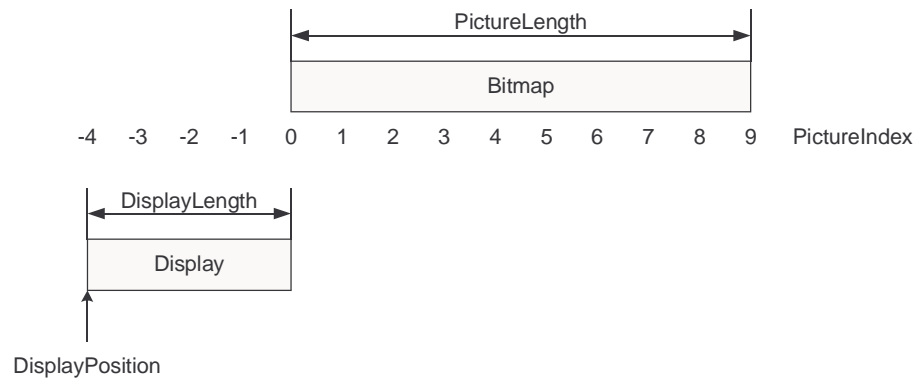
At the end the variable „PictureLength“ shows the length of the created picture.

I used some unused characters as placeholders for pictures. The pictures are also stored in the flash and simply copied to the displayed bitmap.

Remarks

Because the color cannot be chosen the font is copied to the red, blue and green picture array. So the text appears as white.

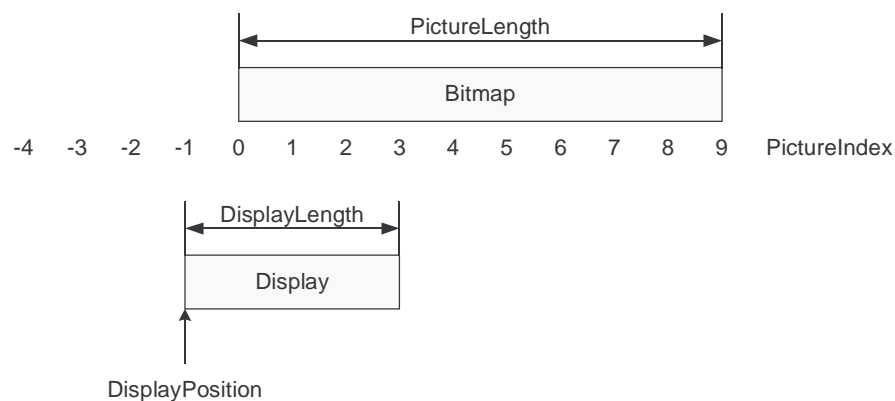
3.7.7.4 Implementation of the scrolling



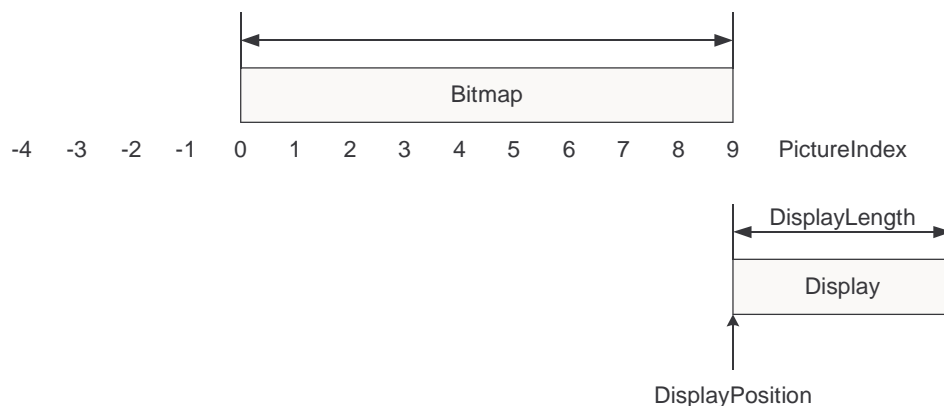
If the picture is created and completely in the picture-array it can be displayed.

The rectangle „Display“ on the graphic represents a round of the propeller.

Startet is the output on the posotion 0 – DisplayLength. If the Position is smaller than 0 no picture is displayed. To scroll one pixel, the DisplayPosition is incremented by one.



Only the pixels of the display which are inside the bitmap are displayed. This can be calculated as follows: $0 \leq \text{PictureIndex} \leq \text{PictureLength}$.

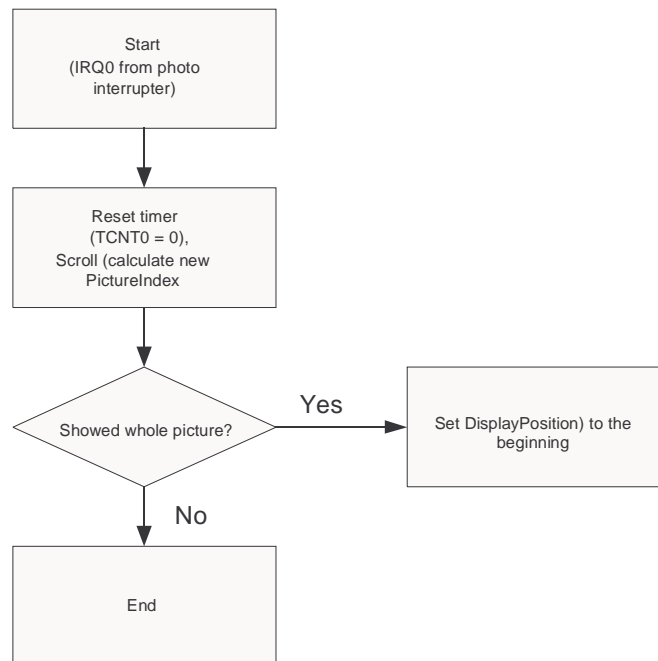


Now the bitmap was displayed completely and after this the display-window „Display“ can be moved to the start: $\text{DisplayPosition} = 0 - \text{DisplayLength}$.

3.7.7.5 Picture synchronization (IRQ0)

Every time the light beam of the photo interrupter is interrupted, IRQ0 is fired.

The function synchronizes the timer which drives the LED's by resetting it to 0. Also the scrolling is issued in this moment.



Code for IRQ0 (called by the photo interrupter)

```

void IRQ0(void)
{
    TCNT0 = 0;                      // Reset Timer

    PictureIndex = DisplayPosition + DisplayLength;

    // Scroll
    DisplayPosition = DisplayPosition + ScrollSteps;
    if (DisplayPosition > PictureLength)
    {
        DisplayPosition = 0 - DisplayLength;
    }

    dummy = ISR;
    ISR = ISR & 254;                // Interrupt 0 rücksetzen
}
  
```

After every time a round from the propeller is complete, the photo interrupter creates this interrupt and calls the IRQ-Function IRQ0.

To synchronize the timer with the propeller, the timer value is set to 0. Now the scrolling appears with actualize the variable „DisplayPosition“. If the scrolling has to be pixelwise, 1 is added to „DisplayPosition“.

When a higher value than 1 is added after a round, the text scrolls faster.

3.7.7.6 Picture Display (IRQ TCNT0 Compare Match)

Controlled by a timerinterrupt (TCNT0 Compare Match), the function „DisplayUpdate“ is called periodically. It's controlling the LED's which are connected to the ports E and D.

```
void DisplayUpdate(void)
{
    static int divider = 0;
    static int counter = 0;
    int PictureIndexTemp;

    if (PictureIndex > -1)
    {
        if (divider < 3)
        {
            switch (counter)
            {
                case 0: // Red
                    PictureIndexTemp = PictureIndex-2;
                    if ((PictureIndexTemp > -1) & (PictureIndexTemp < PictureLength))
                    {
                        PCDR = 0;
                        P1DR = 192;

                        PEDR = Picture[PictureIndexTemp][0] & 255; // Lower 8-Bits of the pic
                        PDDR = (Picture[PictureIndexTemp][0] >> 8) & 255; // Upper 8-Bits of the pic
                    }
                    else
                    {
                        PEDR = 0;
                        PDDR = 0;
                    }
                    break;
                ...<cut> same for green and blue...
            }
        }
        else
        {
            PEDR = 0;
            PDDR = 0;
        }

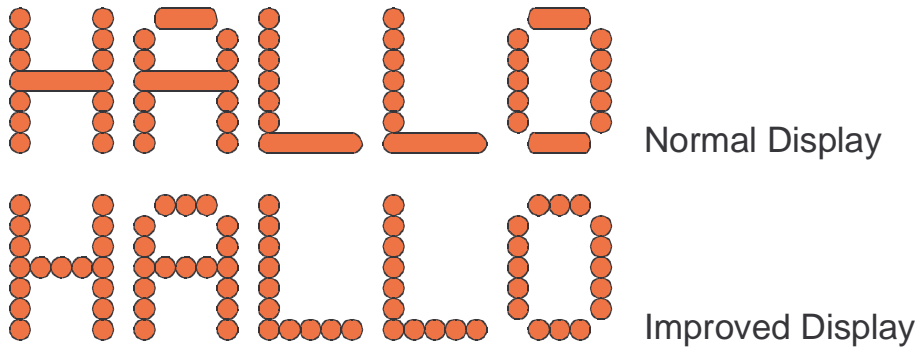
        counter++;
        if (counter > 2)
        {
            counter = 0;
            divider++;
        }

        if (divider > 7)
        {
            divider = 0;
            if (PictureIndex > -2)
            {
                PictureIndex--;
            }
        }
    }
}
```

With port C and port 1 the FET's, which control the colors, are controlled to select the desired color.

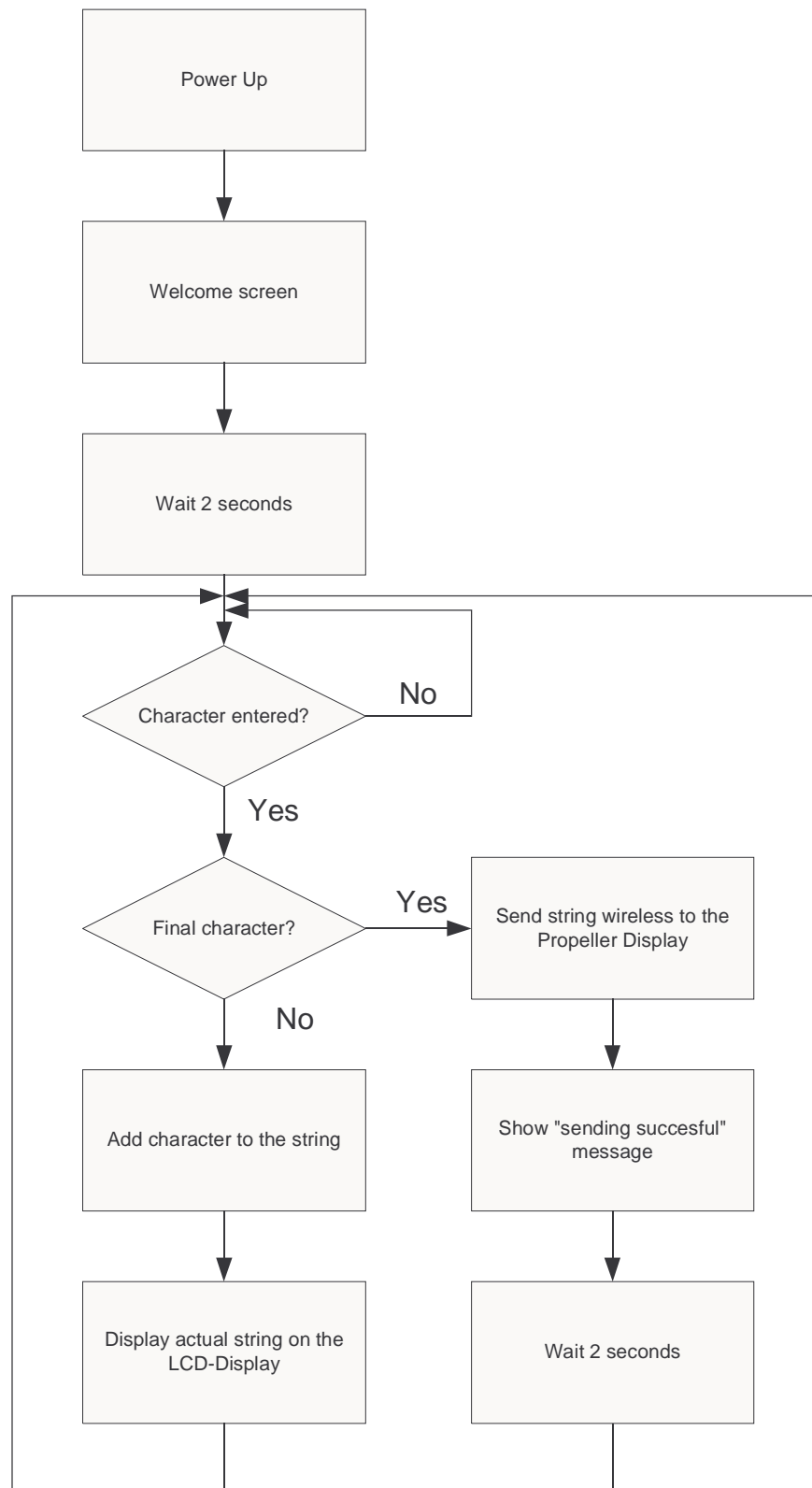
Remarks

For a nicer picture the LED's only flashes a short time when the propeller is on a position. Then they are darkly while the propeller move the LED's to the next pixel position and they flash again. This is done with the divider.



3.7.8 Software for the Terminal

3.7.8.1 Sequency



3.7.8.2 Entering the text

To enter a text, the rotation switch can be rotated until the cursor on the LCD-Display is over the desired character on the alphabet.

Now, a push to the rotation switch selects the character and adds it to the string.



LCD-Display of the terminal

The first three lines of the display shows the current text. On the end of the string, a little arrow is shown.

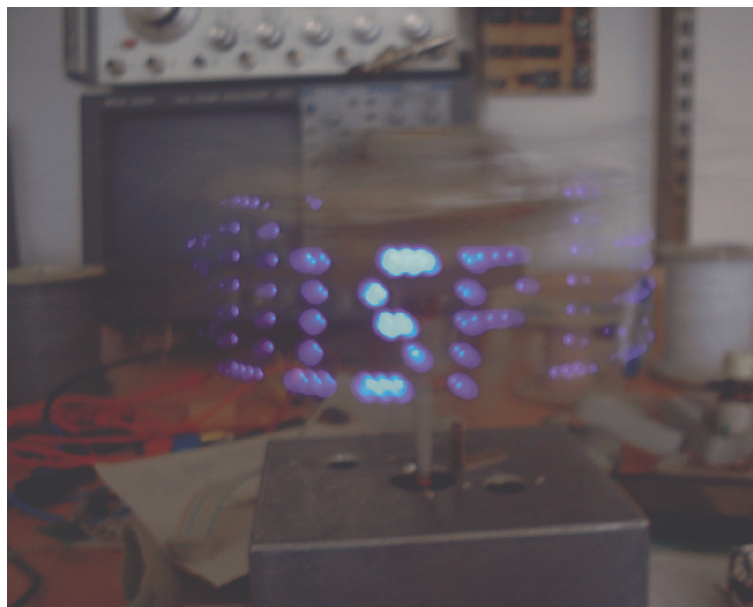
On the example above the text „Propeller Display“ has been entered.

Because not the whole alphabet can be shown at a time, it scrolls when the start or end of the display is reached by the cursor.

3.7.8.3 Sending text to the Propeller Display

If the entered text is complete, we select the arrow from the alphabet showed on the last line of the display and then the text will be transferred to the Propeller Display.

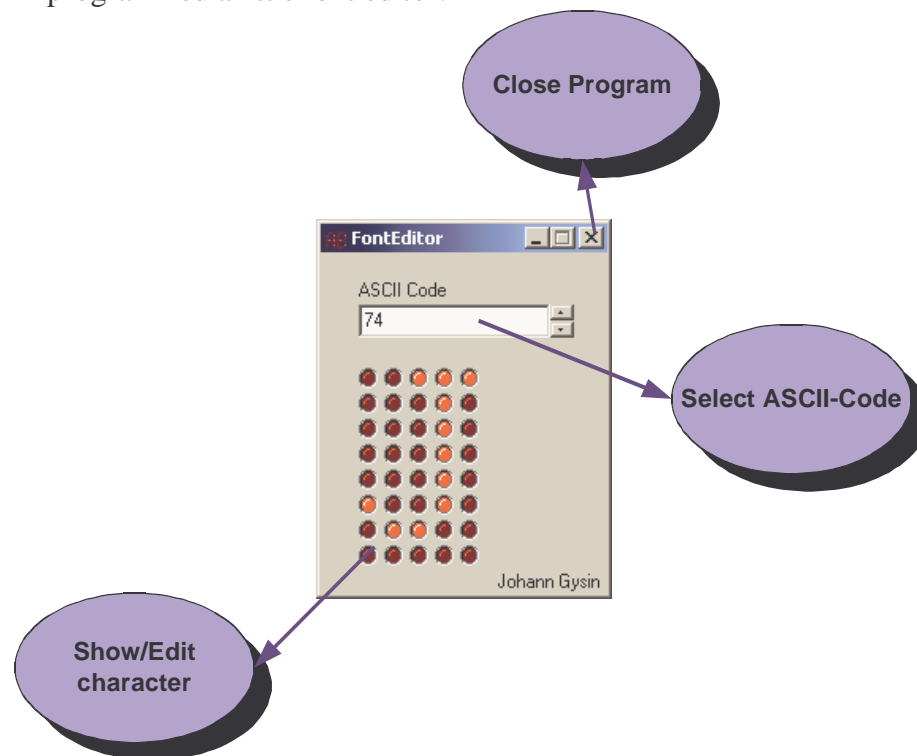
3.7.8.4 Result



Very first prototype shows: „Propeller Display“

3.7.9 Font Editor

In Delphi i programmed a little font editor.



On top of the program a ASCII code can be selected.

After that, by clicking on the virtually LED's the character can be designed.

When the program will be closed, it generates a C-File with an array with the bitmapped characters in it. The organization is as follows: font[ASCII-Code][index]. Each bit represents a pixel.

This generated C-File can be included in the project.

Automatically generated code with the font

```
const unsigned char font[256][5] = {
    {218,140,220,148,218},
    {228,138,68,42,196},
    {236,130,78,42,204},
    {196,42,202,42,196},
    {194,34,194,38,194},
    {0,0,0,0,0},
    {0,0,242,0,0},
    {0,224,0,224,0},
    {40,254,40,254,40},
    {36,84,254,84,72},
    {196,200,16,38,70},
    ...
    {48,138,10,138,60}
};
```

4 Tests

4.1 Checklist coarse

Propeller Display

<i>Function</i>	<i>OK</i>
Motor is running after power up	✓
A demo text is showed	✓
Wireless transferred text is displayed	✓
After power down the motor stopps	✓

Terminal

<i>Funktion</i>	<i>OK</i>
Text can be entered after power up	✓
Easy entering of text	✓
Text can be transferred to the Propeller Display	✓
Message when transfer was corrupt	×

4.2 Microcontroller PCB

<i>Function</i>	<i>Measured</i>	<i>OK</i>
Supply (5V, 3.3V)	4.99V, 3.26V	✓
Quarzfrequency 18.432MHz	18.432MHz	✓
Software is flashable to the microcontroller	-	✓
Correct start up after a power on reset	-	✓
IRQ's are fired (timer, external pins)	-	✓
I/O's can be read and written	-	✓

4.3 Photo Interrupter

<i>Function</i>	<i>OK</i>
Signal is changing when light beam is interrupted	✓

5 Finish

5.1 Checklist

Are the postulated parts of the project ok?

<i>Project part</i>	<i>OK</i>
Basics elaborated	✓
Priorities elaborated	✓
Realizing of the mechanics	✓
Bring power to the propeller (without battery)	✓
Wireless data transfer to the propeller	✓
Drive the LED's correctly	✓
Tests	✓
Optional: Receive a SMS from a handy and show the text	✗



Photo of the second prototype

5.2 Things that can be done better

5.2.1 Propeller (Mechanics)

If the propeller is lighter and more stable, the rotation can be faster. This gives a clear picture without flicker.

5.2.2 Terminal

When there was an error in the transmission of the text to the propeller display a message should be shown on the display.

5.2.3 Wireless data transfer

Sometimes the text isn't transferred without errors. To make the data transfer more safely, a checksum and retransmission should be implemented

5.2.4 Display

It's possible to modulate the LED currents with a PWM signal. Then every RGB-Color is possible by mixing the red, blue and green light.