TECHNISCHE HOCHSCHULE
OSTWESTFALEN-LIPPE
UNIVERSITY OF
APPLIED SCIENCES
AND ARTS

DDS Signalgenerator

Vertiefungspraktikum

10.12.21 | Hannes Krause und Tim Fischer

Überblick

- **Aufgabenstellung & Herausforderungen**
- **Hintergrundwissen**
- **Hardware**
- **Aufbau**
- **Arduino Programm**
- **Remote Programm**
- **Vorführung**
- **Messung und Fehleranalyse**
- **Ausblick**
- **Quellen**

Aufgabenstellung & Herausforderungen

Aufgabenstellung

- **Softwareentwurf DDS-Generator**
- **Festfrequenz**
- **Lineares & logarithmisches Wobbeln**
- **Einstellung aller Frequenzen in 10Hz-Schritten**
- **Menü**
- **Fernsteuerung über PC**

Herausforderungen

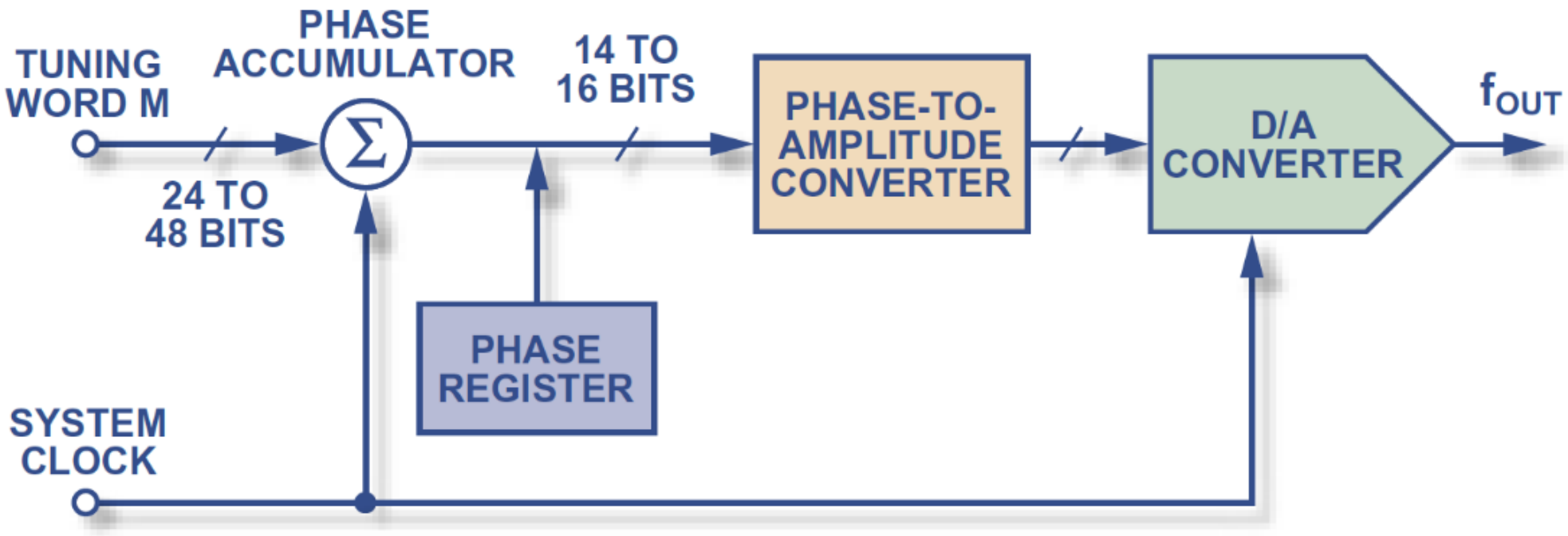
- **Display mit zwei Zeilen stellt hohe Anforderungen an Menü**
- **Begrenzte Eingabemöglichkeit (Rotary Encoder + 3 Taster)**
- **Anforderung von linearem und logarithmischem Frequenzlauf**

Hintergrundwissen

Was ist ein DDS-Generator?

- **DDS = Direct Digital Synthesis/Direct Digital Synthesizer**
- **Verfahren zur Erzeugung analoger Wellenformen**
- **Digital erzeugtes, zeitveränderliches Signal mittels D/A-Wandler in analoge Ausgangsgröße umgewandelt**
- **DDS & D/A-Wandler auf einem Chip: Complete DDS**
- **Referenztakt & Steuerwort benötigt**

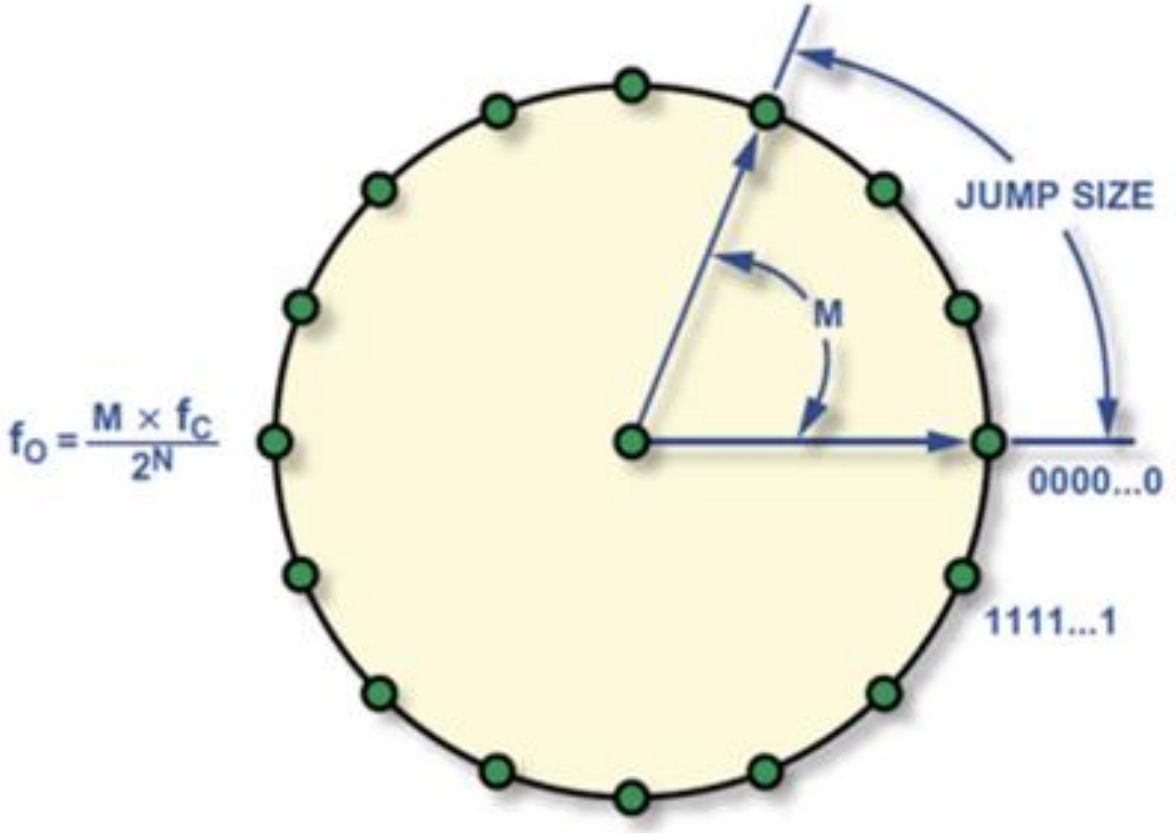
Was ist ein DDS-Generator?



Was ist ein DDS-Generator?

- **Akkumulator addiert pro Taktzyklus Wert des Steuerworts auf aktuellen Akkumulator-Wert**
- **Bei Überlauf Rücksetzen auf Null**
- **→sägezahnförmiger Verlauf des Wertes**
- **→kann als diskretes Maß für Phasenwinkel eines Sinus betrachtet werden**

Was ist ein DDS-Generator?

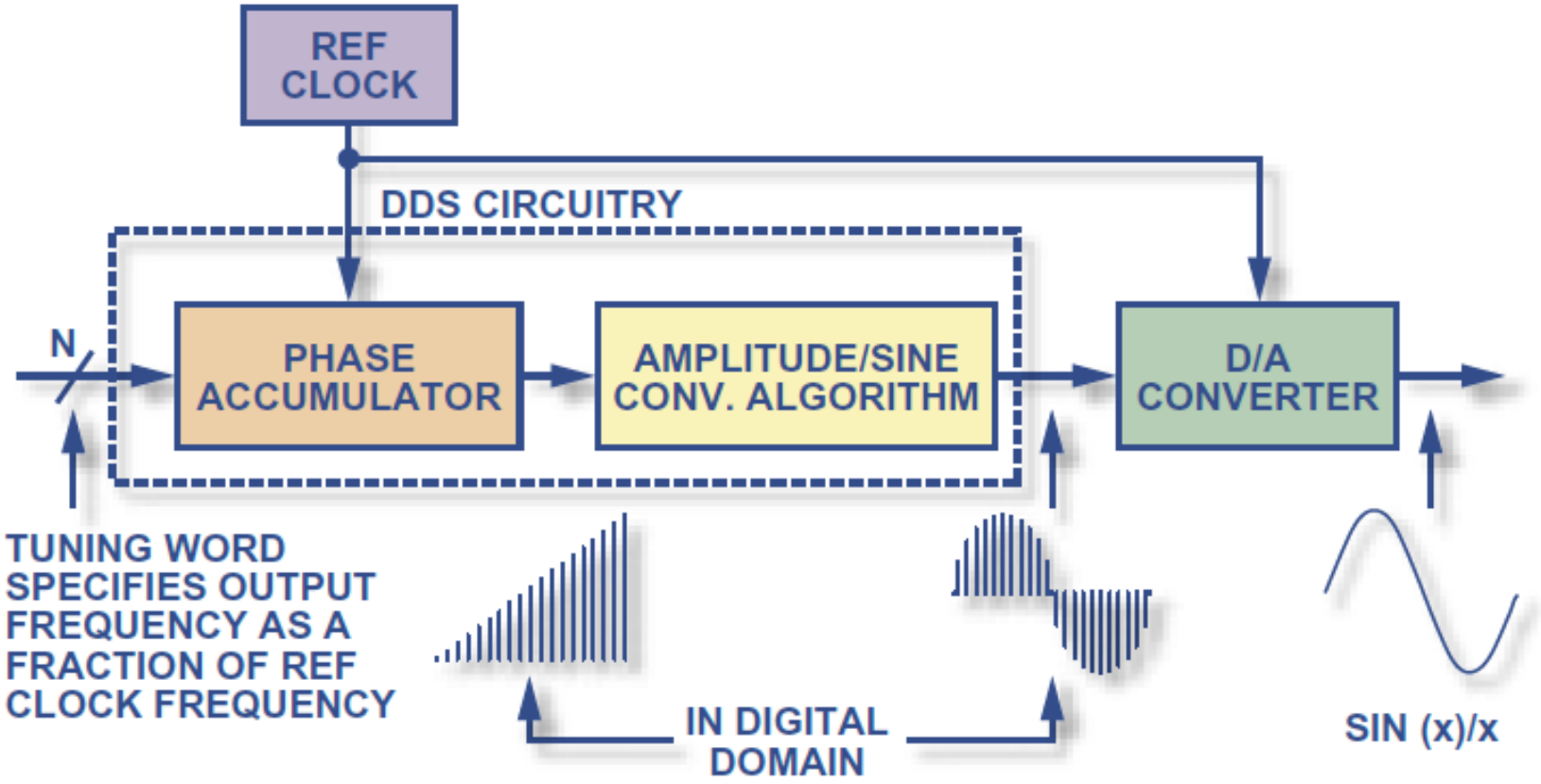


n	NUMBER OF POINTS
8	256
12	4096
16	65535
20	1048576
24	16777216
28	268435456
32	4294967296
48	281474976710656

Was ist ein DDS-Generator?

- $f_{out} = \frac{M * f_c}{2^n}$
- **Nach Nyquist-Shannon gilt:** $f_{out,max} = \frac{f_c}{2}$
- **tatsächliche Maximalfrequenz deutlich kleiner, da dann bessere Signalgüte & Weiterverarbeitung möglich**
- **Zuordnung von Funktionswerten zu Phasenwerten über Lookup-Table oder Algorithmen (z.B. CORDIC)**
- **Erzeugen des quasi-zeitkontinuierlichen , sinusförmigen Ausgangssignals durch den D/A-Wandler**

Was ist ein DDS-Generator?



Was ist ein DDS-Generator?

- **Kompakte & kostengünstige Herstellung**
- **Vollst. digital programmierbar → simple Hardware**
- **Frequenzauflösung im Microhertz-Bereich**
- **Extrem schnelle, exakte Frequenzänderung**
- **Qualitativ hochwertiges Ausgangssignal mit großem Frequenzbereich**
- **Geringer Leistungsbedarf**

Frequenzlauf

- **Auch Sweep, Chirp oder Wobbel genannt**
- **Wechselsignal konstanter Amplitude**
- **Frequenz ändert sich zeitlich periodisch zwischen Start- und Endwert**
- **Änderung in unterschiedlicher Form möglich**

Linearer Frequenzlauf

- **Lineare Frequenzänderung vom Start- zum Endwert:**

$$f(t) = ct + f_0$$

- **Mit Frequenzänderung c:**

$$c = \frac{f_1 - f_0}{T}$$

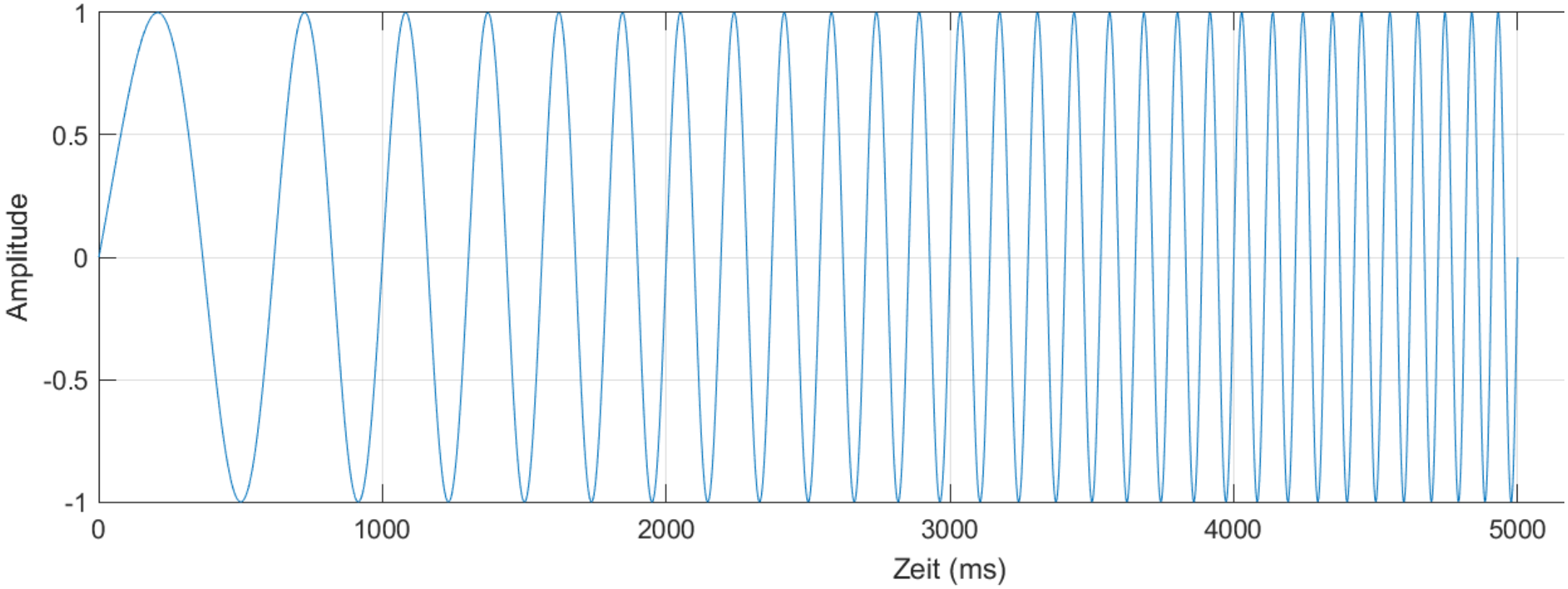
- **Integration der Frequenz liefert Phase:**

$$\varphi(t) = \varphi_0 + 2\pi \int_0^t f(\tau)\, d\tau$$

- **Zeitfunktion des linear gesweepten Signals:**

$$x(t) = \sin[\varphi(t)\,] = \sin\left[\varphi_0 + 2\pi\left(\frac{c}{2} * t^2 + f_0 t\right)\right]$$

Linearer Frequenzlauf



Logarithmischer Frequenzlauf

- **Lineare Frequenzänderung vom Start- zum Endwert:**

$$f(t) = f_0 k^t$$

- **Mit Basis k:**

$$k = \left(\frac{f_1}{f_0}\right)^{\frac{1}{T}}$$

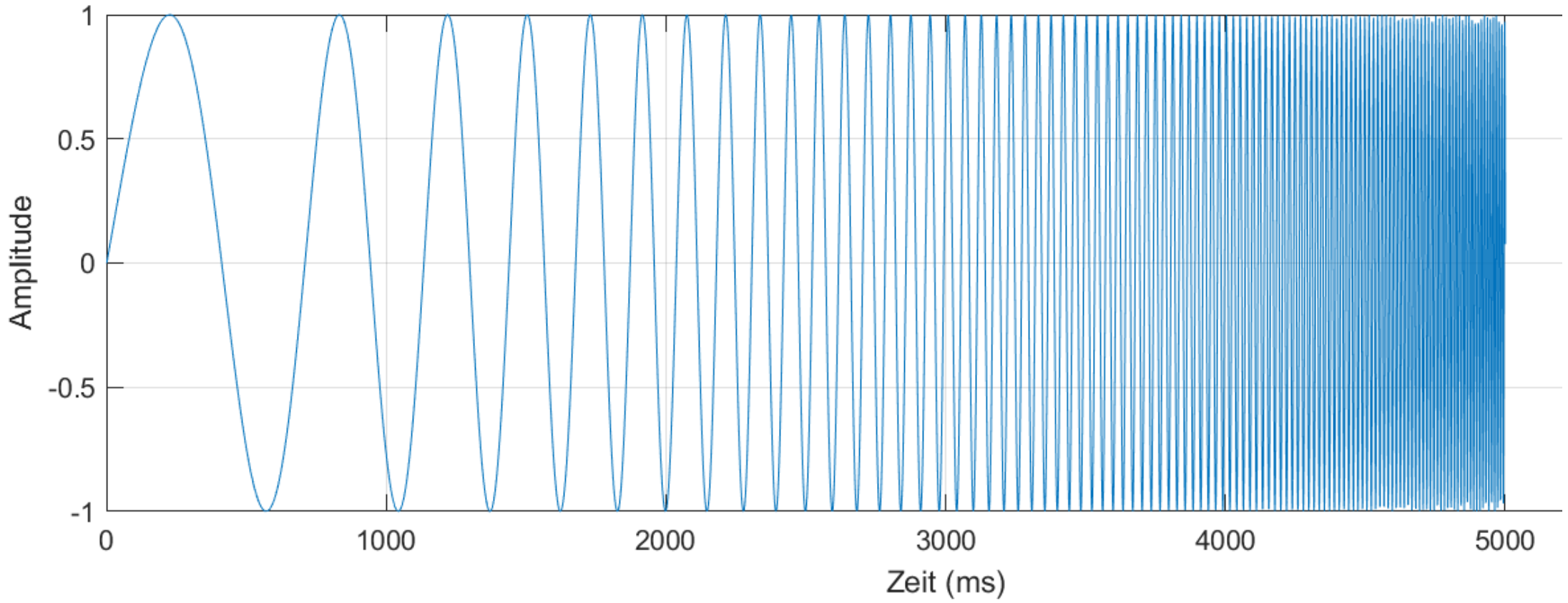
- **Integration der Frequenz liefert Phase:**

$$\varphi(t) = \varphi_0 + 2\pi f_0 \left(\frac{k^t - 1}{\ln(k)}\right)$$

- **Zeitfunktion des logarithmisch gesweepten Signals:**

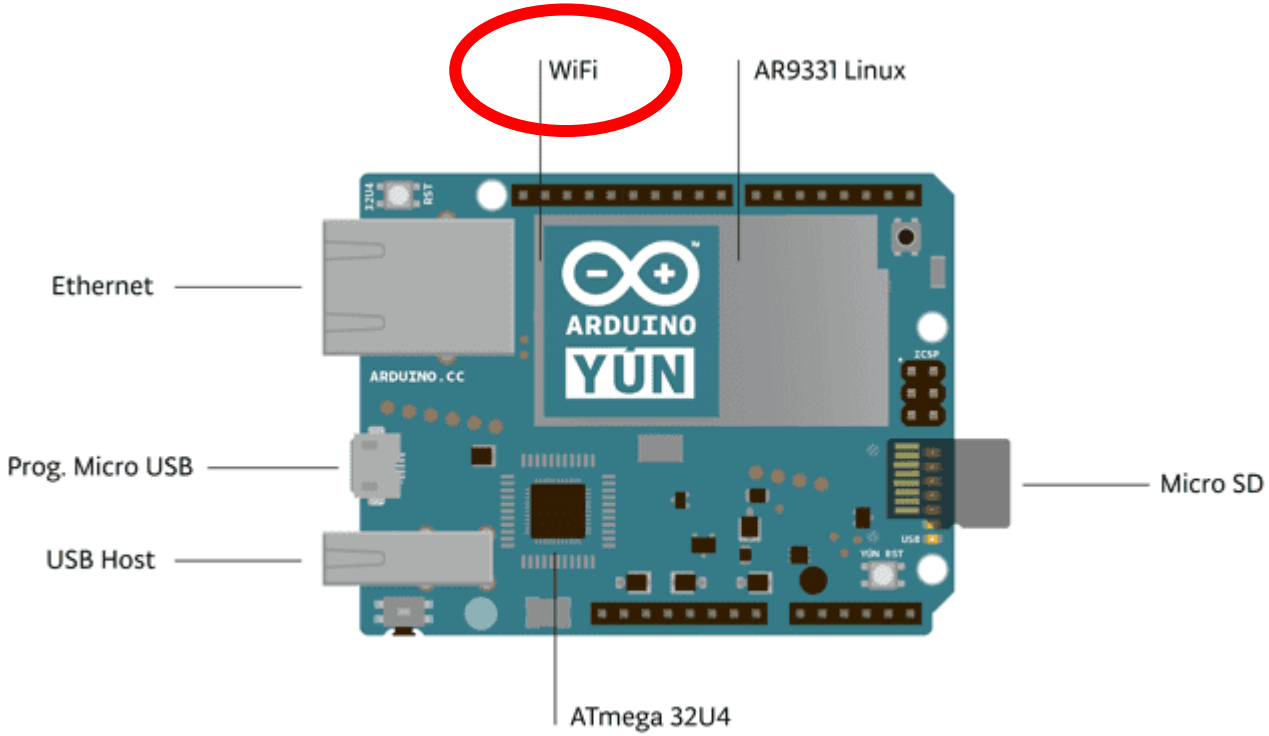
$$x(t) = \sin[\varphi(t)\,] = \sin\left[\varphi_0 + 2\pi f_0 \left(\frac{k^t - 1}{\ln(k)}\right)\right]$$

Logarithmischer Frequenzlauf



Verwendete Hardware

Arduino Yun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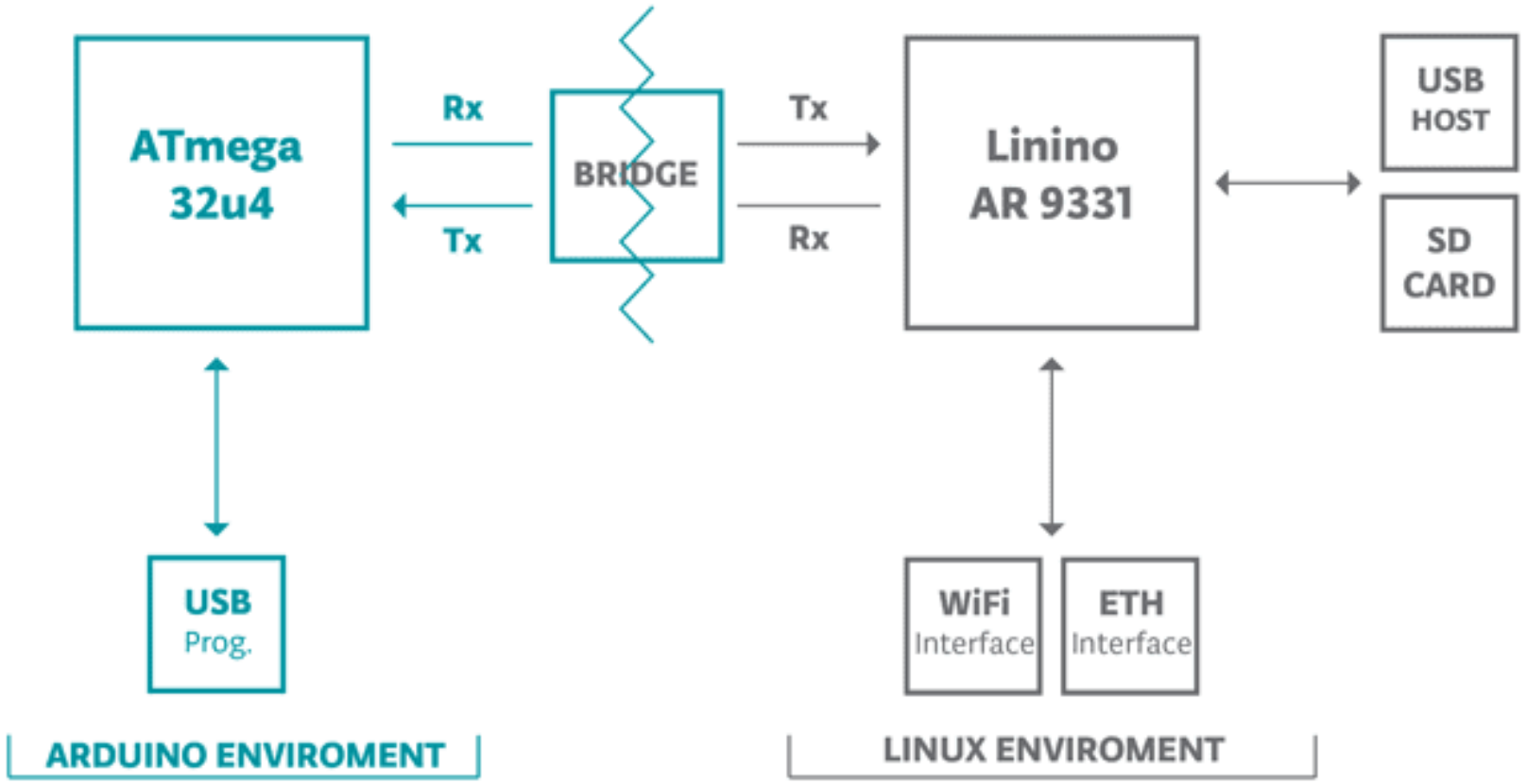
AR9331 Linux
Ethernet
Prog. Micro USB
USB Host
Micro SD
ATmega 32U4
ARDUINO
YÚN
ARDUINO.CC

Arduino Yun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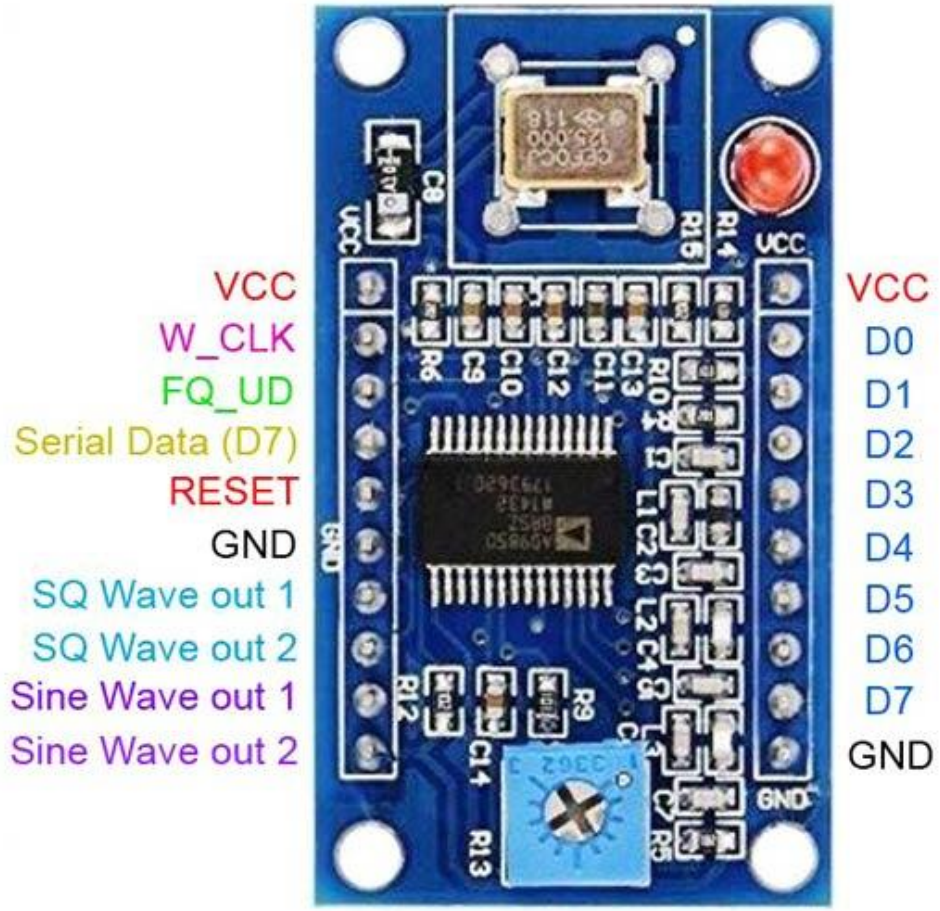
32u4
Rx
Tx
BRIDGE
Tx
Rx
Linino
AR 9331
USB
HOST
SD
CARD
USB
Prog.
WiFi
Interface
ETH
Interface
ARDUINO ENVIROMENT
LINUX ENVIROMENT

ADS9850 (HC-SR08)



ADS9850 (HC-SR08)

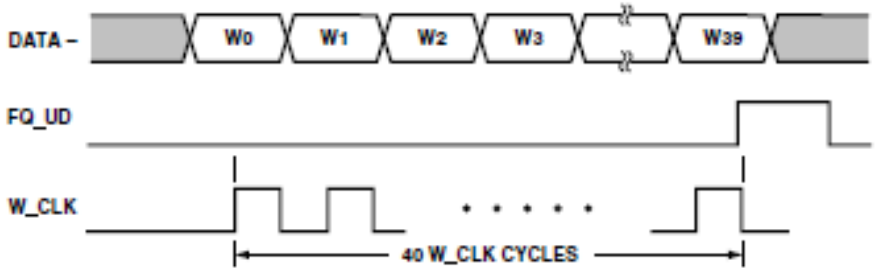
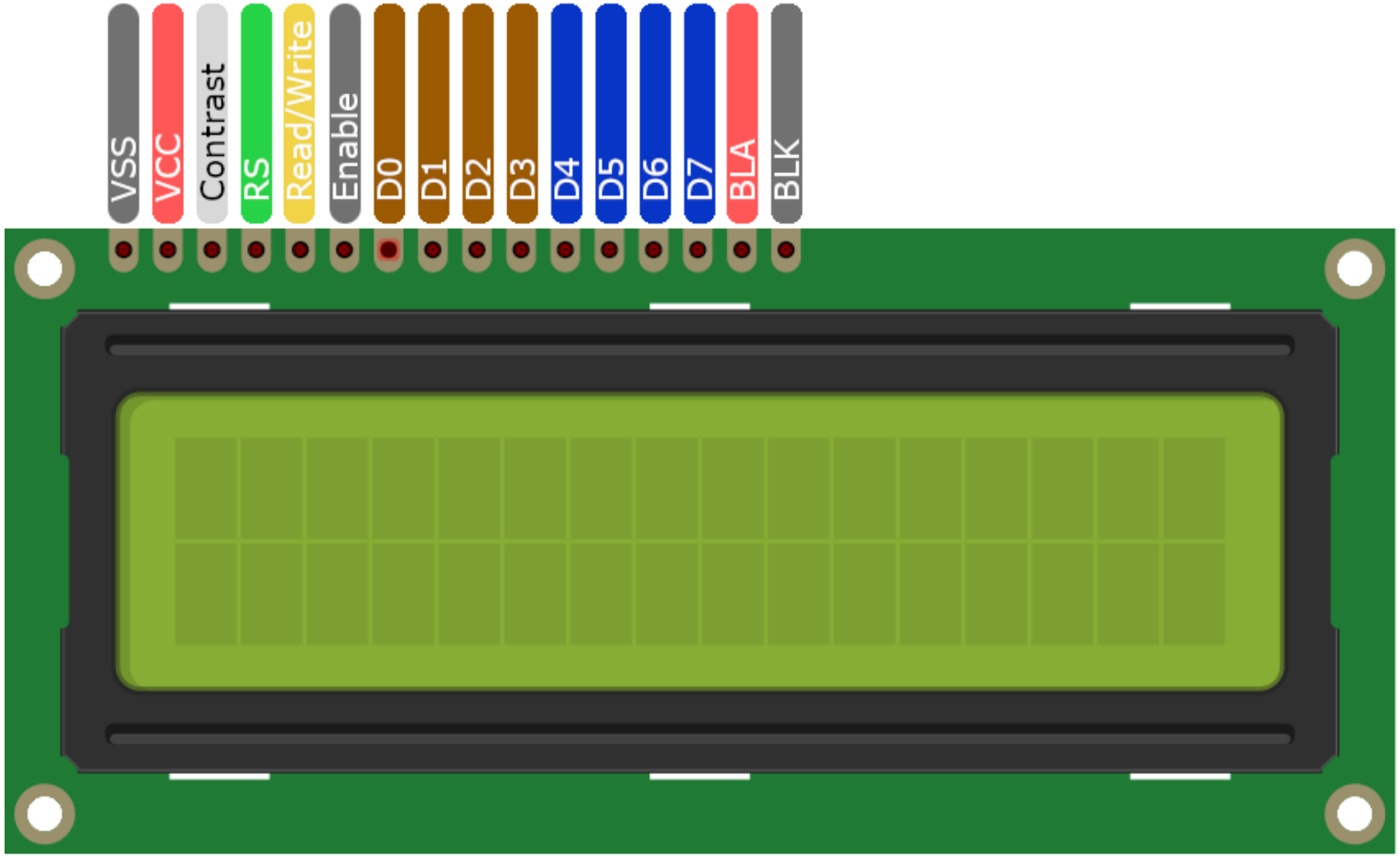


Figure 12. Serial Load Frequency/Phase Update Sequence

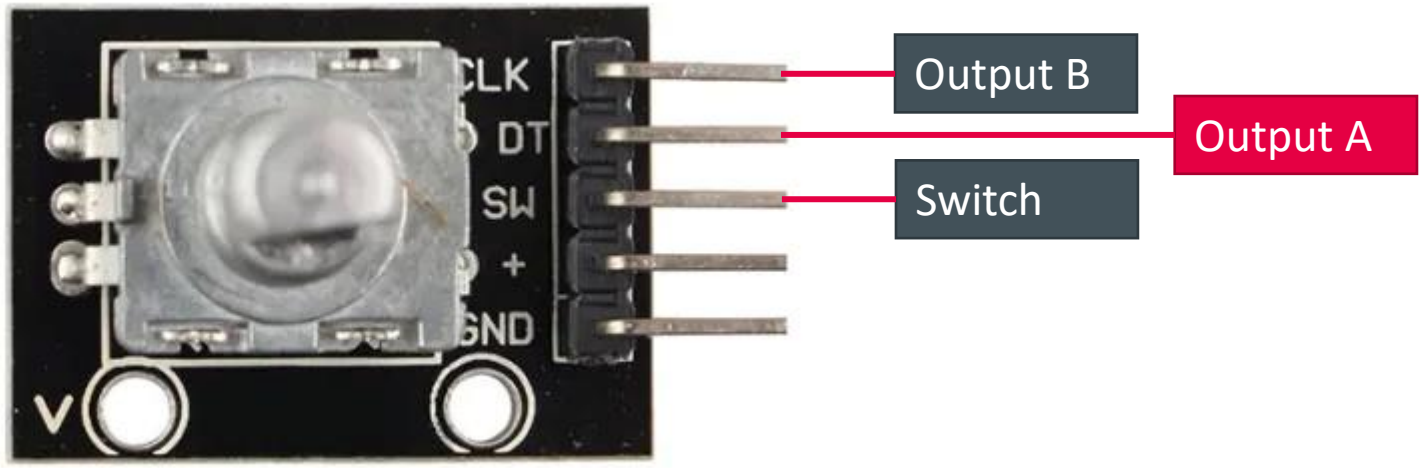
Table IV. 40-Bit Serial Load Word Function Assignment

W0	Freq-b0 (LSB)	W14	Freq-b14	W28	Freq-b28
W1	Freq-b1	W15	Freq-b15	W29	Freq-b29
W2	Freq-b2	W16	Freq-b16	W30	Freq-b30
W3	Freq-b3	W17	Freq-b17	W31	Freq-b31 (MSB)
W4	Freq-b4	W18	Freq-b18	W32	Control
W5	Freq-b5	W19	Freq-b19	W33	Control
W6	Freq-b6	W20	Freq-b20	W34	Power-Down
W7	Freq-b7	W21	Freq-b21	W35	Phase-b0 (LSB)
W8	Freq-b8	W22	Freq-b22	W36	Phase-b1
W9	Freq-b9	W23	Freq-b23	W37	Phase-b2
W10	Freq-b10	W24	Freq-b24	W38	Phase-b3
W11	Freq-b11	W25	Freq-b25	W39	Phase-b4 (MSB)
W12	Freq-b12	W26	Freq-b26		
W13	Freq-b13	W27	Freq-b27		

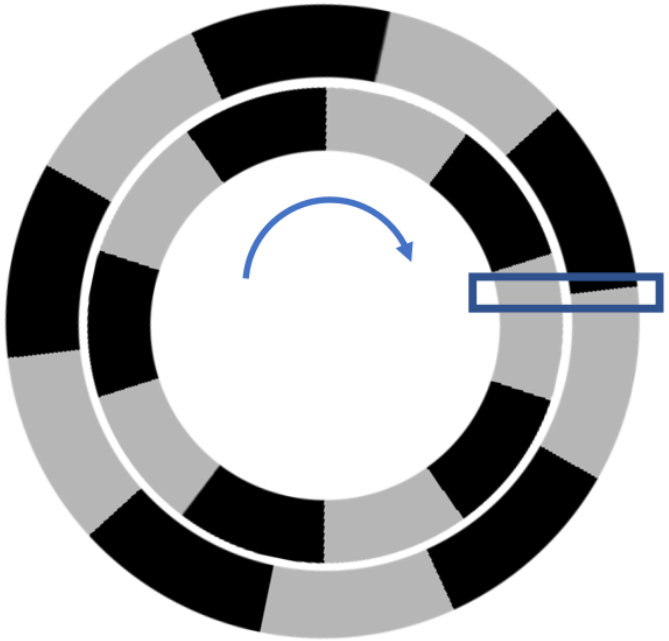
LCD mit HD44780-Controller



Drehinkrementalgeber

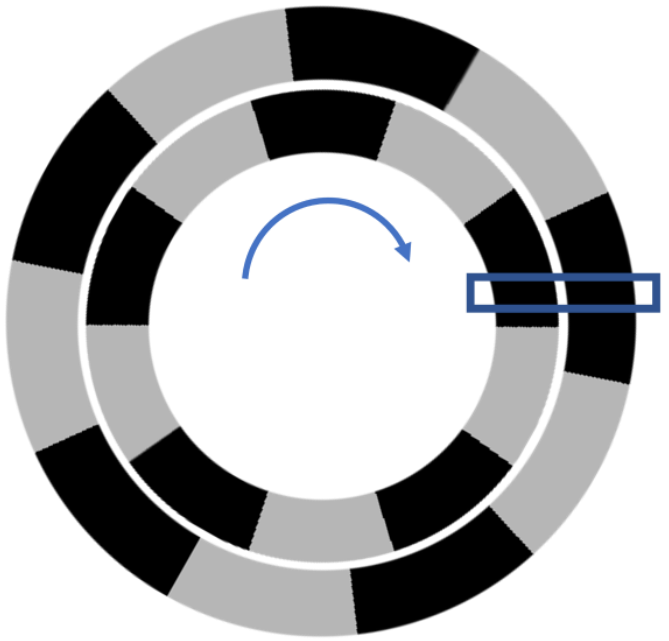


Drehinkrementalgeber



Innen: A
Außen: B

A	B
0	1

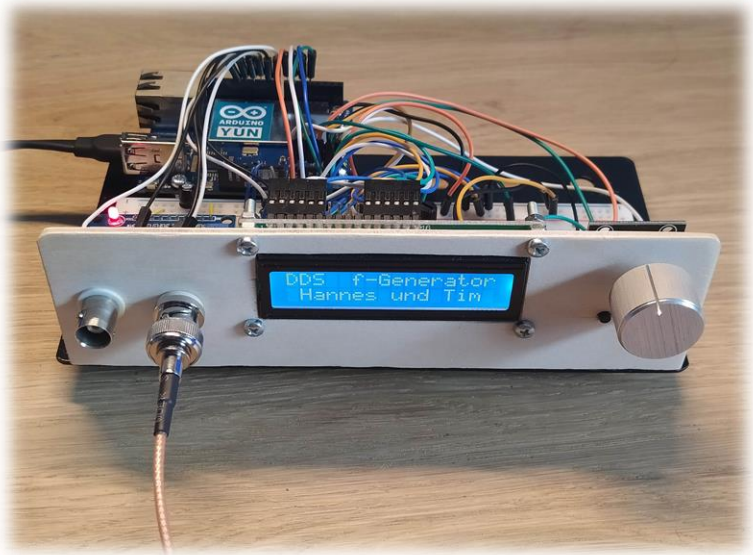


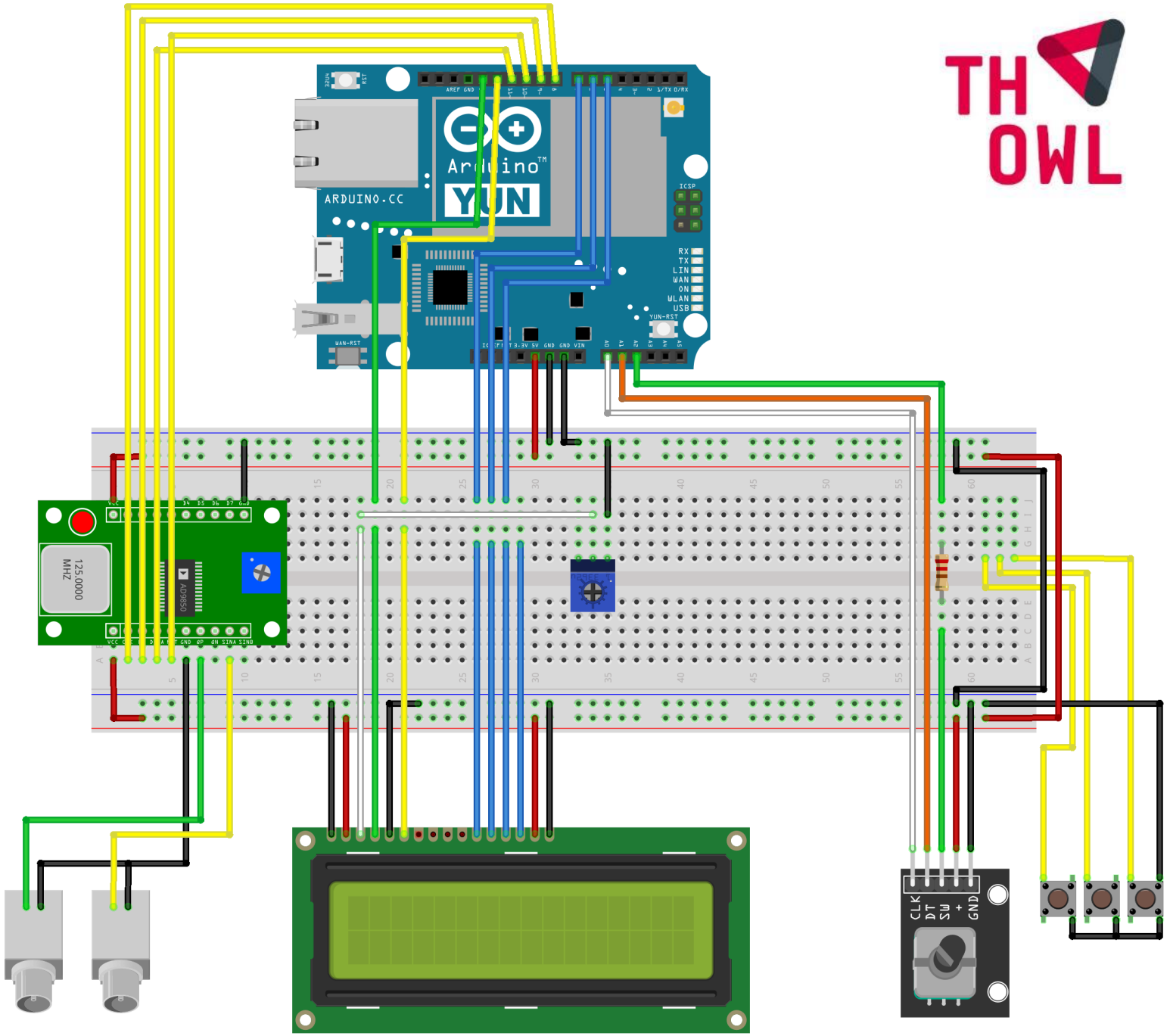
Innen: A
Außen: B

A	B
1	1

Der Aufbau

Der Aufbau





Das Arduino-Programm

Menüstruktur

- **Nutzen der „LCD-Simple Menu Library“**
- **Strukturierung durch verschiedene Menüebenen / Untermenüs**
- **Unterschiedlich strukturierte Menüpunkte für unterschiedliche Aufgaben:**

```
SimpleMenu(String _name, void (*_CallBack)()); //function menu
```

```
SimpleMenu(String _name,int *_value, int _min, int _max); //Value menu with min and max
```

Menüstruktur

```
153 SimpleMenu Menu[4] = {
154   SimpleMenu("Statische Freq.", 4, MenuSubStatic),
155   SimpleMenu("Lin. Freqlauf", 6, MenuSubLin),
156   SimpleMenu("Log. Freqlauf", 6, MenuSubLog),
157   SimpleMenu("Info", info)
158 };
```

Menüstruktur

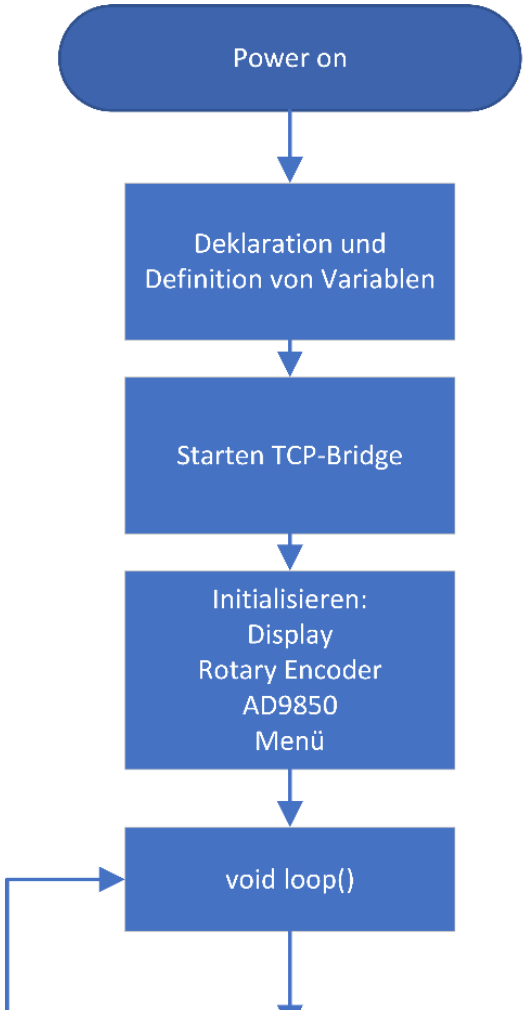
```
144 SimpleMenu MenuSubLog[6] = {
145   SimpleMenu("Startfrequenz", setLogStartFreq),
146   SimpleMenu("Anzahl Dekaden", &logDecades, 0, 7),
147   SimpleMenu("Anzahl Schritte", &logSteps, 50, 500),
148   SimpleMenu("Sweepzeit", setLogSweeptime),
149   SimpleMenu("Starten", logFreqStart),
150   SimpleMenu("Zurueck", goBack)
151 };
```

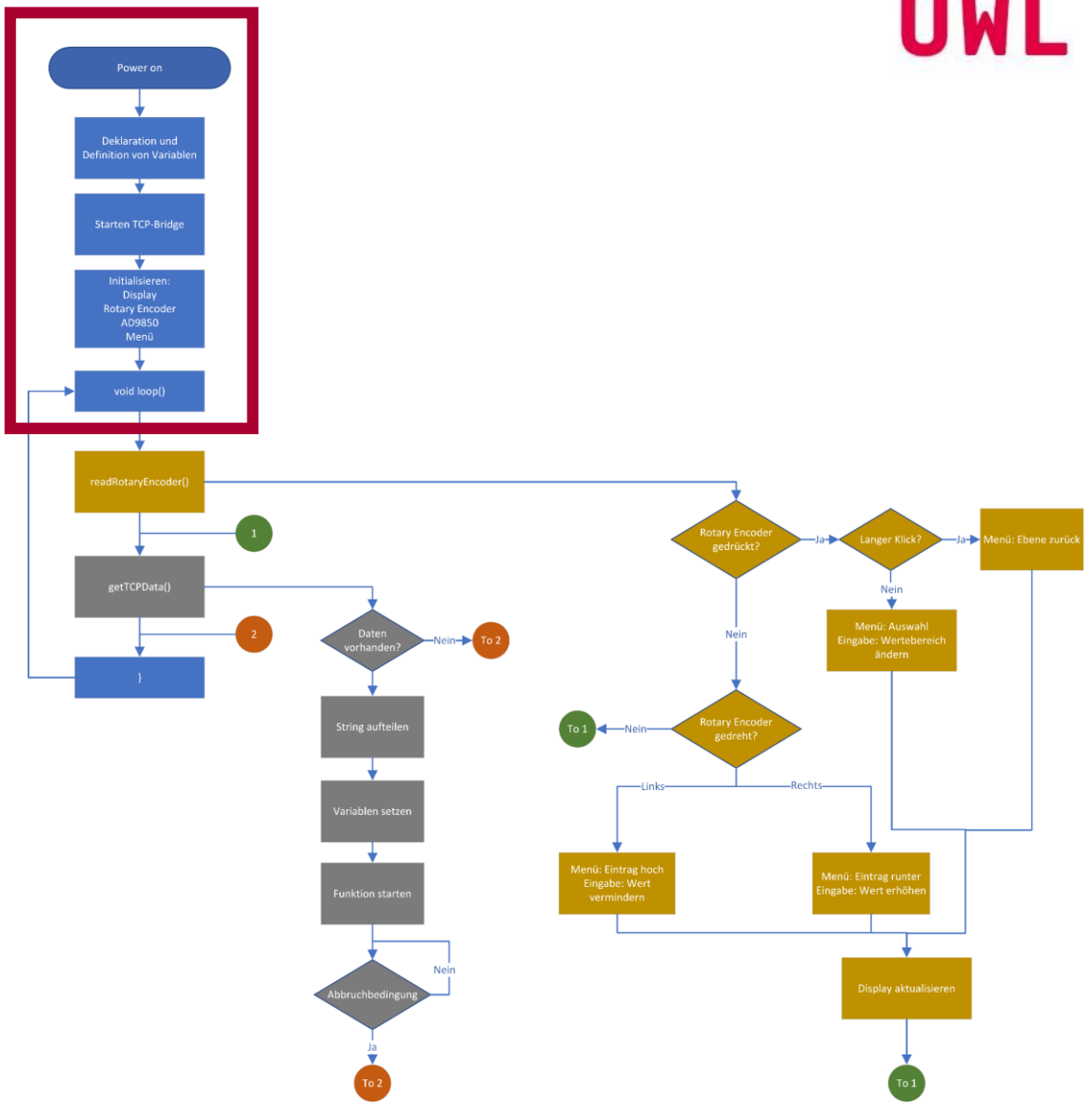
Menüstruktur

```
32          void home();
33          void select();
34          void back();
35          void returned();
36          void up();
37          void down();
```

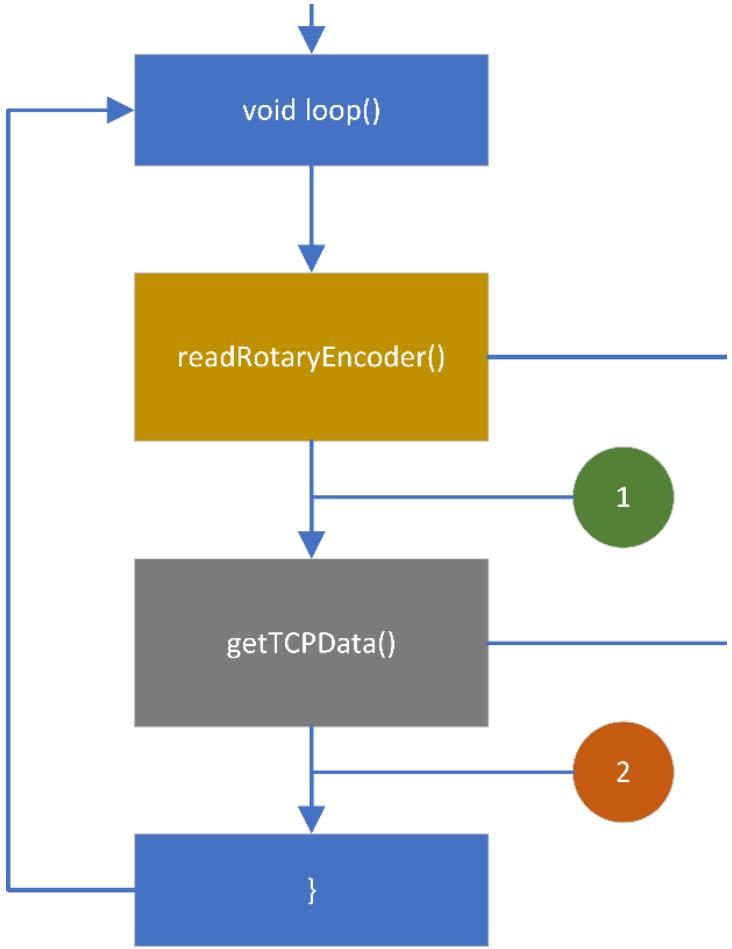
```
40          SimpleMenu *next();
41          SimpleMenu *next(int index);
42          int getValue();
43          bool hasValue();
44          int getIndex();
45          void print();
```

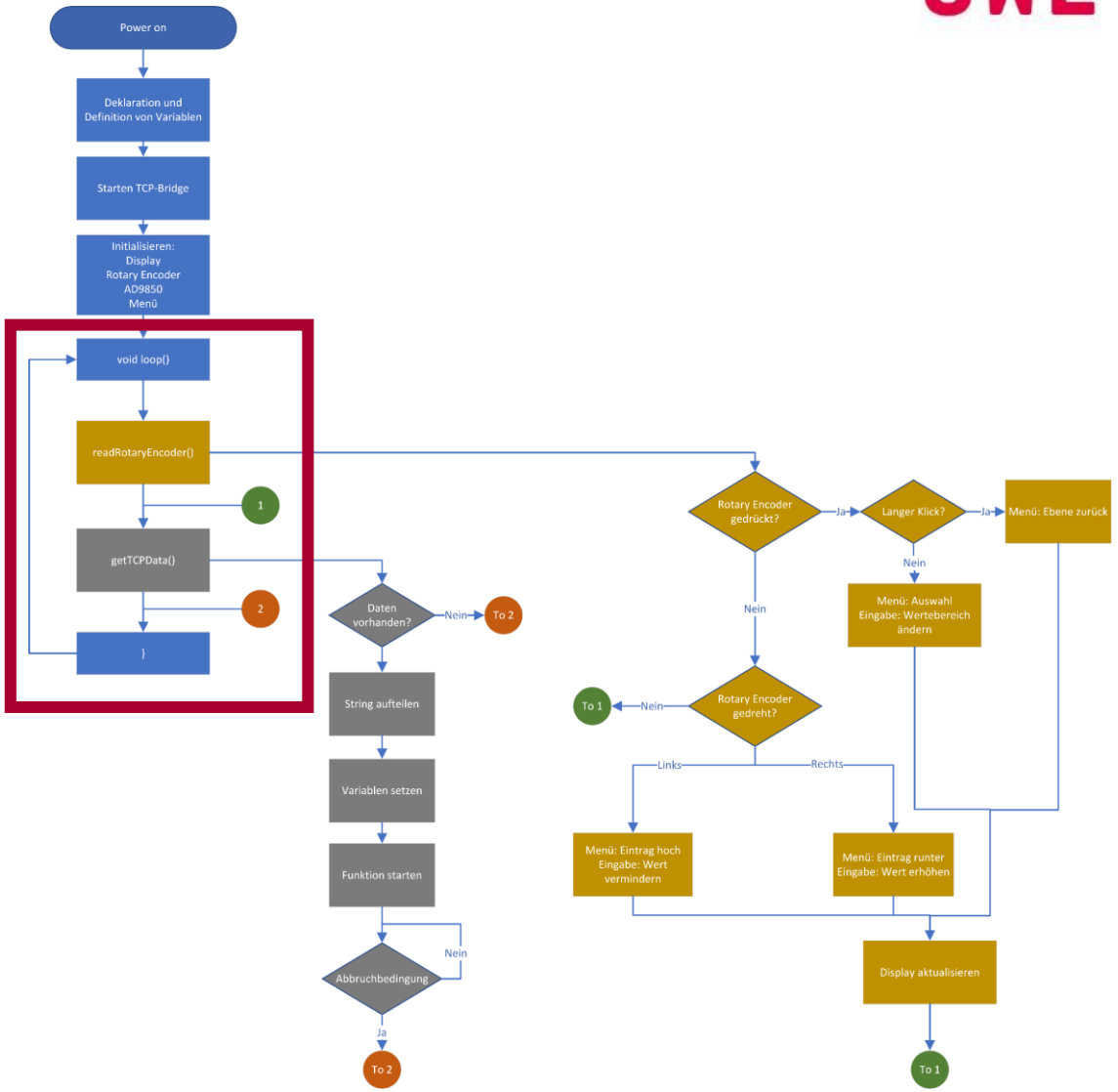
Programmablauf



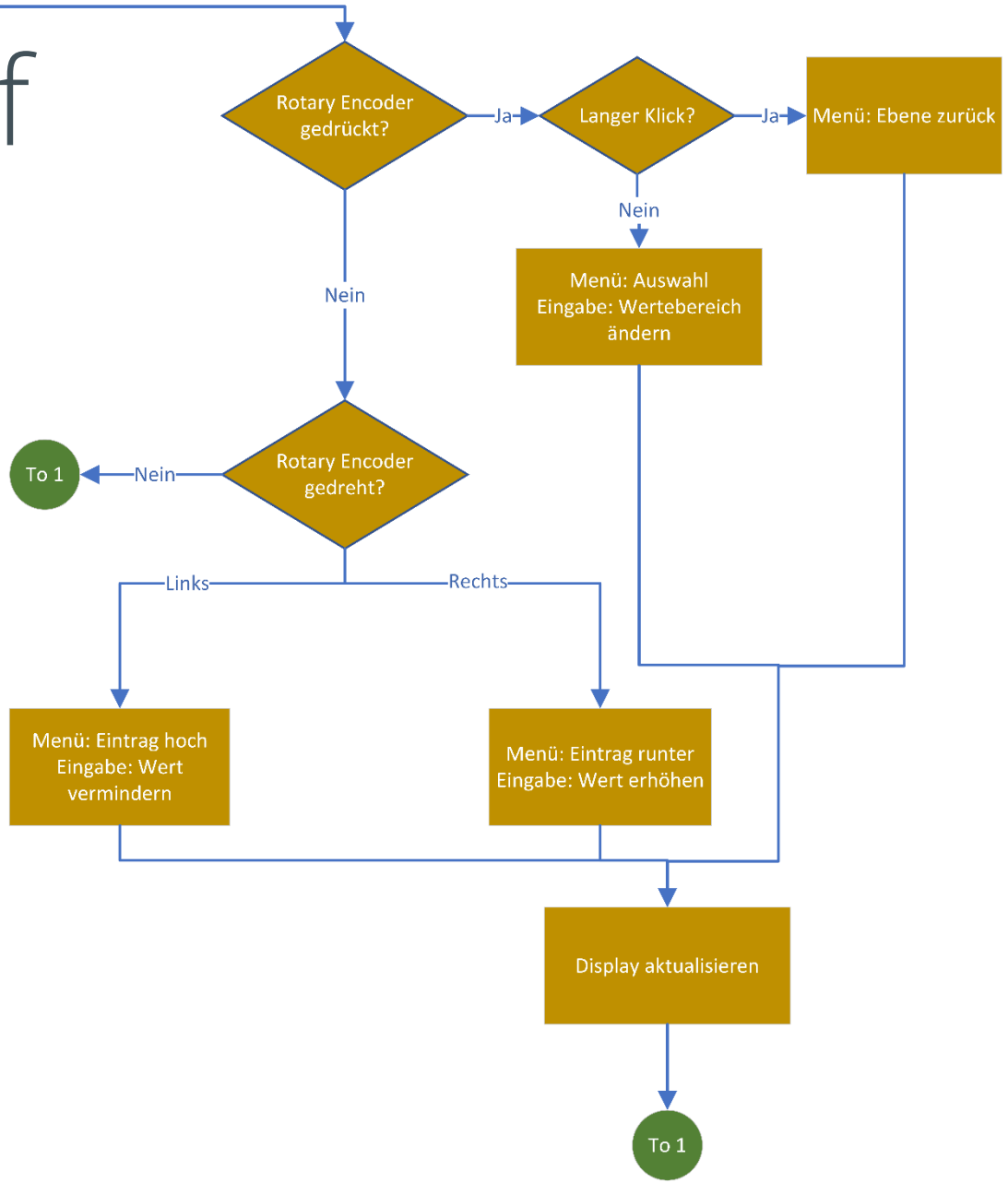


Programmablauf





Programmablauf



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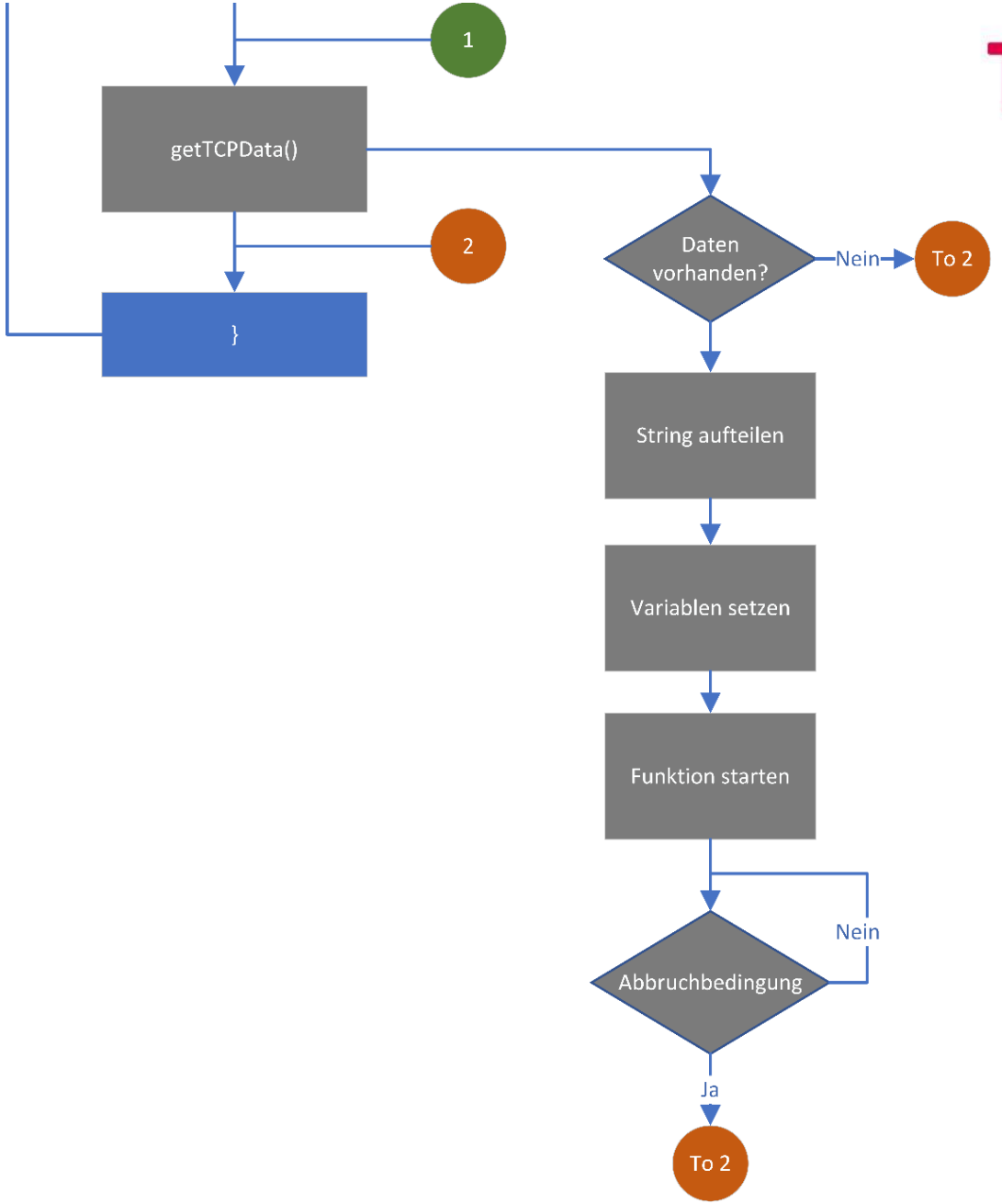


Ausgewählte Funktionen

```
113 //general function heads
114 void setHighValue(long int *value, int mode);
115 void info();
116 void goBack();
117
118 //function heads for TCP connection
119 void startBridge();
120 void getTCPData();
121
122 //funtion heads for frequency output
123 void setStaticFreq();
124 void setLinStartFreq();
125 void setLogStartFreq();
126 void setLinEndFreq();
127 void staticFreqStart();
128 void setLinSweeptime();
129 void setLogSweeptime();
130 void linFreqStart();
131 void logFreqStart();
132 void linSweep(long int freqStart, long int freqStop, int nstep, long int tms);
133 void logSweep(long int freqStart, int nDec, int nstep, int tms);
```

setHighValue

```
493 void setHighValue(long int *value, int mode) {
494   valueMode = mode;
495   stepMode = 0;
```

- **Zur Einstellung sämtlicher Variablenwerte**
- **Adressübergabe der zu ändernden Variable als Pointer**
- **Übergabe Eingabeformat als „mode“**

setHighValue

```
496   while (1) {
497   //leave loop, if RotaryEncoder is held long
498     readRotaryEncoder();
499     if (doBreak == 1) {
500       doBreak = 0;
501       break;
502     }
```

Funktion verlassen

Schrittweite wählen

```
503 //increment step mode by clicking the encoder
504     if (doSelect == 1) {
505       doSelect = 0;
506       stepMode++;
507       if (stepMode > 3) {
508         stepMode = 0;
509       }
510     }
```

setHighValue

- **Unterscheidung, ob Frequenz oder Zeit**
- **Inkrementieren bzw. Dekrementieren des Variablenwertes**
- **Festlegen der Grenzwerte**

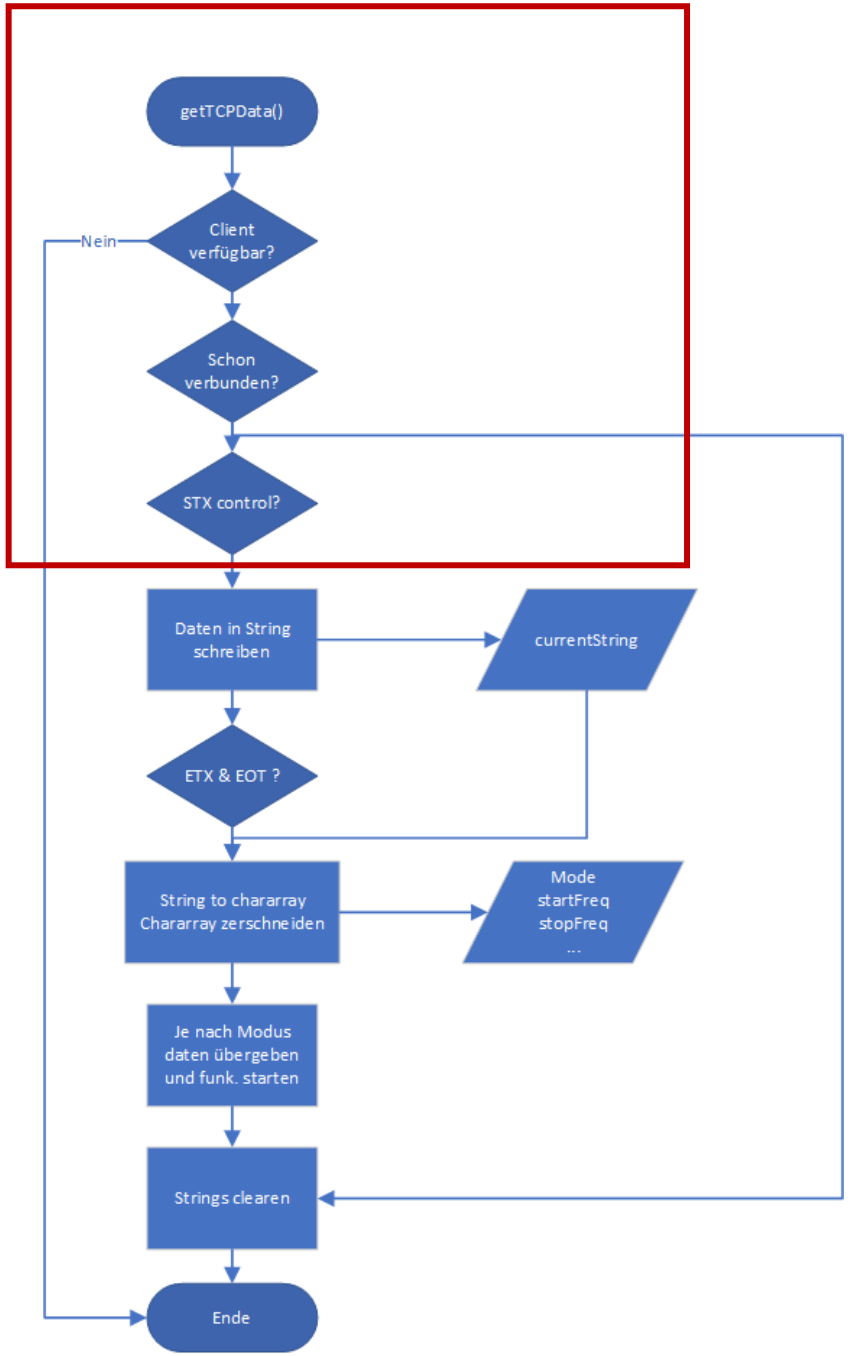
```
512   switch (valueMode) {
513     case 1:
514       //if Encoder is turned right:
515       if (turnRight == 1) {
516         turnRight = 0;
517         *value += changeValue;
518         if (*value > 40000000) {
519           *value = lastValue;
520         }
521       }
522       //if Encoder is turned left:
523       else if (turnLeft == 1) {
524         turnLeft = 0;
525         *value -= changeValue;
526         if (*value < 10) {
527           *value = lastValue;
528         }
529       }
```

setHighValue

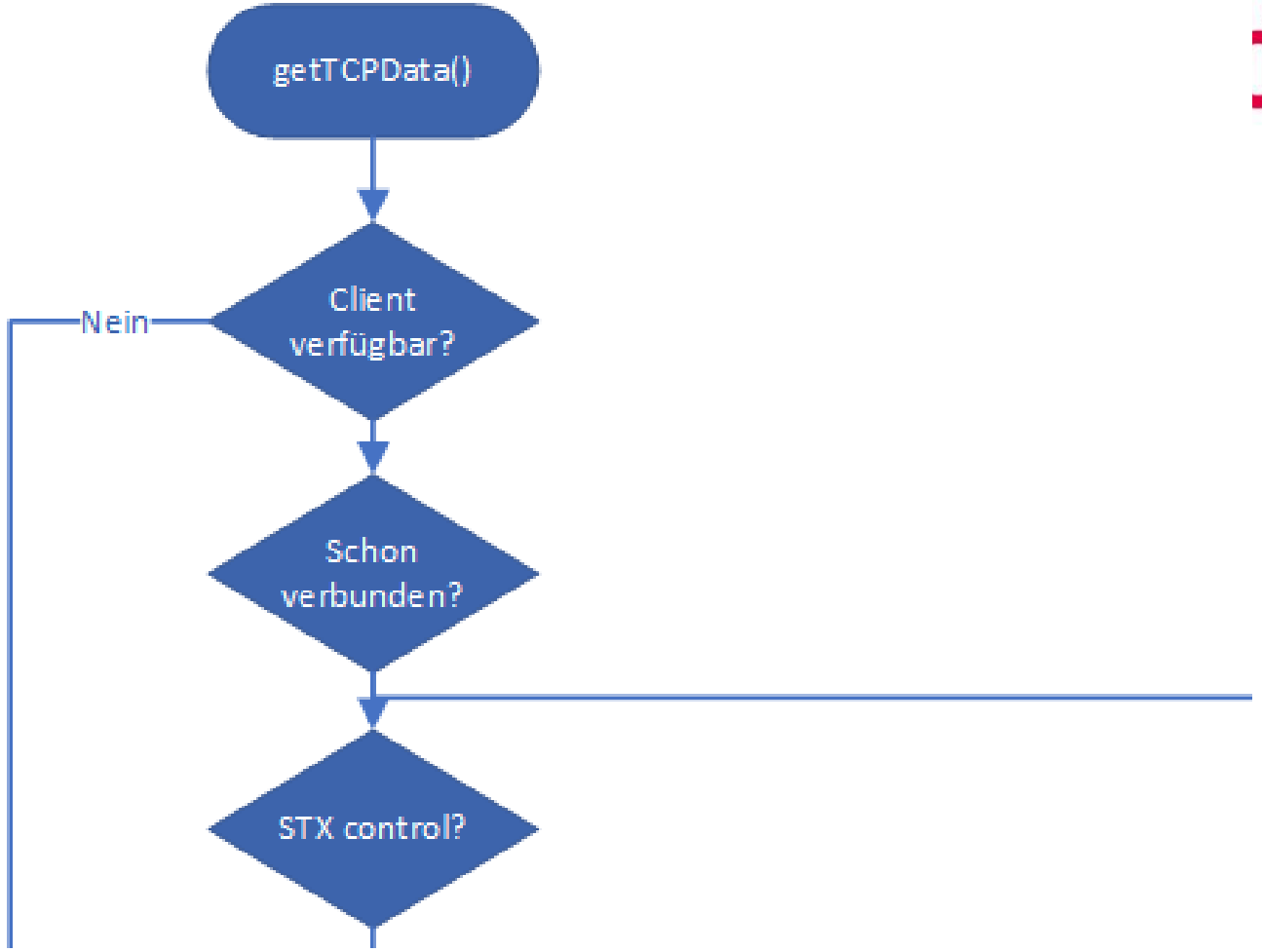
- **Festlegen der Schrittweite**
- **10Hz, 100Hz, 10kHz, 1MHz**
- **10ms, 100ms, 1s, 10s**

```
532       //definig different step sizes
533       switch (stepMode) {
534         //1 step = 10Hz
535         case 0:
536           changeValue = 10;
537           lcd.setCursor(0, 1);
538           lcd.print("Step:  10Hz");
539           break;
540         case 1:
541           changeValue = 100;
542           lcd.setCursor(0, 1);
543           lcd.print("Step: 100Hz");
544           break;
545         case 2:
```

getTCPData()


getTCPData()
Client verfügbar?
Nein
Schon verbunden?
STX control?
Daten in String schreiben
currentString
ETX & EOT ?
String to chararray Chararray zerschneiden
Mode
startFreq
stopFreq
...
Je nach Modus daten übergeben und funk. starten
Strings clearen
Ende

getTCPData()


getTCPData()
Client verfügbar?
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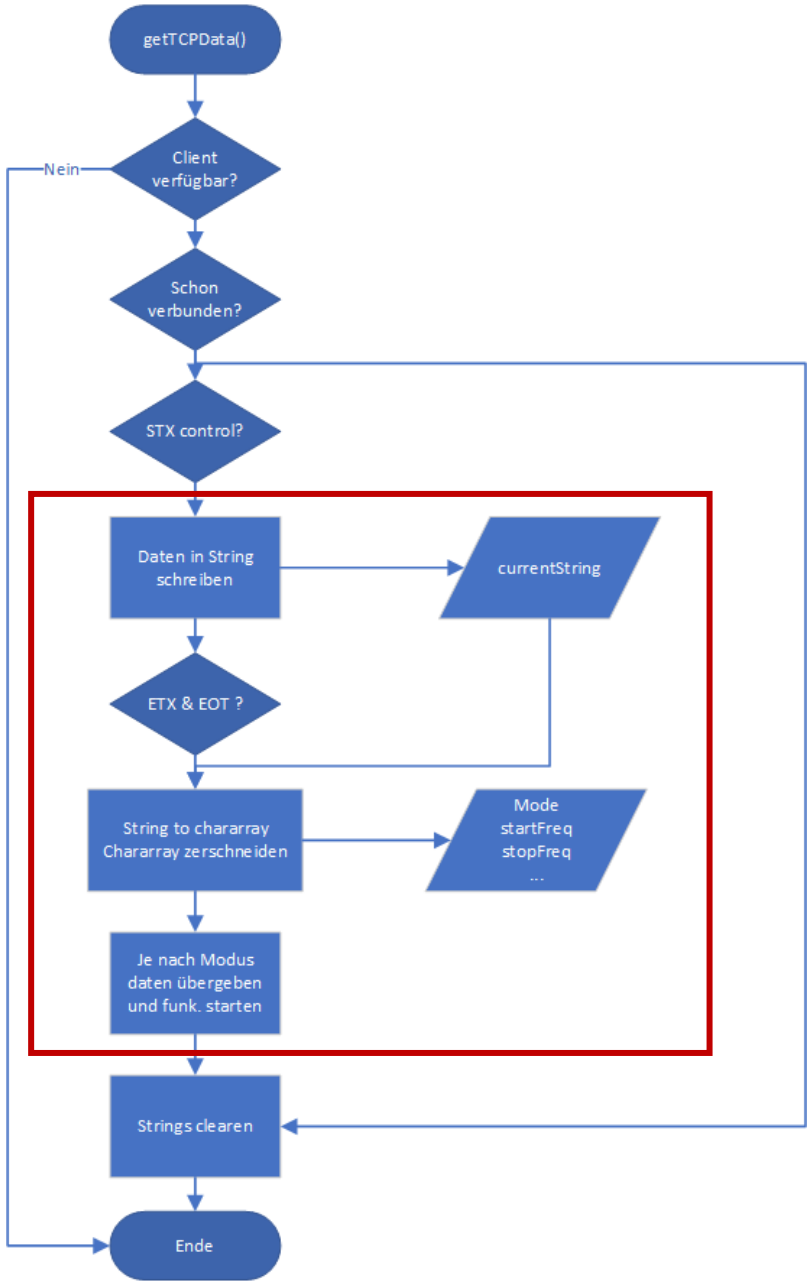
getTCPData()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Je nach Modus daten übergeben und funk. starten
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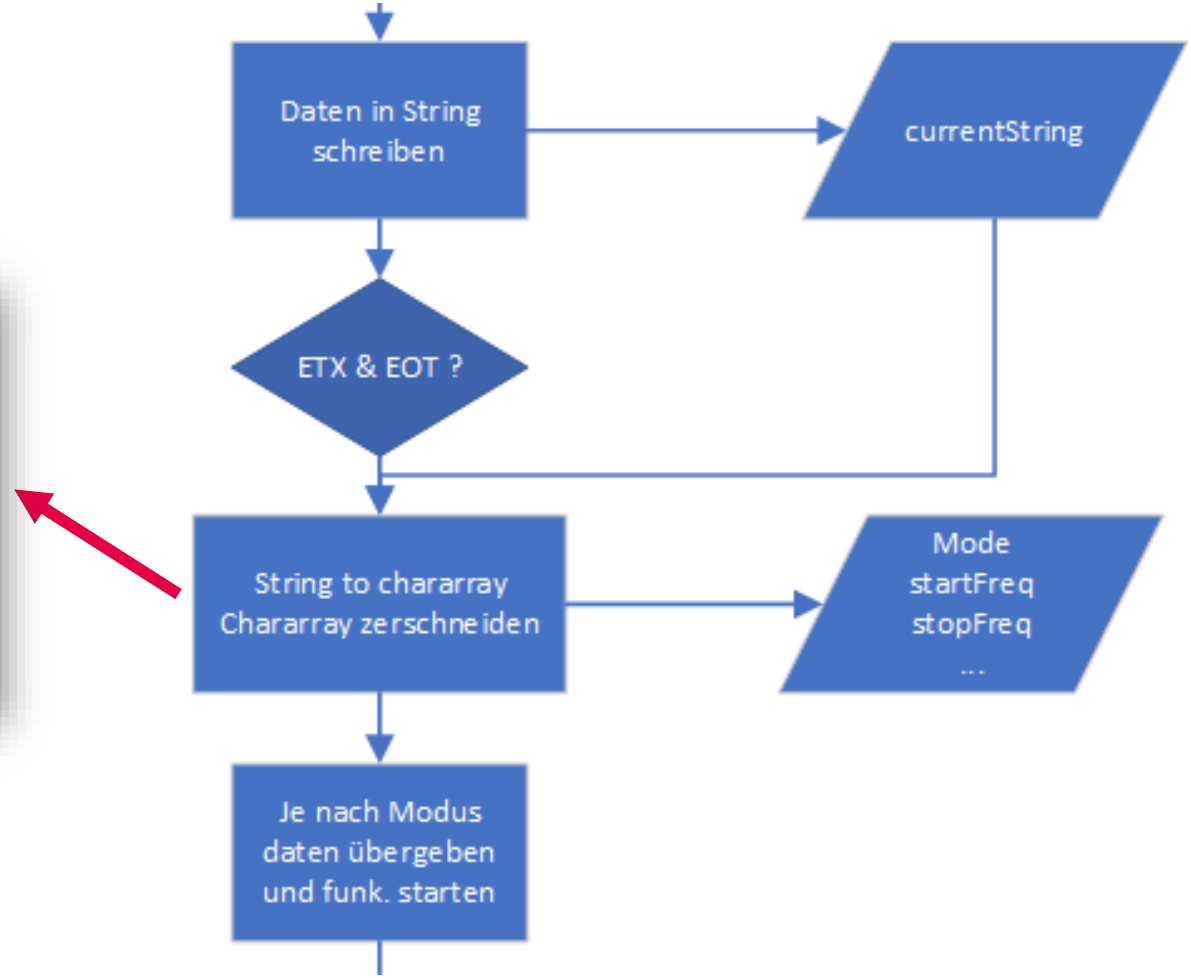
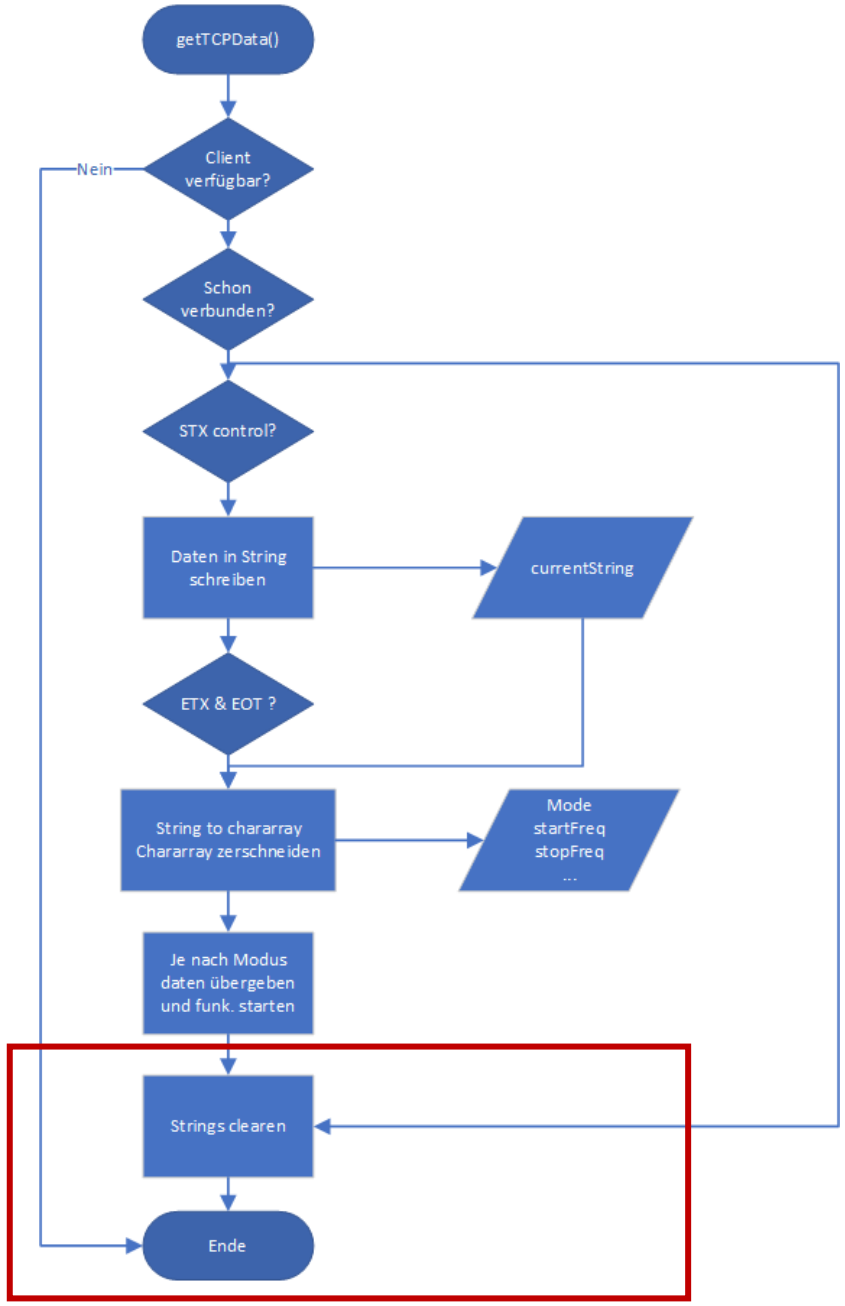
getTCPData()

```
//Convert String to char-Array (atoi only
currentString.toCharArray(workString, 30)

//cut String into the single parameters
mode = atoi(strtok(workString, ";"));
startFreq = atol(strtok(NULL, ";"));
stopFreq = atol(strtok(NULL, ";"));
nDec = atoi(strtok(NULL, ";"));
nStep = atoi(strtok(NULL, ";"));
tms = atoi(strtok(NULL, ";"));
```



getTCPData()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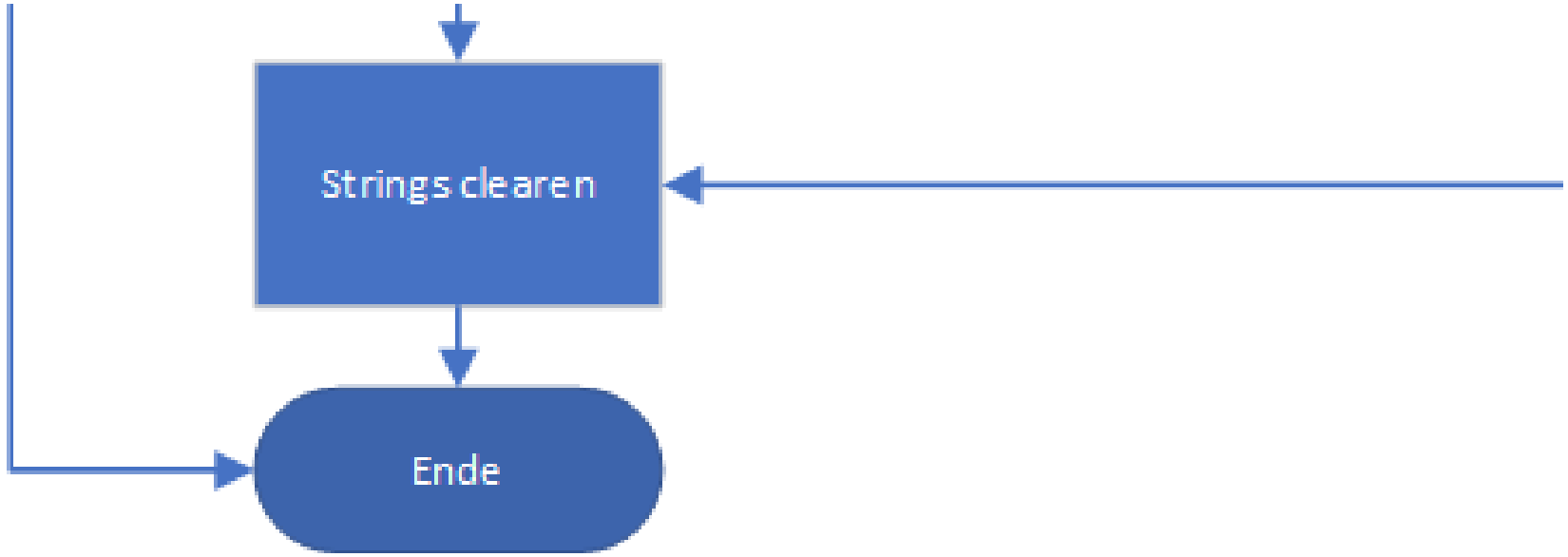


logSweep

```
695 void logSweep(long int freqStart, int nDec, int nstep, int tms) {
696 // freqStart: start frequency
697 // nDec: number of decades
698 // nstep: number of sweep-steps
699 // tms: sweep time in ms
```

- **Berechnung eines exponentiellen Frequenzverlaufs, Übergabe an den DDS**
- **Ausgabe aller wichtigen Parameter auf dem LCD**

logSweep

- **Berechnung Endfrequenz & Zeitspanne pro einzelnem Schritt**

```
732   freqStop = freqStart * pow(10, nDec);
733   //calculate max. duration of one step
734   dt = tms / (nstep - 1);
```

- **Schleife mit Abbruchbedingung, jedem Schritt eigene Frequenz zugeordnet**

```
737   for (i = 0; i < nstep; i++) {
738     readRotaryEncoder();
739     //leave loop, if Encoder is held long
740     if (doBreak == 1) {
741       break;
742     }
```

logSweep

- **Math. Funktion zur Modellierung eines exponentiellen Anstiegs mit bestimmter Schrittanzahl und Wertebereich:**

$$y(i) = 2^{log_2(res)*\frac{i+1}{nstep}} - 1$$

- **res = Wertebereich von y → wenn res = 65536 (16 Bit), dann kann y alle Werte zwischen 0 und 65535 annehmen**
- **i = Zählervariable, pro Schleifendurchlauf inkrementiert**
- **An den DDS übergebene Frequenz in Abhängigkeit von i:**

$$freq(i) = freqStart + \frac{freqStop - freqStart}{res - 1} * y(i)$$

logSweep

- **Umsetzung im Quellcode:**

```
777     y = pow(2, (log(res) / log(2)) * (i + 1) / nstep) - 1;
778     freq = freqStart + ((freqStop - freqStart) / (res - 1.0)) * y;
779     DDS.setfreq(freq, phase);
```

- **Warteschleife, bis Zeit für einen Schritt verstrichen ist:**

```
775     t1 = millis();
```

```
782     //wait until next step can be executed
783     while ((millis() - t1) < dt) {}
```

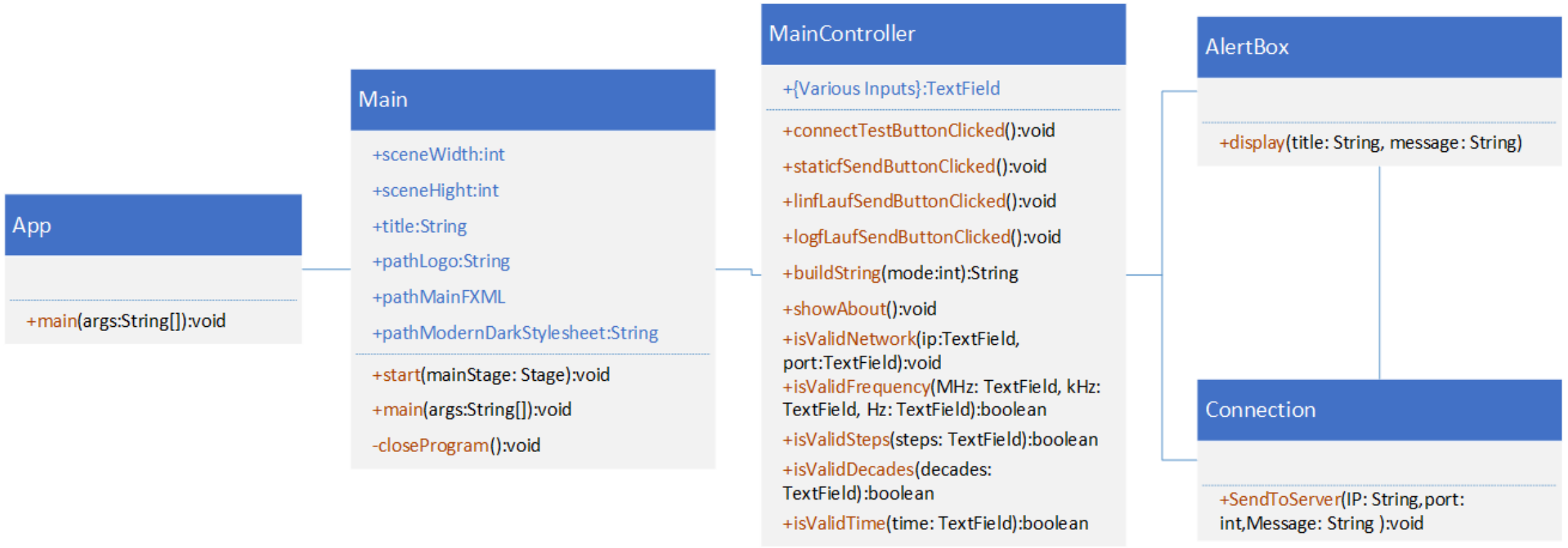
logSweep

- **Wechselnde Displayausgabe:**

```
744     if ((millis() - previousMillis) > interval) {
745       previousMillis = millis();
746       lcd.clear();
747       if (page == 0) {
748         page = 1;
749       }
750       else {
751         page = 0;
752       }
753     }
```

Das remote Programm

Klassen


App
+main(args:String[]):void
Main
+sceneWidth:int
+sceneHight:int
+title:String
+pathLogo:String
+pathMainFXML
+pathModernDarkStylesheet:String
+start(mainStage: Stage):void
+main(args:String[]):void
-closeProgram():void
MainController
+{Various Inputs}:TextField
+connectTestButtonClicked():void
+staticfSendButtonClicked():void
+linfLaufSendButtonClicked():void
+logfLaufSendButtonClicked():void
+buildString(mode:int):String
+showAbout():void
+isValidNetwork(ip:TextField, port:TextField):void
+isValidFrequency(MHz: TextField, kHz: TextField, Hz: TextField):boolean
+isValidSteps(steps: TextField):boolean
+isValidDecades(decades: TextField):boolean
+isValidTime(time: TextField):boolean
AlertBox
+display(title: String, message: String)
Connection
+SendToServer(IP: String, port: int, Message: String):void

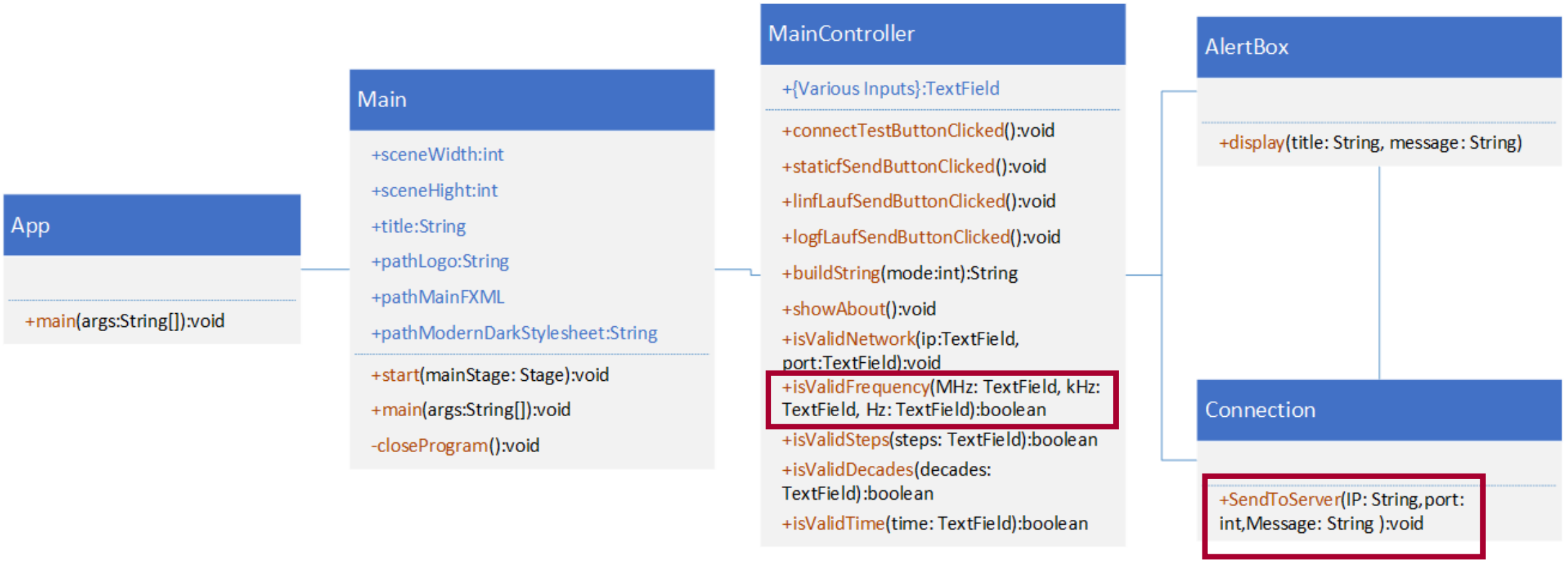
JavaFX -> FXML

```
<AnchorPane>
   <children>
      <Label fx:id="ipLabel" layoutX="41.0" layoutY="13.0" text="IP:">
         <font>
            <Font size="16.0" />
         </font>
      </Label>
      <TextField fx:id="ipInput" layoutX="75.0" layoutY="13.0" onAction="#connectTestButtonClicked" promptText="127.0.0.1" text="192.168.0.168" />
      <Label fx:id="portLabel" layoutX="267.0" layoutY="13.0" text="Port:">
         <font>
            <Font size="16.0" />
         </font>
      </Label>
```

JavaFX -> FXML

```java
/** Define Textfield-Input for connection (IP and Port of the DDS) (link to fxml) */
@FXML
public TextField ipInput, portInput;
```

Ausgewählte Funktionen

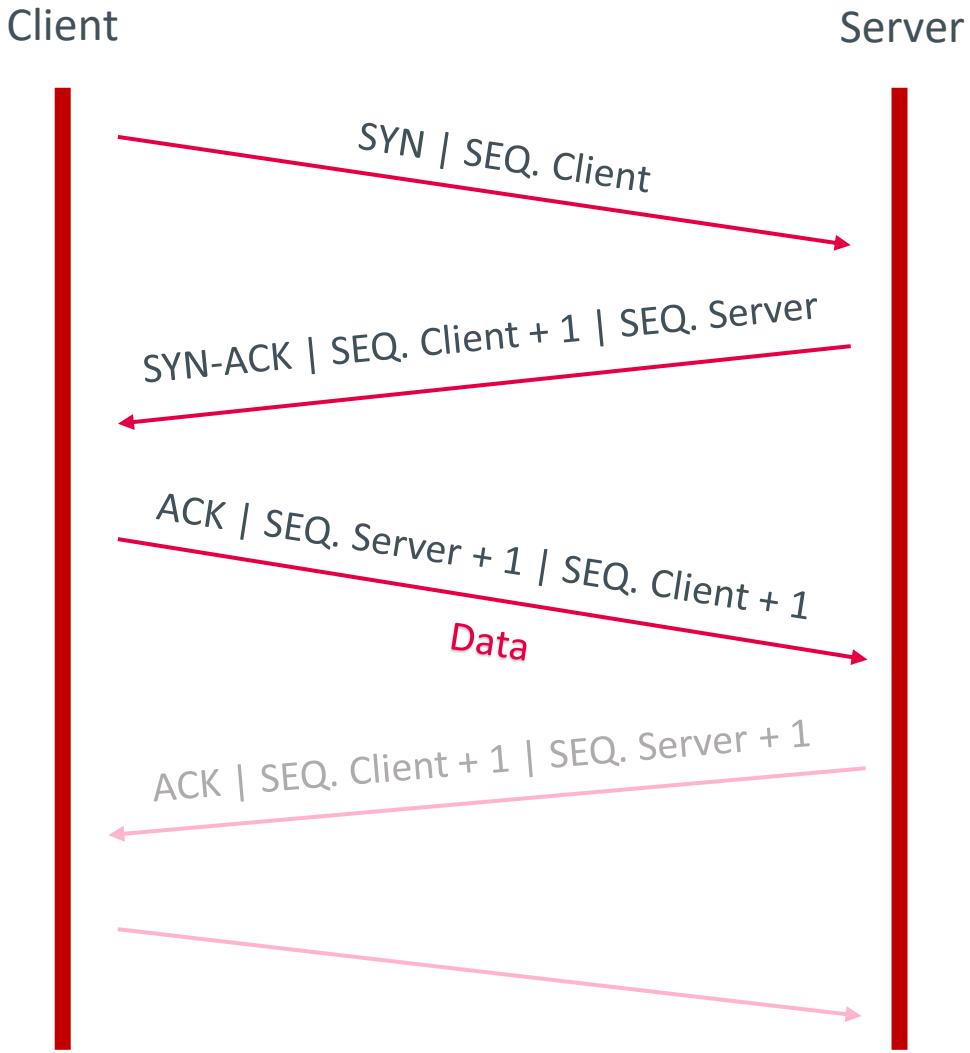


sendToServer(...)

```java
public static void sendToServer(String IP, int port, String Message) {
    //Try to establish a connection
    try (Socket socket = new Socket(IP, port)) {
        //Send data
        OutputStream output = socket.getOutputStream();
        PrintWriter writer = new PrintWriter(output, autoFlush: true);
        writer.println(Message);
        System.out.println("Message send: " + Message);
        System.out.println("To: " + IP + ":" + port);

    } catch (UnknownHostException ex) {
        //Build exception String
        String unknownHostExceptionString = "Server not found: ".concat(ex.getMessage());
        //Give out error message
        System.out.println(unknownHostExceptionString);
        AlertBox.display( title: "Übermittlungsfehler", unknownHostExceptionString);

    } catch (IOException ex) {
        //Build exception String
        String unknownIOExceptionString = "IO Error: ".concat(ex.getMessage());
        //Give out error message
        System.out.println(unknownIOExceptionString);
        AlertBox.display( title: "Übermittlungsfehler", unknownIOExceptionString);
    }
}
```



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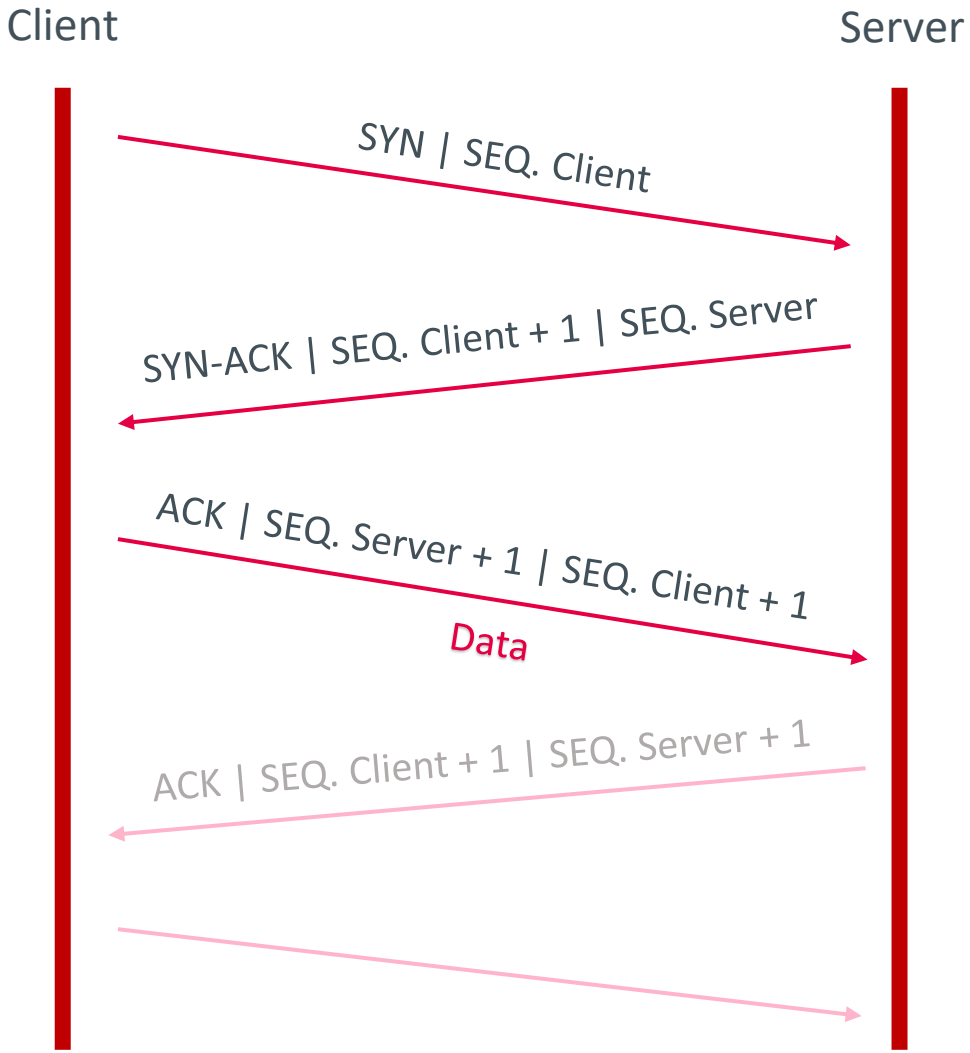
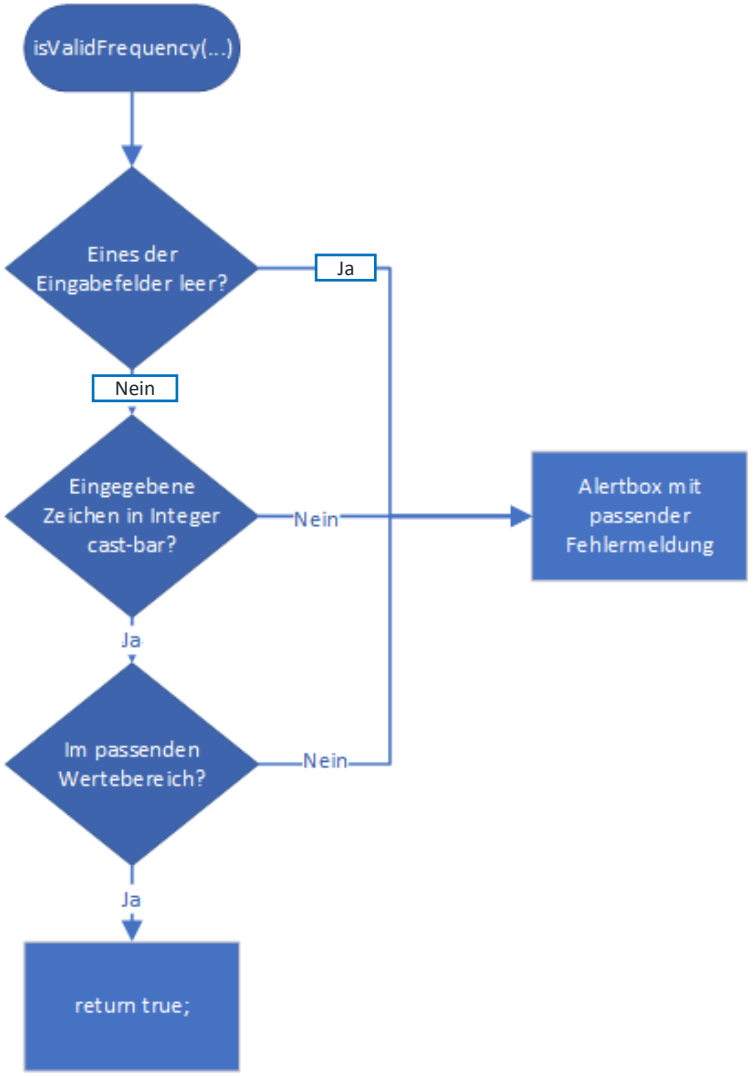
        //Give out error message
        System.out.println(unknownIOExceptionString);
        AlertBox.display( title: "Übermittlungsfehler", unknownIOExceptionString);
    }
}
```



isValidFrequency(...)

```java
public boolean isValidFrequency(TextField MHz, TextField kHz, TextField Hz){
    if ((!MHz.getText().isEmpty()) && (!kHz.getText().isEmpty()) && (!Hz.getText().isEmpty())){
        try{
            int MHzInput = Integer.parseInt(MHz.getText());
            int kHzInput = Integer.parseInt(kHz.getText());
            int HzInput = Integer.parseInt(Hz.getText());
            int freqInput = (MHzInput*1000000) + (kHzInput*1000) + HzInput;
            System.out.println(freqInput);
            if((freqInput <= 40000000) && (freqInput >= 10)){
                return true;
            }
            else{...}
        }
        catch(NumberFormatException e){...}
    }
    else{...}
}
```

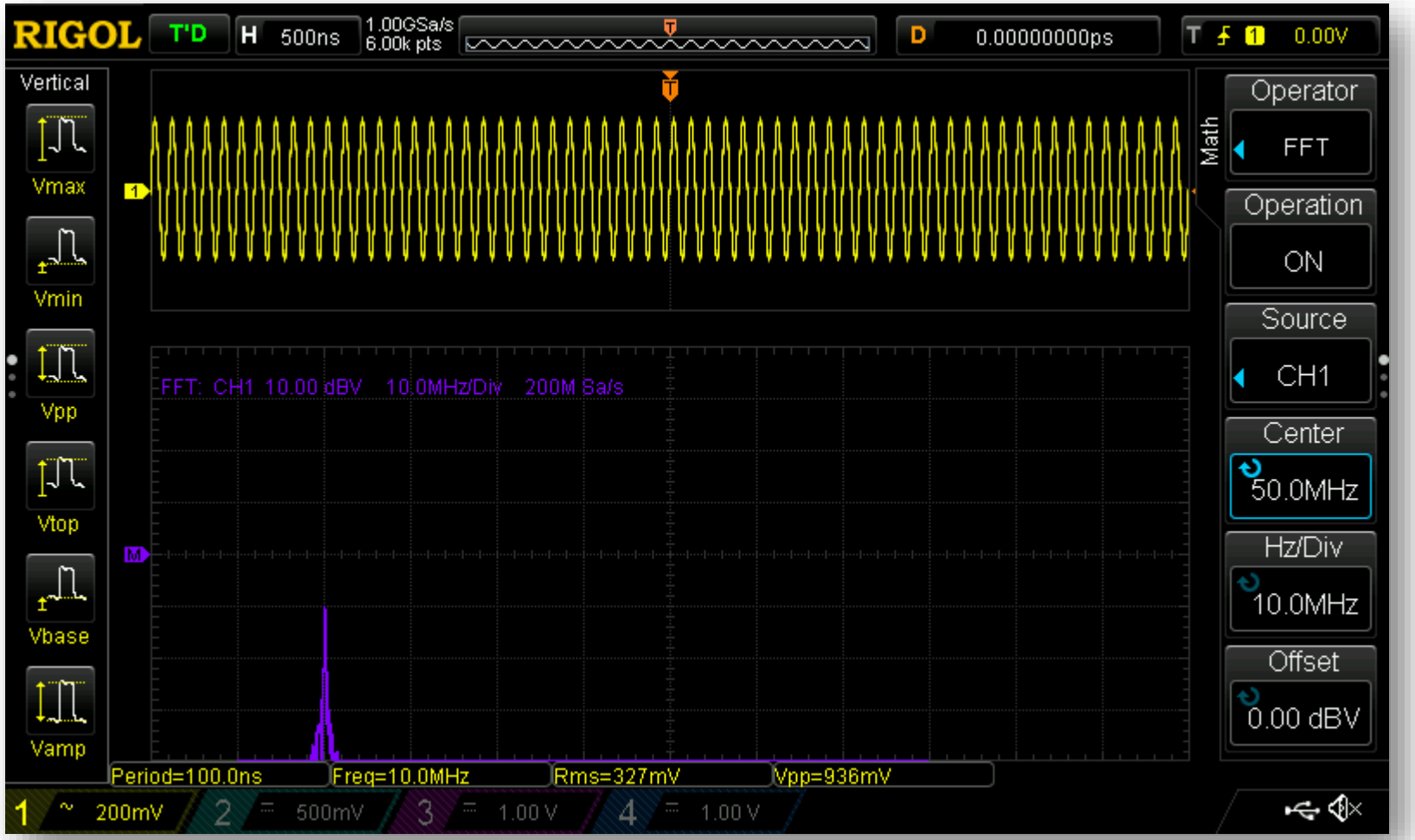


Vorführung

Messung und Fehleranalyse

Frequenzmessung

FFT


RIGOL
T'D
H 500ns
1.00GSa/s
6.00k pts
D 0.00000000ps
T 1 0.00V
Vertical
Vmax
Vmin
Vpp
Vtop
Vbase
Vamp
Math
FFT: CH1 10.00 dBV 10.0MHz/Div 200M Sa/s
Period=100.0ns
Freq=10.0MHz
Rms=327mV
Vpp=936mV
1 200mV
2 500mV
3 1.00 V
4 1.00 V
Operator
FFT
Operation
ON
Source
CH1
Center
50.0MHz
Hz/Div
10.0MHz
Offset
0.00 dBV

Ausblick

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Quellen

Quellen

- **Siehe Dokumentation**

TH OWL

TECHNISCHE HOCHSCHULE
OSTWESTFALEN-LIPPE
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APPLIED SCIENCES
AND ARTS

Vielen Dank für Eure Aufmerksamkeit!