Arbeitskreis Hardware

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<table>
<thead>
<tr>
<th>Date</th>
<th>Topic (preliminary)</th>
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<td>2.5</td>
<td>Introduction to embedded interaction, microcontrollers, hardware &amp; software tools</td>
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<td>9.5</td>
<td><em>keine Veranstaltung (CHI)</em></td>
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<td>16.5</td>
<td>ISP adapter soldering, AVR architecture</td>
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<td>23.5</td>
<td>LED displays, LED multiplexing, transistors, electronics basics</td>
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<td>30.5</td>
<td>AVR architecture, AVR assembler, sensors: light, force, acceleration, etc.</td>
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<td>PCB design &amp; fabrication, EAGLE, 3D printing</td>
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<td><em>keine Veranstaltung (Pfingsten)</em></td>
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<td>20.6</td>
<td>Actuation: stepper motors, servo motors, I2C: interfacing to other chips</td>
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<td>USB to serial chips, storage on memory cards, capacitive sensors</td>
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<td>Displays (character LCDs, graphics LCDs), audio (speakers, amplification, op-amps)</td>
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<td>Communication: fixed-frequency RF, ZigBee, Bluetooth</td>
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<td>18.7</td>
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<td>25.7</td>
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INTERFACING HARDWARE
ATtiny45 Universal Serial Interface (USI)

• Two modes: two-wire mode, three-wire mode

• Serial Port Pins

• PB2
  – SCL: USI Clock (Two Wire Mode)
  – USCK: USI Clock (Three Wire Mode)

• PB1
  – DO: USI Data Output (Three Wire Mode)
  – MISO: SPI Master Data Input / Slave Data Output

• PB0
  – SDA: USI Data Input (Two Wire Mode)
  – DI: USI Data Input (Three Wire Mode)
  – MOSI: SPI Master Data Output / Slave Data Input

Source: Atmel Datasheet
Universal Serial Interface, Block Diagram

- **USIDR**: Data Register (shift register)
- **USIBR**: Buffer Register (buffers data register)
- **USISR**: Status Register
- **USICR**: Control Register

Source: Atmel Datasheet
USI Two-Wire Mode, I2C

Source: Atmel Datasheet

Shift direction

Open drain bus (wired-and)
USI Three-Wire Mode

Source: Atmel Datasheet

 registers interchanged after 8 clocks
ATtiny45 USI Registers

- **USIDR**: Data Register (shift register)
  - [Diagram: MSB, 7:0 bits, R/W]

- **USIBR**: Buffer Register (buffers data register)
  - [Diagram: R/W]

- **USISR**: Status Register
  - **SIF**: Start condition interrupt flag (two-wire mode)
  - **OIF**: Overflow interrupt flag (4-bit counter)
  - **PF**: Stop condition flag (two-wire mode, bus arbitration)
  - **DC**: Data output collision (two-wire mode, bus arbitration)
  - **CNT3..0**: 4-bit counter (counts bits sent/received)

Figure sources: Atmel Datasheet
ATtiny45 USI Registers

- **USICR: Control Register**
  - **SIE**: Start Condition Interrupt Enable
  - **OIE**: Counter Overflow Interrupt Enable
  - **WM1,WM0**: Wire Mode
    - 0,0: port pins operate as normal
    - 0,1: three-wire mode (DO, DI, USCK)
    - 1,0: two-wire mode (SDA, SCL, bi-directional, open drain)
    - 1,1: two-wire mode (as (1,1), but SCL held low on counter overflow)
    - data direction bits need to be set correctly
  - **CS1,CS0**: Clock Source Select
  - **CLK**: Clock Strobe
  - **TC**: Toggle Clock Port Pin

Figure sources: Atmel Datasheet
Universal Serial Bus (USB)

- High data rates (difficult to process with ATtiny)
  - USB 1.0: 1.5 Mbit/s (Low-Speed) and 12 Mbit/s (Full-Speed)
  - USB 2.0: 480 Mbit/s (High-Speed)
  - USB 3.0: 5 Gbit/s (Super-Speed)

- 500mA max. (at $V_{CC} = 5V$)

- Some AVRs have built-in USB modules
Universal Asynchronous Receiver/Transmitter (UART)

- Sequential transmission/reception of a sequence of bits
- Framing (start bit = 0, stop bit = 1; 8 data bits, no parity bit)

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<th>Start (0)</th>
<th>Bit 0 (lsb)</th>
<th>Bit 1</th>
<th>Bit 2</th>
<th>Bit 3</th>
<th>Bit 4</th>
<th>Bit 5</th>
<th>Bit 6</th>
<th>Bit 7 (msb)</th>
<th>Stop (1)</th>
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- Timing diagram

- Hardware handshake: Request-to-send, clear-to-send
USB to Serial UART
FTDI FT232RL

• UART = Universal Asynchronous Receiver/Transmitter

• http://www.ftdichip.com/Products/ICs/FT232R.htm

Source: FTDI Datasheet
FTDI FT232RL Virtual COM Port Drivers

- Virtual COM port drivers
  - http://www.ftdichip.com/Drivers/VCP.htm

- USB device appears as virtual COM port
  - cd /dev
  - ls -l | grep usb
  - cu.usbserial-FTF56DZT
tty.usbserial-FTF56DZT

- Shows up in System Profiler
Use Virtual COM Port in Java

• Requires Java Serial Communications API
  – various implementations

• Windows

• Mac OS X, Linux

  – https://github.com/nyholku/purejavacomm
  – http://iharder.sourceforge.net/current/java/
Example: Sending to VCP in Java

```java
import java.io.*;
import java.util.*;
import gnu.io.*;

public static void main(String[] args) throws Exception {
    Enumeration ports = CommPortIdentifier.getPortIdentifiers();
    while (ports.hasMoreElements()) {
        CommPortIdentifier portId = (CommPortIdentifier) ports.nextElement();
        if (portId.getPortType() == CommPortIdentifier.PORT_SERIAL) {
            if (portId.getName().equals("/dev/tty.usbserial-FTF56DZT")) {
                SerialPort sp = (SerialPort) portId.open("HelloWorld", 2000);
                OutputStream os = sp.getOutputStream();
                sp.setSerialPortParams(9600,
                    SerialPort.DATABITS_8,
                    SerialPort.STOPBITS_1,
                    SerialPort.PARITY_NONE);
                os.write("hello world").getBytes();
                try { Thread.sleep(2000); } catch (InterruptedException ex) {} 
                sp.close();
            }
        }
    }
}
```
Direct Driver Interface

• Virtual COM Port (VCP) driver has limitations
• Full access to FT232R chip using proprietary driver
  – http://www.ftdichip.com/Drivers/D2XX.htm
• Example: Reading configuration data stored in EEPROM
  
  ```c
  FT_STATUS ftStatus;
  FT_HANDLE ftHandle0;
  FT_PROGRAM_DATA Data;
  FT_DEVICE ftDevice;
  ftStatus = FT_Open(iport, &ftHandle0);
  ftStatus = FT_GetDeviceInfo(ftHandle0, &ftDevice, NULL, ...);
  ftStatus = FT_EE_Read(ftHandle0, &Data);
  FT_Close(ftHandle0);
  ```
FT232R EEPROM Contents

ftHandle0 = 0x100826400
Signature1 = 0
Signature2 = -1
Version = 2
VendorId = 0x0403
ProductId = 0x6001
Manufacturer = FTDI
ManufacturerId = FT
Description = UM232R USB <-> Serial
SerialNumber = FTF56DZT
MaxPower = 100
PnP = 1
SelfPowered = 0
RemoteWakeup = 1
UseExtOsc = 0x0
HighDriveIOs = 0x0
EndpointSize = 0x40

PullDownEnableR = 0x0
SerNumEnableR = 0x1
InvertTXD = 0x0
InvertRXD = 0x0
InvertRTS = 0x0
InvertCTS = 0x0
InvertDTR = 0x0
InvertDSR = 0x0
InvertDCD = 0x0
InvertRI = 0x0
Cbus0 = 0x2
Cbus1 = 0x3
Cbus2 = 0x1
Cbus3 = 0x1
Cbus4 = 0x5
RIIsVCP = 0x0
Mass Data Storage

- Microcontrollers have extremely limited storage (EEPROMs for config. data)
- External I2C EEPROMs: still limited
- Memory cards: large capacity, easy to interface
- Example: Micro-SD cards
  - extended from MultiMediaCard (MMC)
  - max. 2GB for SDSC (Standard-Capacity)
  - file system: typically FAT16
  - communication: SPI (Serial Peripheral Interface)
  - $V_{CC} = 3.3V$, $I = 20-100$ mA
- Details: www.uni-koblenz.de/~physik/informatik/ECC/sd.pdf
TOUCH SENSORS
Capacitive Touch Sensor Controller Freescale Semiconductor MPR121

- VCC = 1.71..3.6 V
- I = 29 µA at 16 ms sampling interval
- 12 capacitance sensing inputs, connect to electrodes
- I²C interface

Source: Freescale Semiconductor Datasheet
Capacitive Touch Sensor Controller
Freescale Semiconductor MPR121

Source: Freescale Semiconductor Datasheet
Capacitive Touch Sensor Controller
Freescale Semiconductor MPR121

- Programmable charge current and charge time
  - $I = 1..63\mu A$, $T = 0.5-63\ \mu s$

$$C = \frac{Q}{U} = \frac{I \cdot T}{U} \iff U = \frac{I \cdot T}{C}$$

- ADC measures voltage after charge time
  - Measured voltage inversely proportional to capacitance

- Filters remove high and low frequency noise

- Can be configured for touch recognition
  - Debouncing, touch and release thresholds

- Auto-calibration
  - Continuously measures baseline capacitance
Capacitive Touch Sensor IC
Analog Devices AD7745/AD7746

- 24-Bit capacitance-to-digital converter
  - Temperature sensor
  - Update rate: 10 Hz to 90 Hz
  - $V_{CC} = 2.7..5.25V$, $I = 0.7mA$

- I2C interface

- Operation
  - EXC = square-wave excitation signal
  - CX = capacitance
  - CIN = modulator input
  - modulator samples charge, data filtered, scaled (calibration)

Source: FTDI Datasheet
## Registers

- read/write via I2C

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<th>Address Pointer (Dec)</th>
<th>Address Pointer (Hex)</th>
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<th>Bit 6</th>
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Source: FTDI Datasheet
ATMEL QTouch

• Some AVRs integrate capacitive sensing hardware
  – Can also be implemented on standard microcontrollers

• ATMEL QTouch library