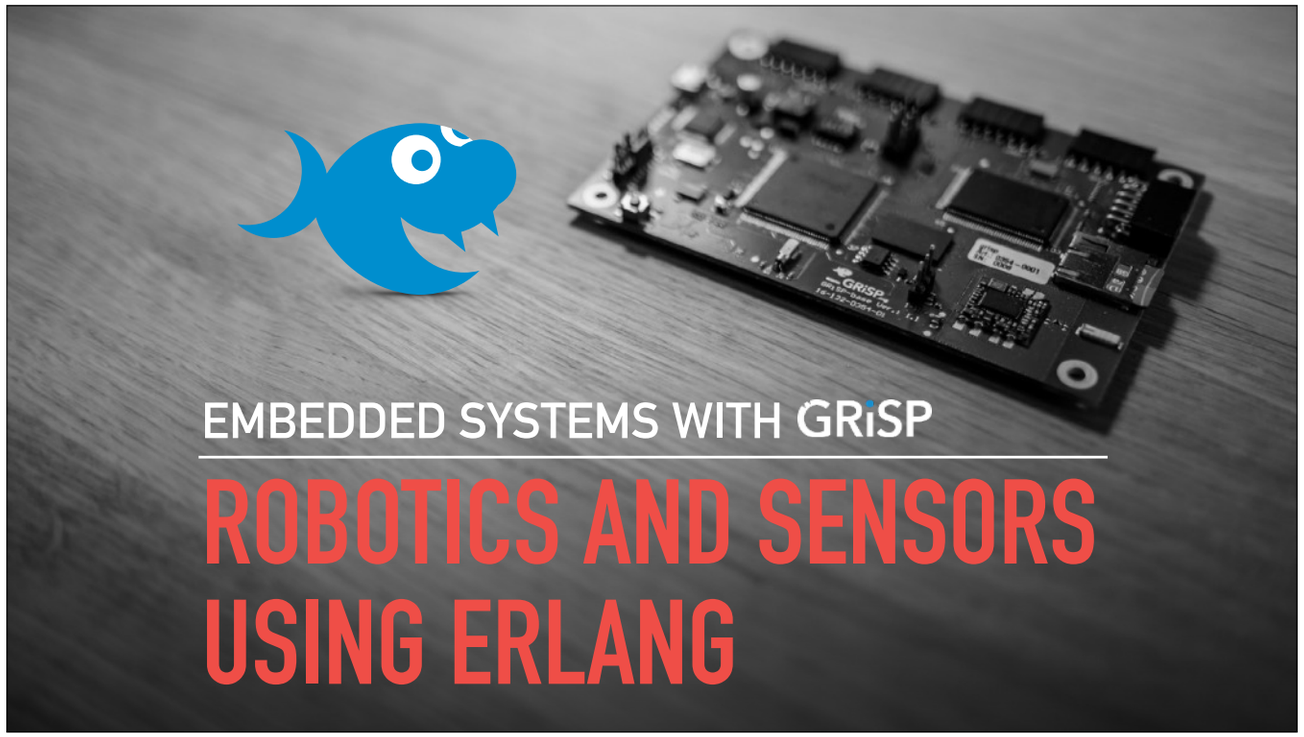

GRiSP


EMBEDDED SYSTEMS WITH GRiSP
ROBOTICS AND SENSORS
USING ERLANG

Adam Lindberg

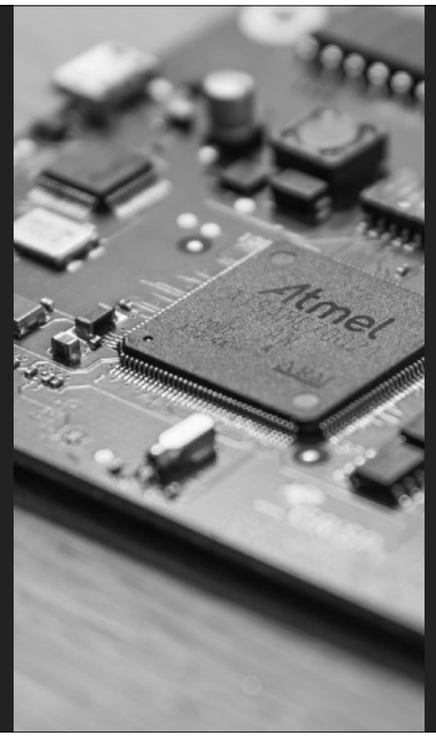
github.com/eproxus

DIPL. PHYS.
PEER STRITZINGER GMBH

HARDWARE
COMPONENTS
SOFTWARE
FUTURE

DEMO

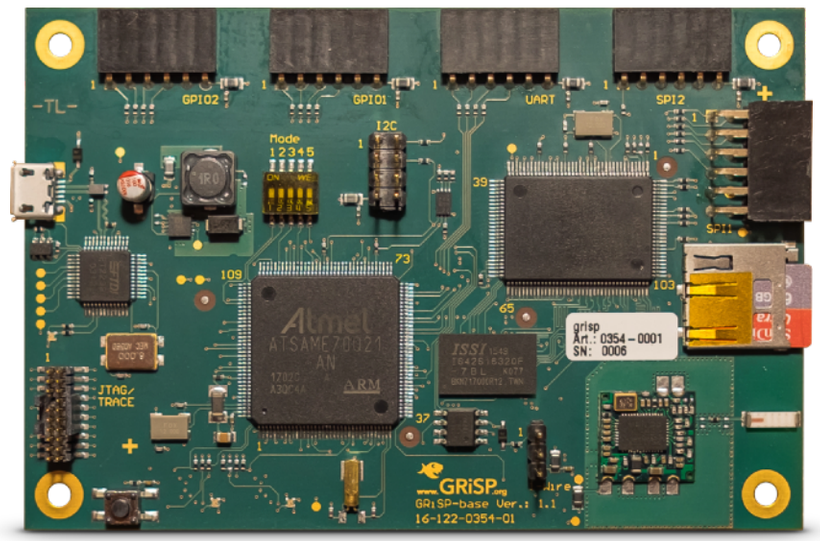
Boot, Serial console, Erlang shell



THE GRISP BOARD

SPECS

Hardware & specifications



EMBEDDED
WIRELESS DEVICE

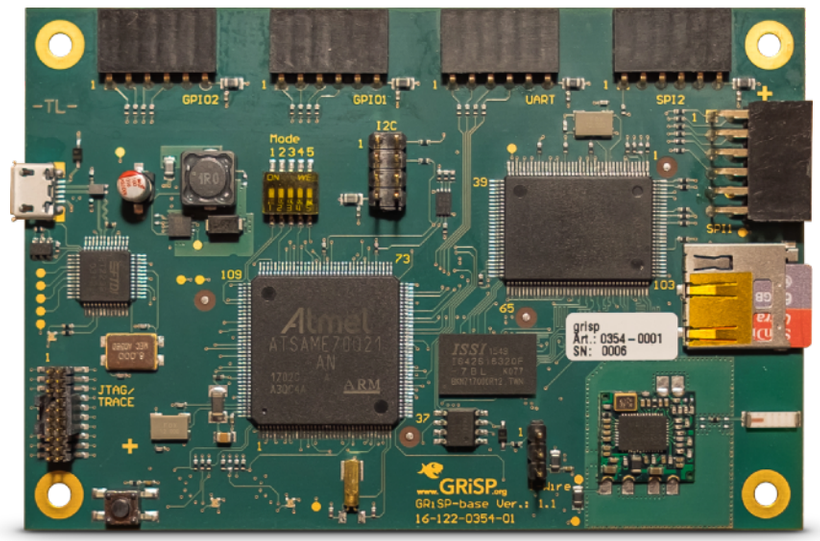
REAL ERLANG
ON
REAL BARE METAL

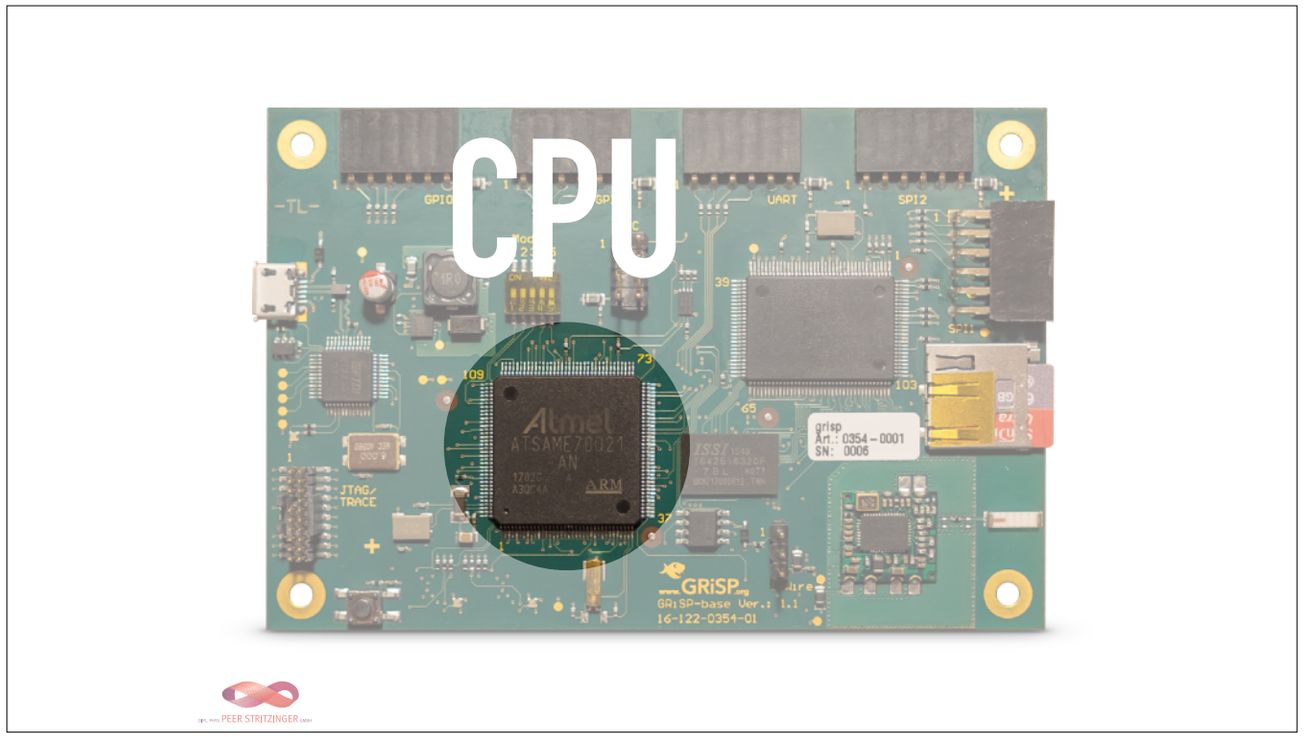
You'll never get Erlang this close to hardware anywhere else

CONNECTORS FOR SENSORS & ACTUATORS

300 MHZ
64 MiB RAM
WIFI
MICROSD

DIPL.-INFO. PEER STRITZINGER GMBH




CPU
GPIO
UART
SPI2
JTAG/
TRACE
Atmel
ATSAME70Q21
AN
ARM
grisp
Art.: 0354 – 0001
SN: 0006
www.GRiSP.org
GRiSP-base Ver.: 1.1
16-122-0354-01

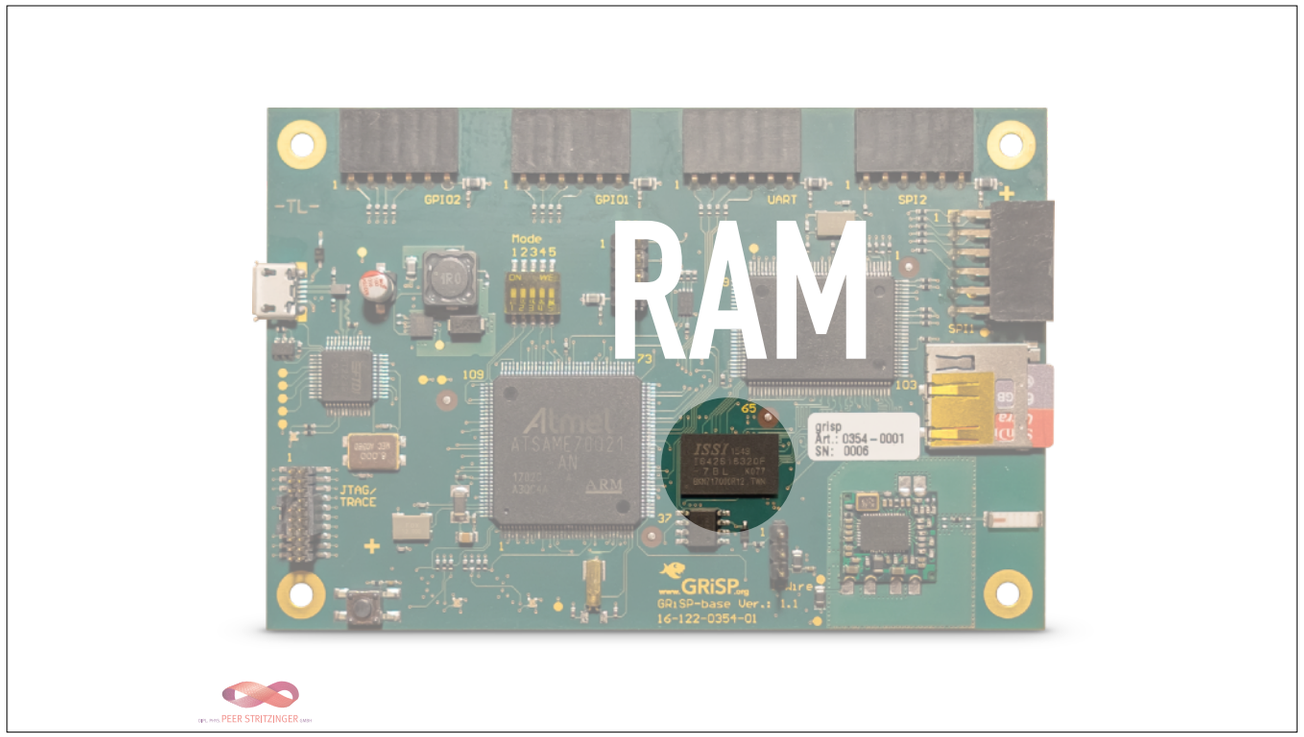
ARM CORTEX M7

ATMEL SAM V71

UP TO 300MHZ

FPU & DSP EXT.

- ARM Cortex M7 Core
- 32-bit System on a Chip (SoC)
- Atmel SAM V71 Microcontroller (MCU)
- Runs up to 300 Mhz
- Single- and double-precision HW Floating Point Unit (FPU)
- Digital Signal Processing extensions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GPIO2
GPIO1
UART
SPI2
Mode
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JTAG/
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Atmel
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ISSI
IS42S16320F
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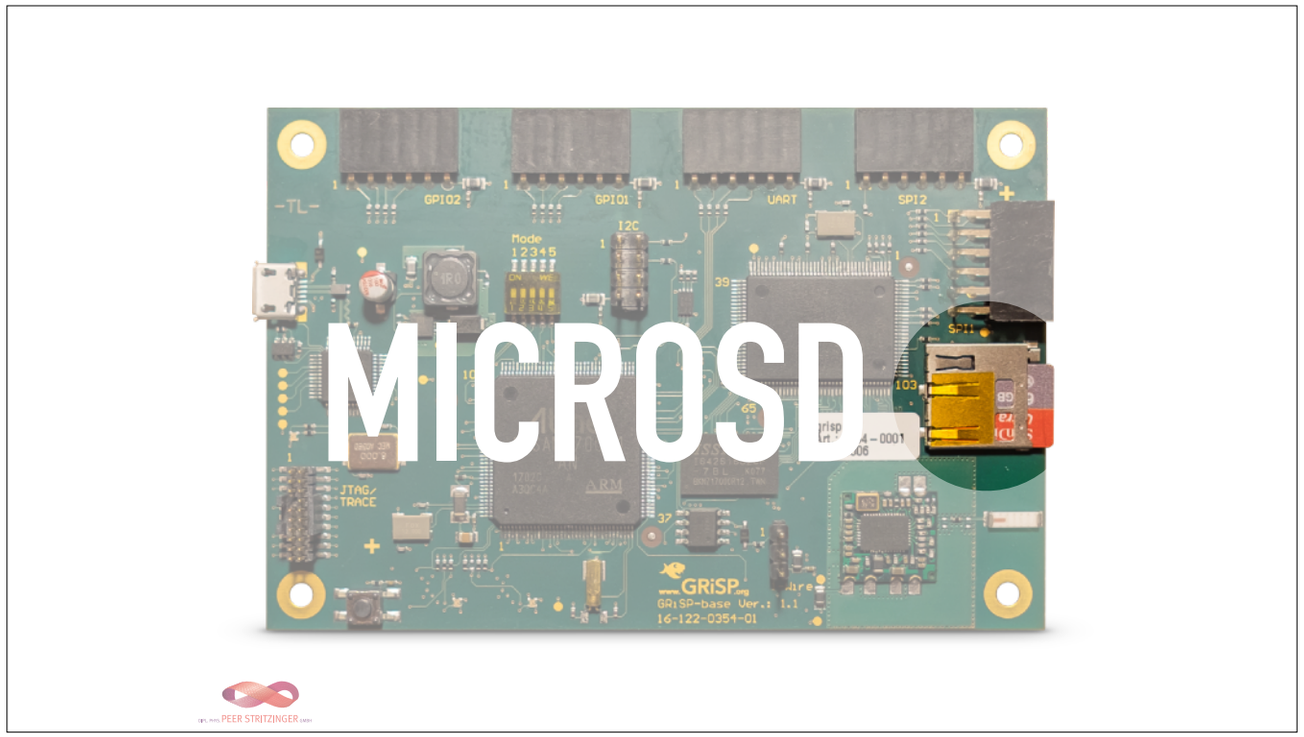
Storage


MICROSD
GPIO2
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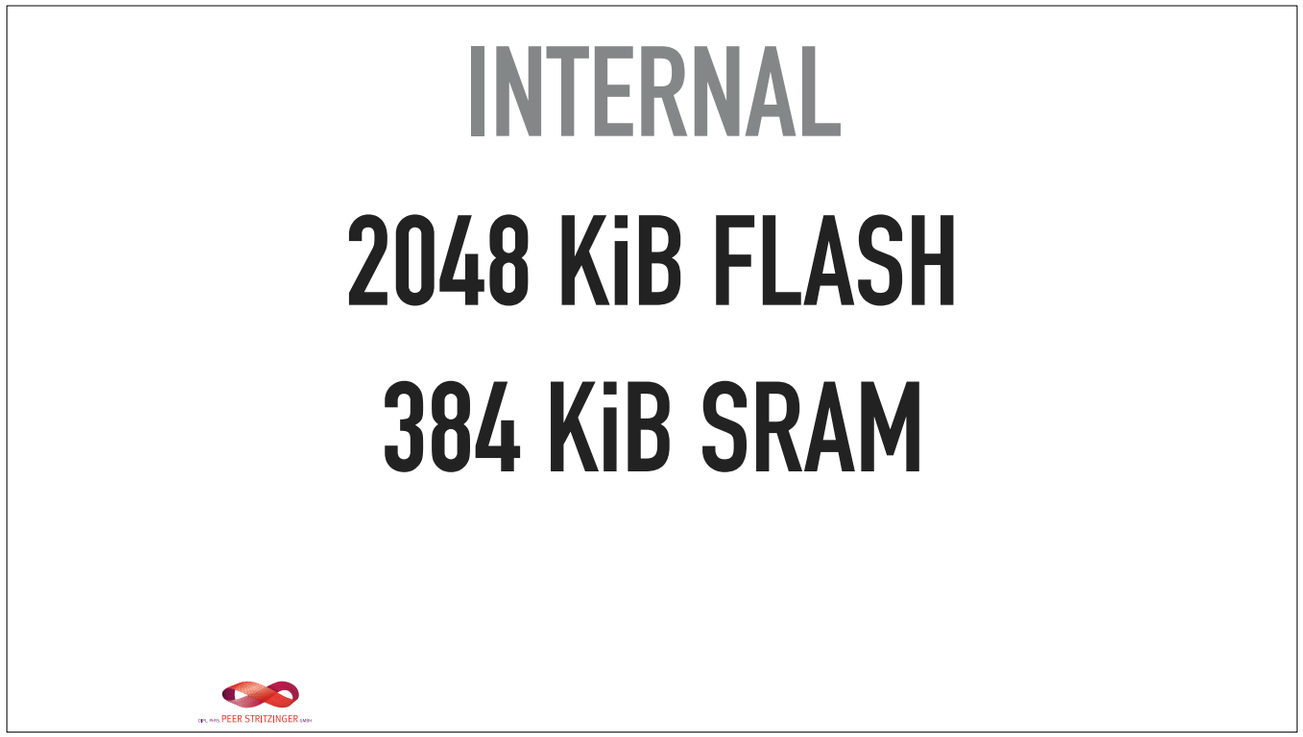
Storage



- Flash used for bootloader

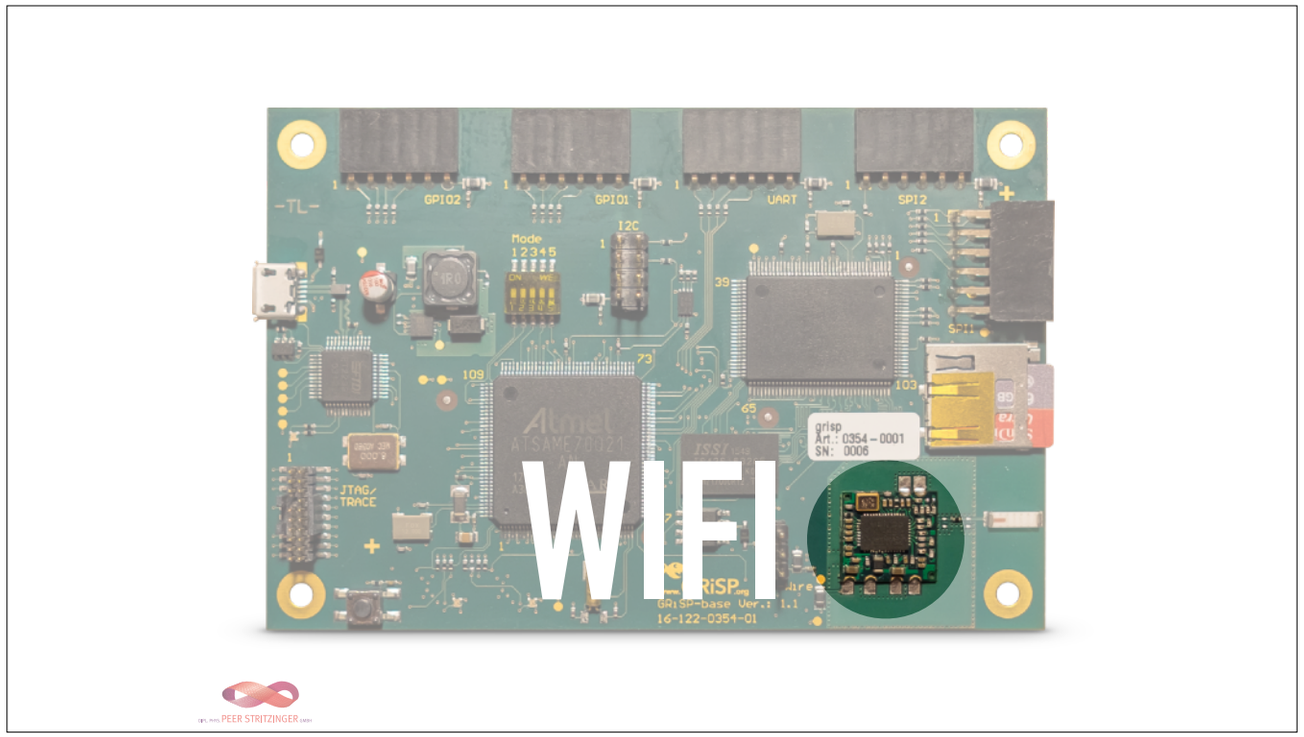
EXTERNAL

64 MiB SDRAM

2 KiB EEPROM

MICROSD

- 64 MiB SDRAM, plenty for Erlang
- EEPROM for storing configs
- MicroSD socket for external storage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WIFI

Storage

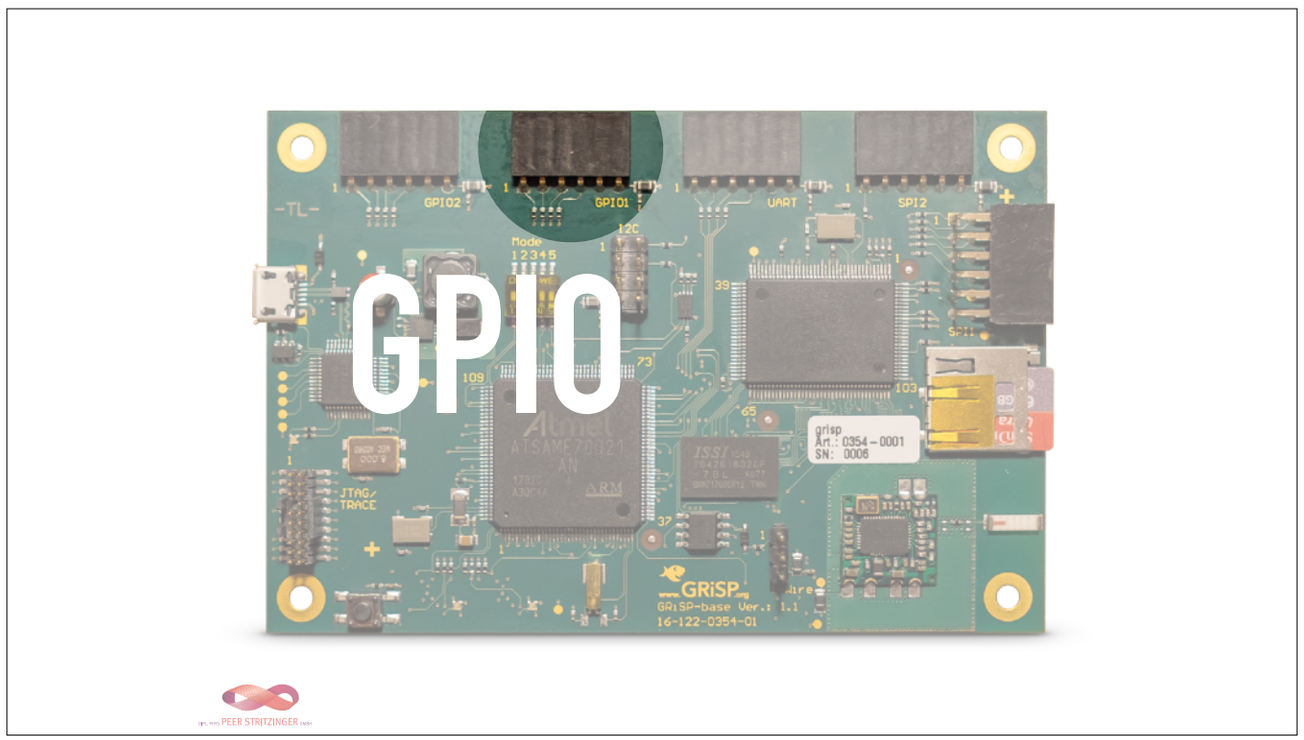
802.11N 2.4 GHZ

UP TO 150 MBPS

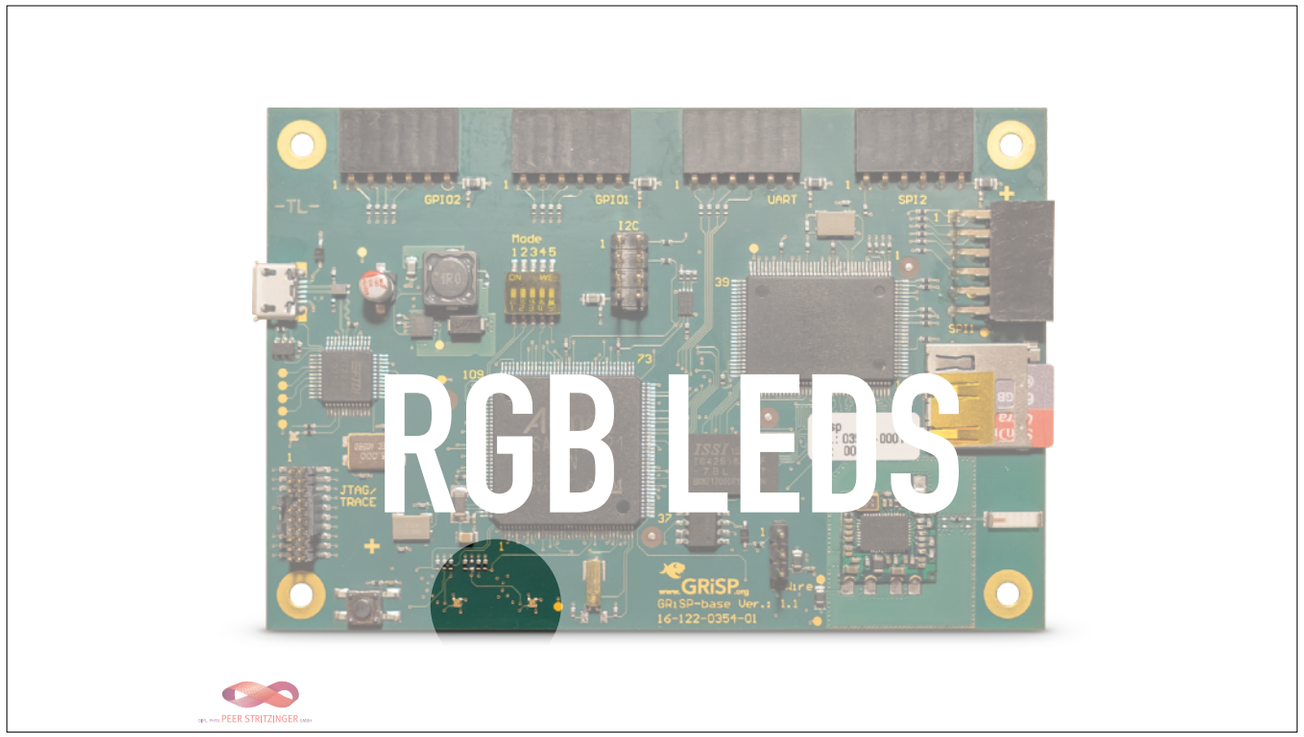
POWER SAVING

- IEEE 802.11 b/g/n for the 2.4 Ghz band
- On-board USB2.0 interface
- 72.2Mbps receive and transmit rate using 20MHz bandwidth
- 150Mbps receive and transmit rate using 40MHz bandwidth
- Power saving mechanism

Two generic GPIO 6-pin ports

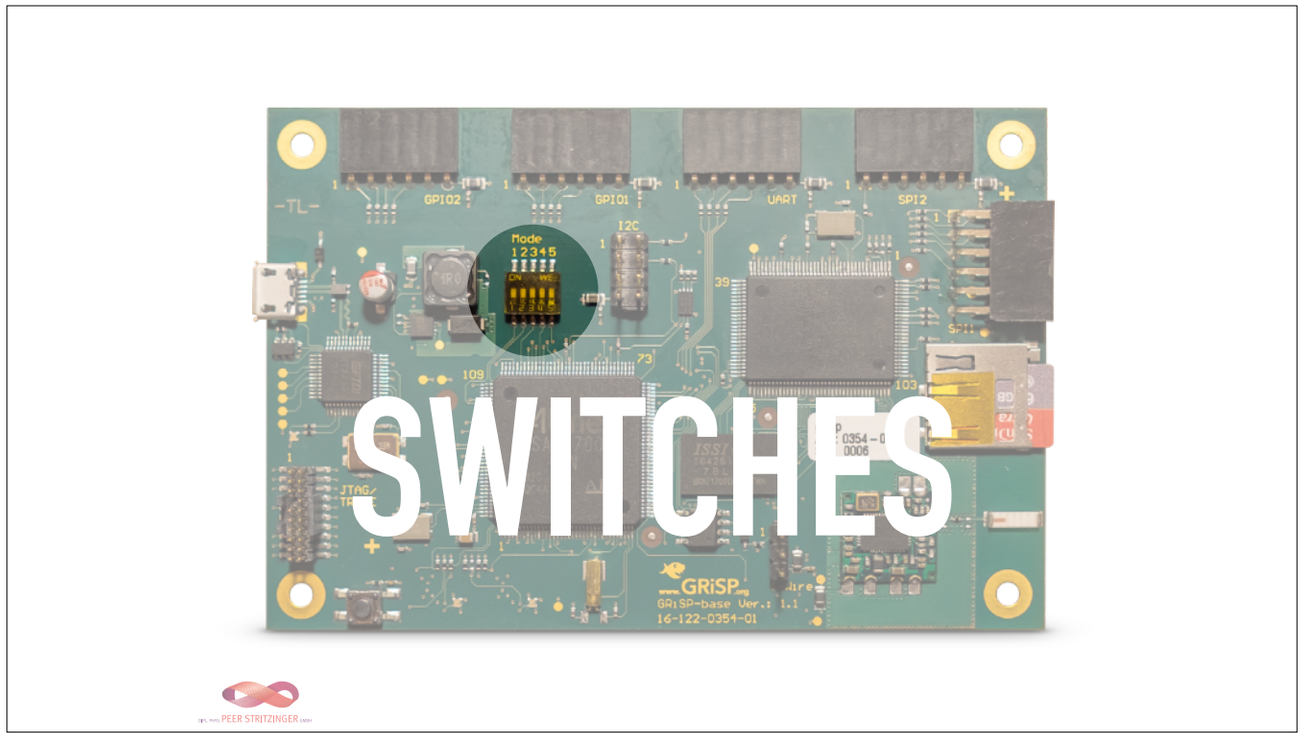


Two generic GPIO 6-pin ports



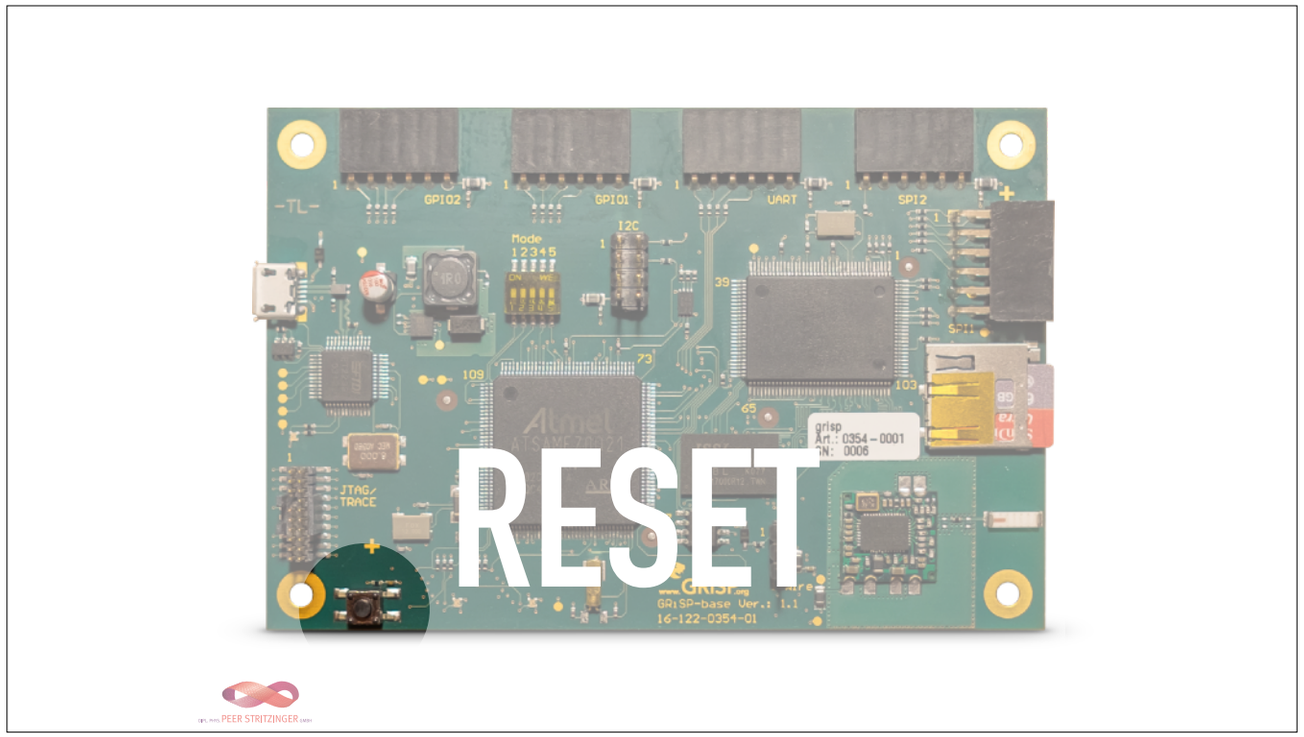
RGB LEDS

Two RGB LEDs



SWITCHES

5 generic DIP switches

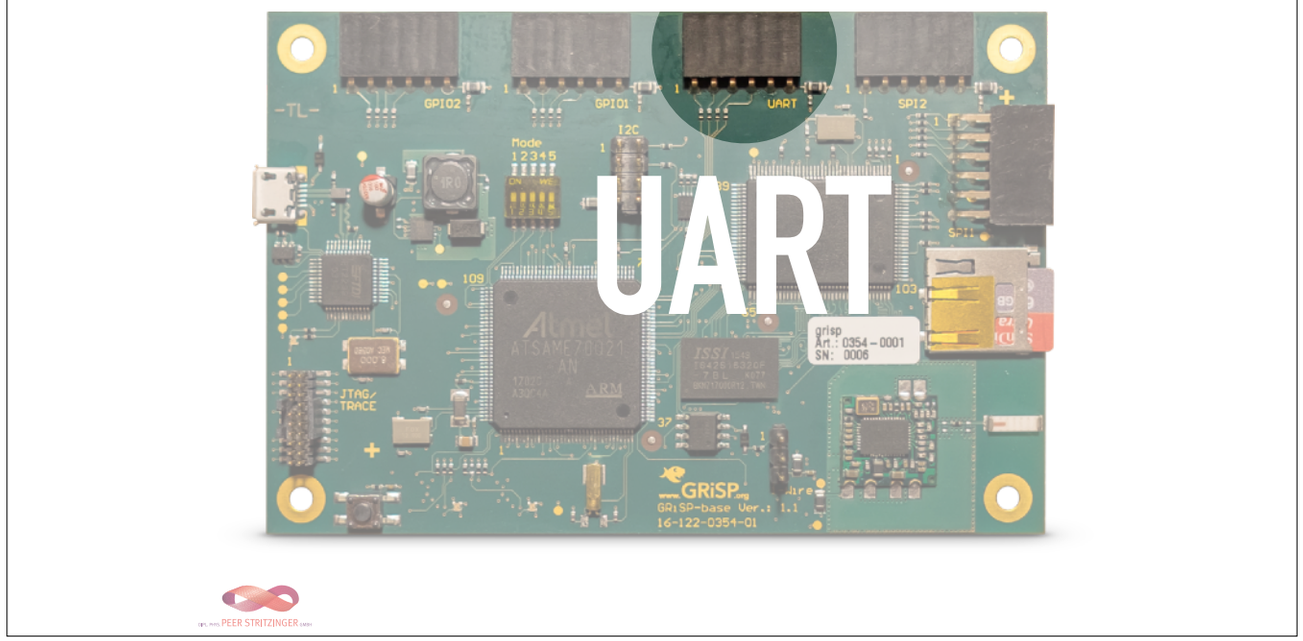


Reset button

GENERAL PURPOSE INPUT/OUTPUT

SUPPORTS PWM

- Generic pins controllable at runtime
- Support for Pulse Width Modulation (PWM)
- LED brightness & precise motor control

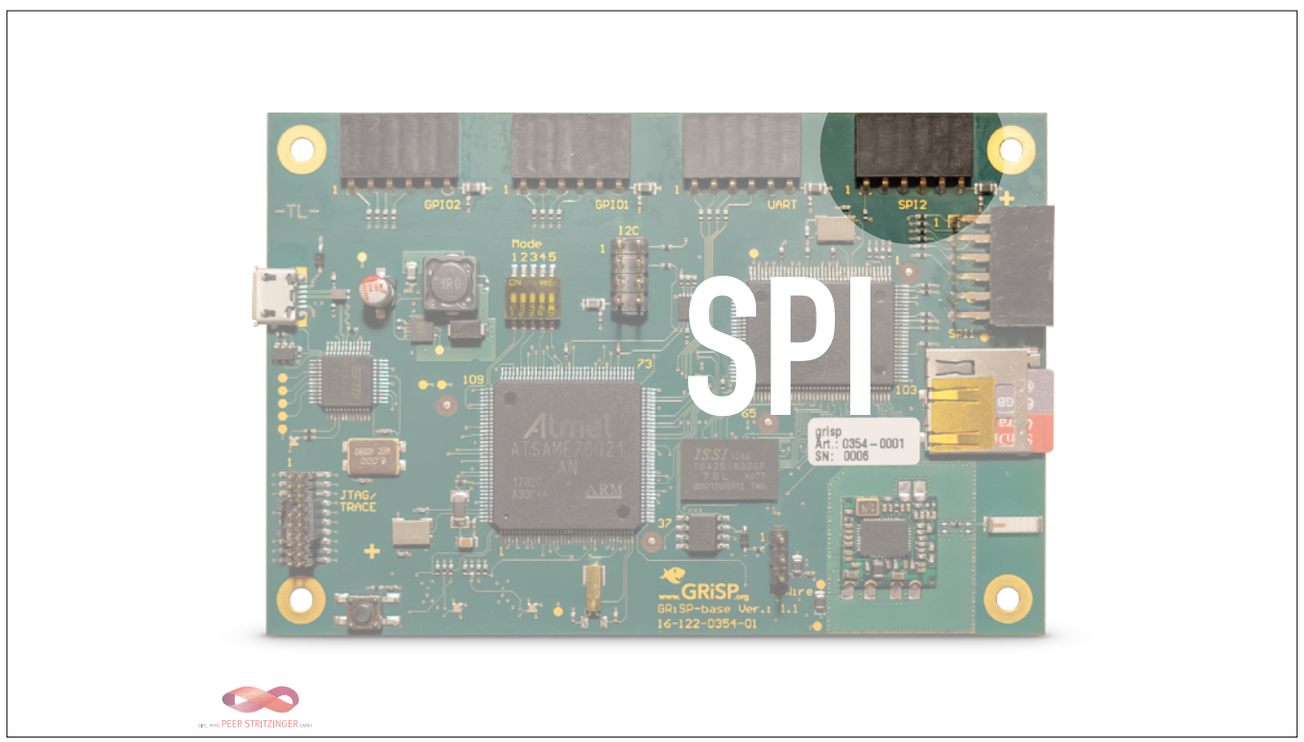


UART

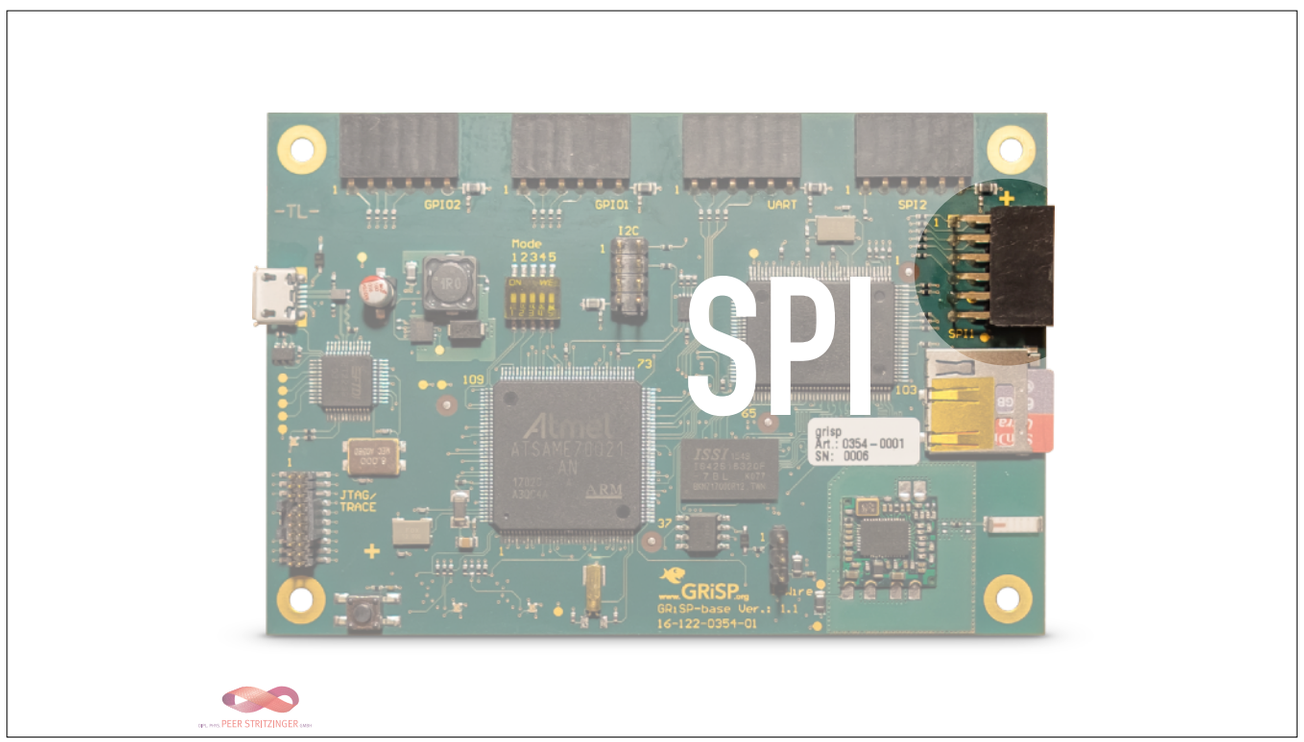
ASYNCHRONOUS
SERIAL COMMUNICATION
BIT STREAMS
CONFIGURABLE

DIPL.-INFO. PEER STRITZINGER GMBH

- Universal Asynchronous Receiver/Transmitter (UART)
- Asynchronous serial communication
- Generic bit streams
- Data format and transmission speeds are configurable



One SPI 6-pin port



One SPI 12-pin port

SYNCHRONOUS
SERIAL COMMUNICATION
BROAD CHIP SUPPORT
UP TO 20 MBIT/S

- Serial Peripheral Interface
- Synchronous serial communication bus
- Simple as GPIO, but serial
- Lots of chips support it
- Fast, up to 20 Mbit/s

MASTER SLAVE PROTOCOL

2 LINES IO

1 CLOCK LINE

1 SLAVE SELECT

POWER & GROUND

- 6-pin master/slave protocol with 4 wires + power & ground
- 2 lines for input/otput (MOSI/MISO)
- 2 lines for clock and slave select
- One extended SPI port with extra interrupt lines (12-pin)

I2C

MASTER SLAVE PROTOCOL

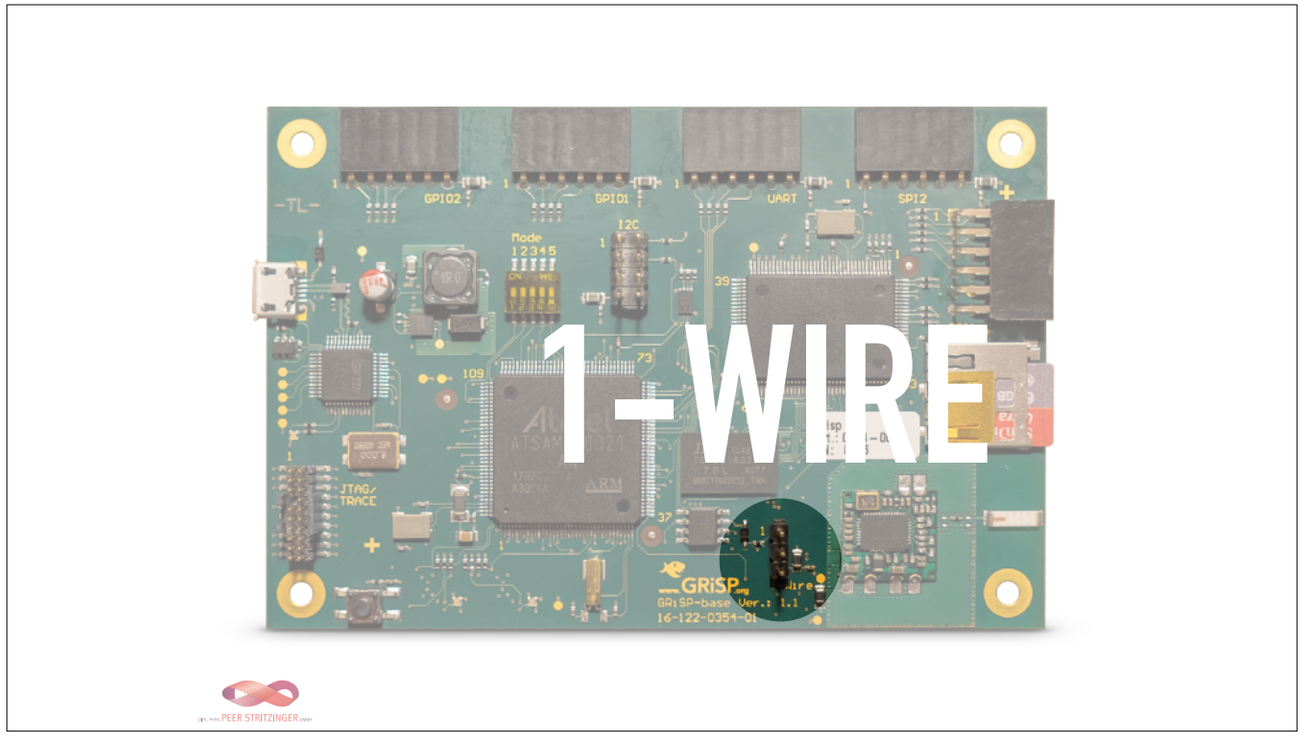
1 DATA LINE

1 CLOCK LINE

POWER & GROUND

ADRESSABLE

- Inter-Integrated Circuit
- Master/slave protocol
- Two lines (data + clock) + power & ground
- Addressable clients, send data packets with address
- Usually for board-local communication, unreliable over longer distances
- Slow, only 0.4 Mbit/s



1-WIRE

PEER STRITZINGER GMBH

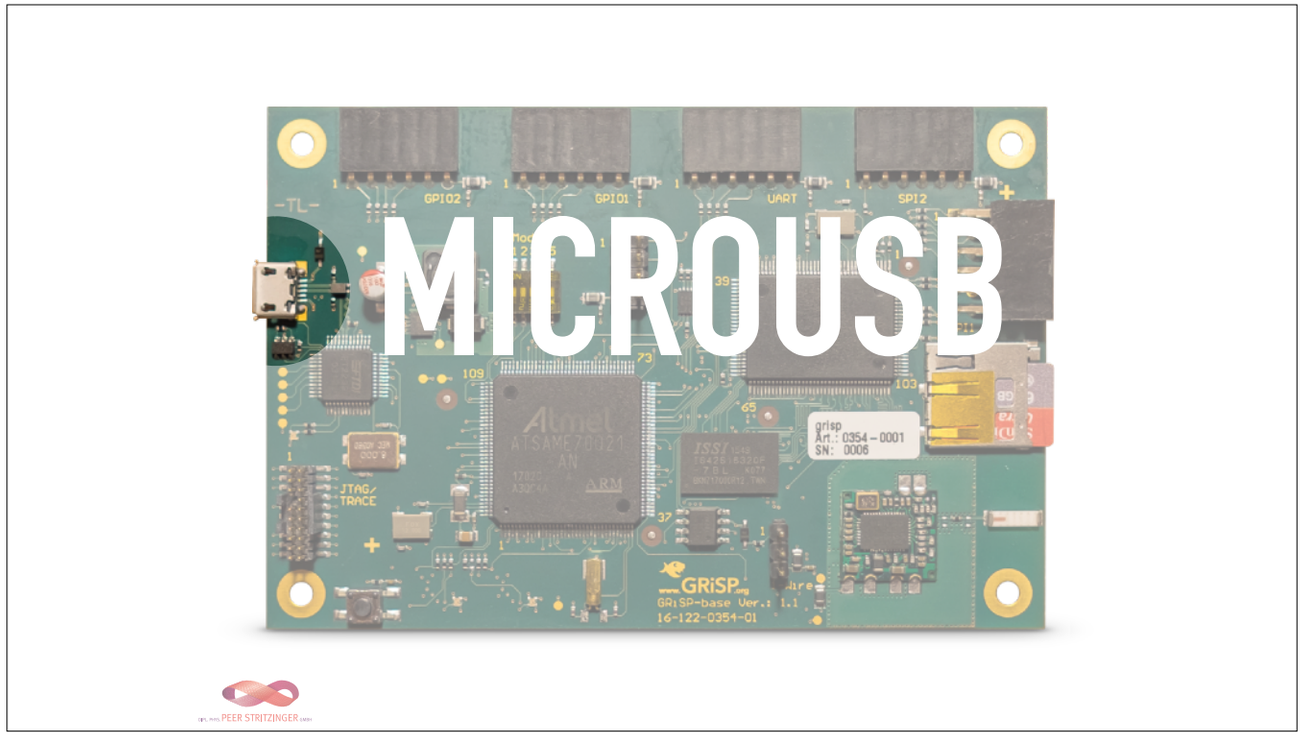
DALLAS 1-WIRE

1 DATA + POWER LINE

GROUND

ADDRESSABLE MICROLAN

- Developed by Dallas Semiconductor Corp.
- Only 1 wire for data (plus ground)
- To power themselves, devices charges a small capacitor when data line is not used
- Similar to I2C but lower data rate and longer distance
- Master plus devices constitutes a MicroLAN
- Devices has a unique 64-bit address (ID + device type)
- Popular devices are buttons, key fobs, weather sensors etc.


MICROUSB
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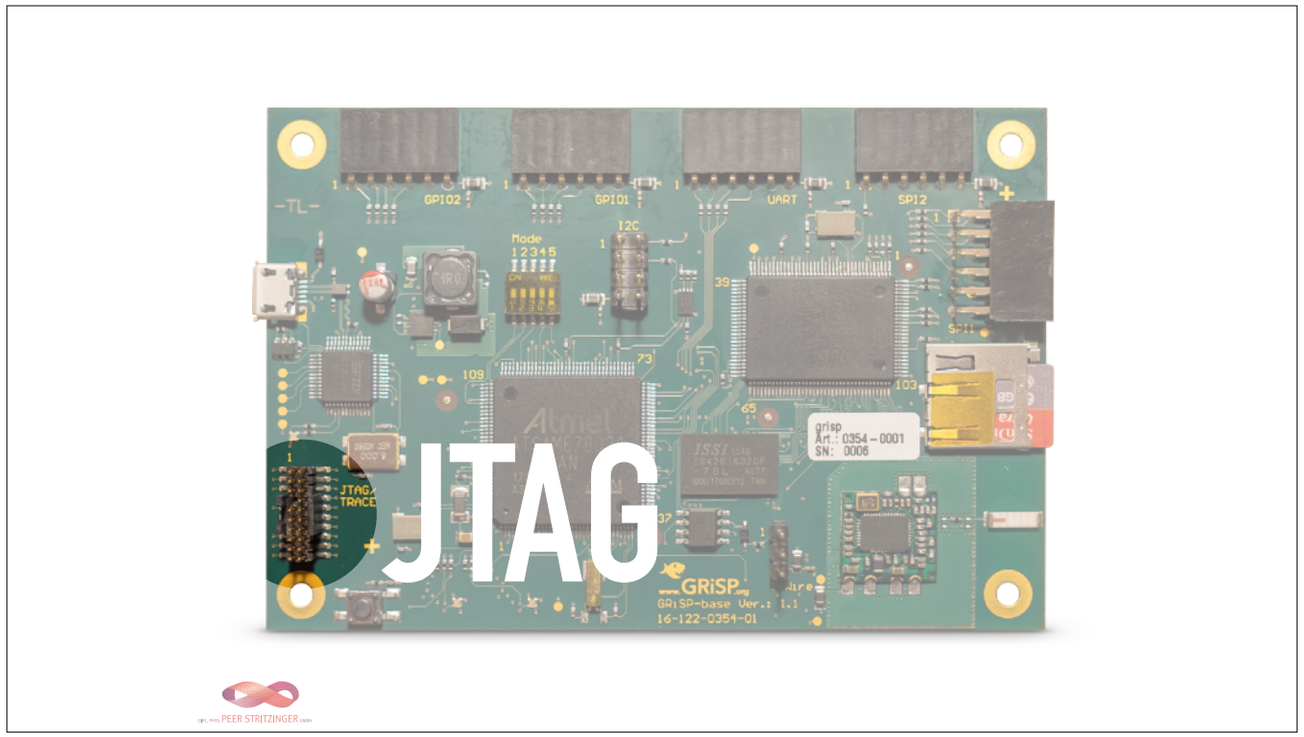

JTAG debugger

MICROUSB FOR POWER & SERIAL CONSOLE JTAG DEBUGGER

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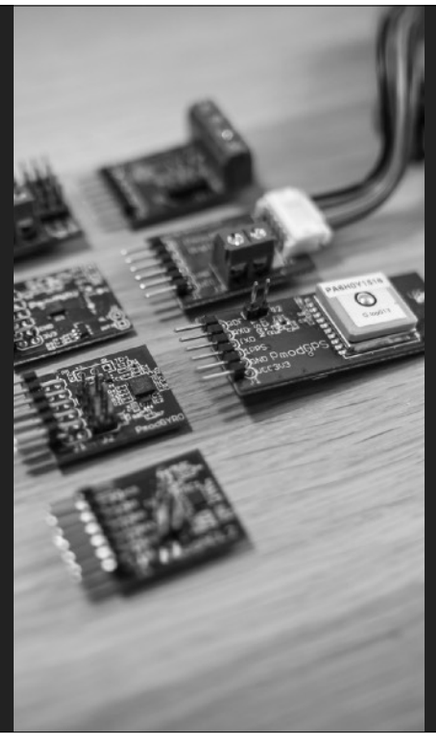
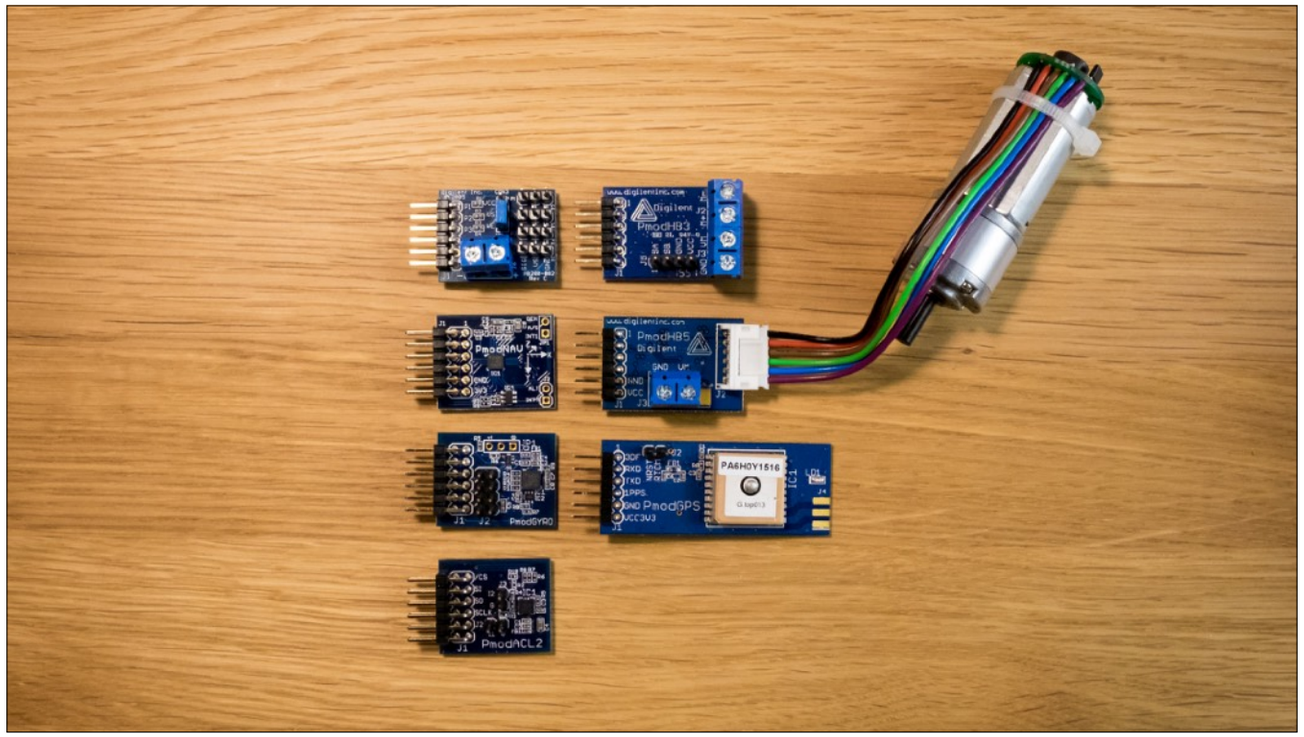
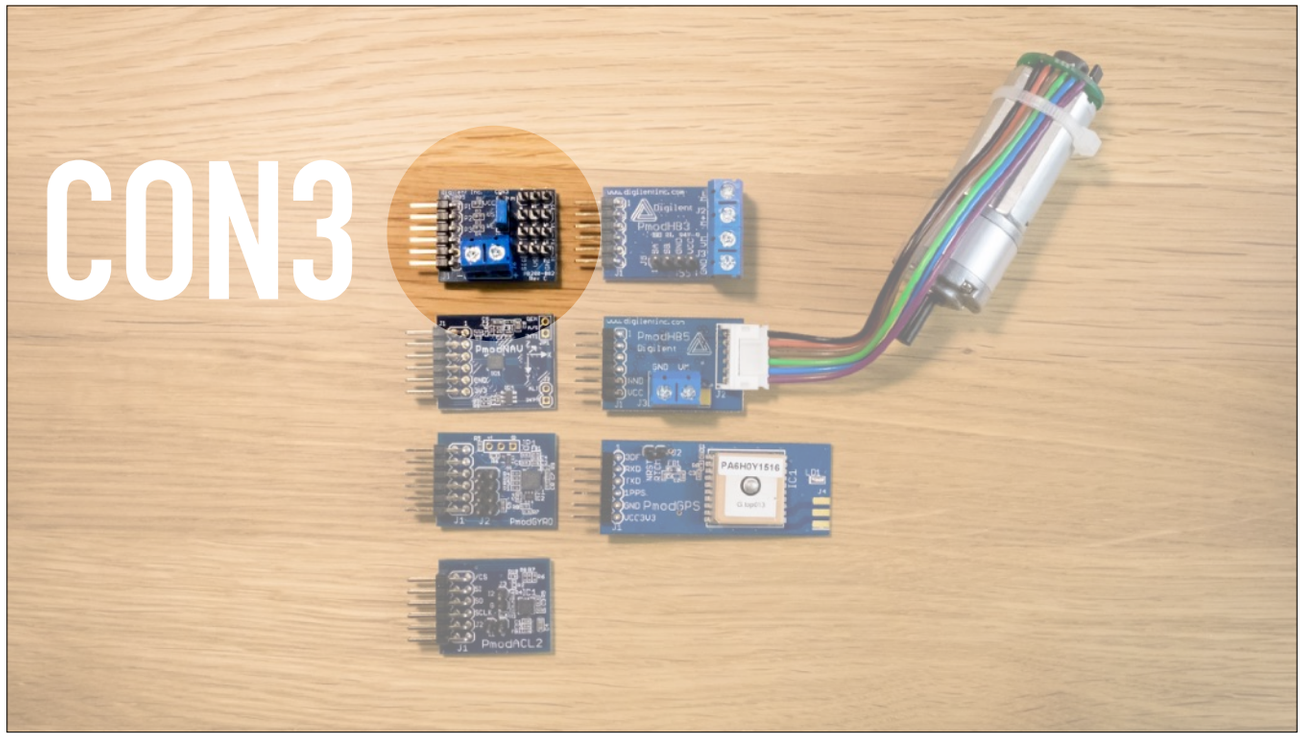
- USB connector
  - Power from laptop or battery pack
  - Serial console
  - JTAG debugger access
- External JTAG connector
  - ARM 2×10 pin



ACCESSORIES

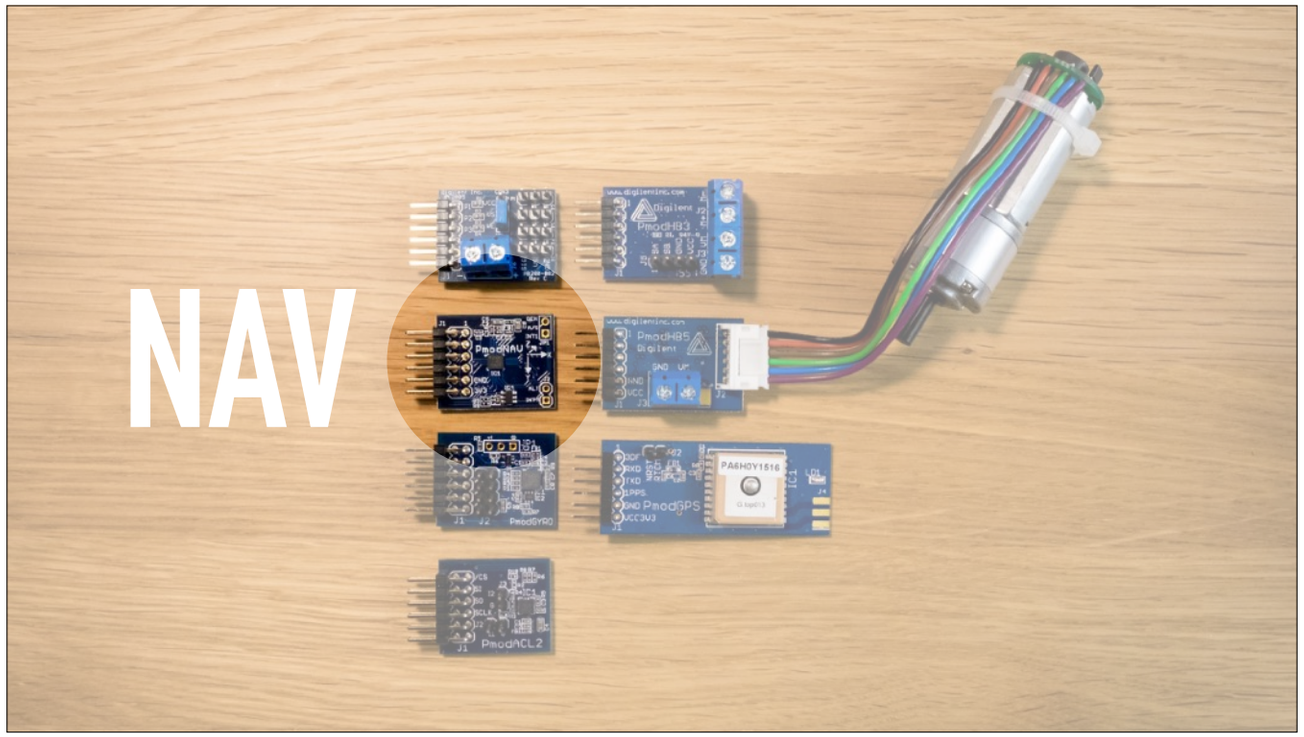
PMODS


PmodHB3
PmodHB5
PmodNAV
PmodGYRO
PmodGPS
PA6H0Y1516
PmodACL2



GPIO

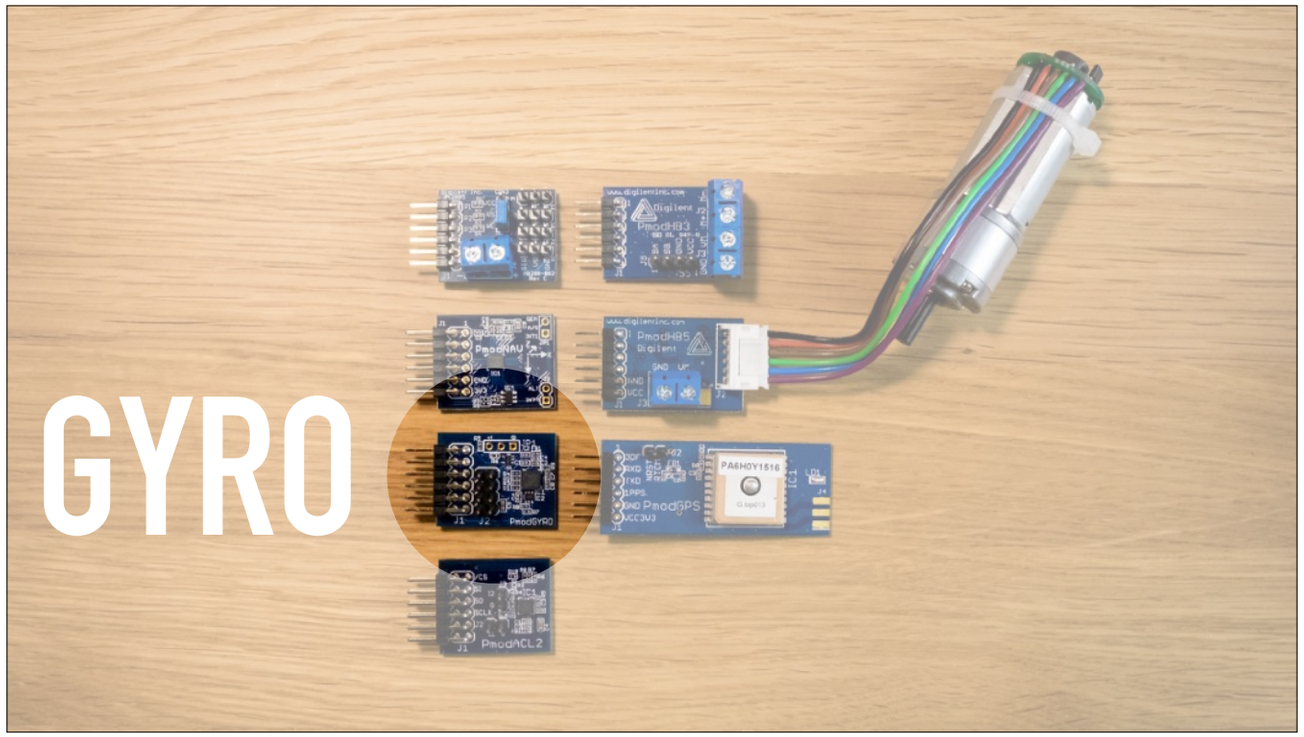
Four standard 3-wire servo motor connectors



SPI

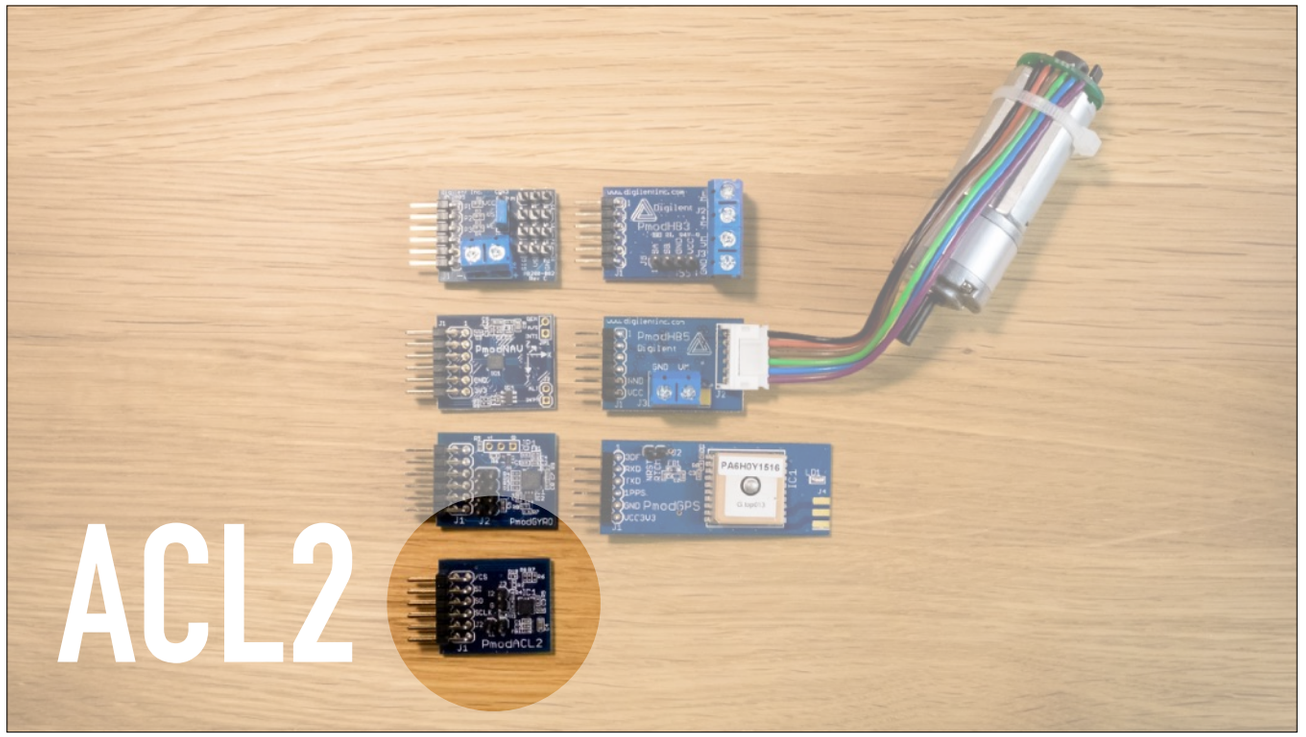
9-axis Inertial Measurement Unit (IMU) Plus Barometer

3-axis accelerometer, 3-axis gyroscope, 3-axis magnetometer



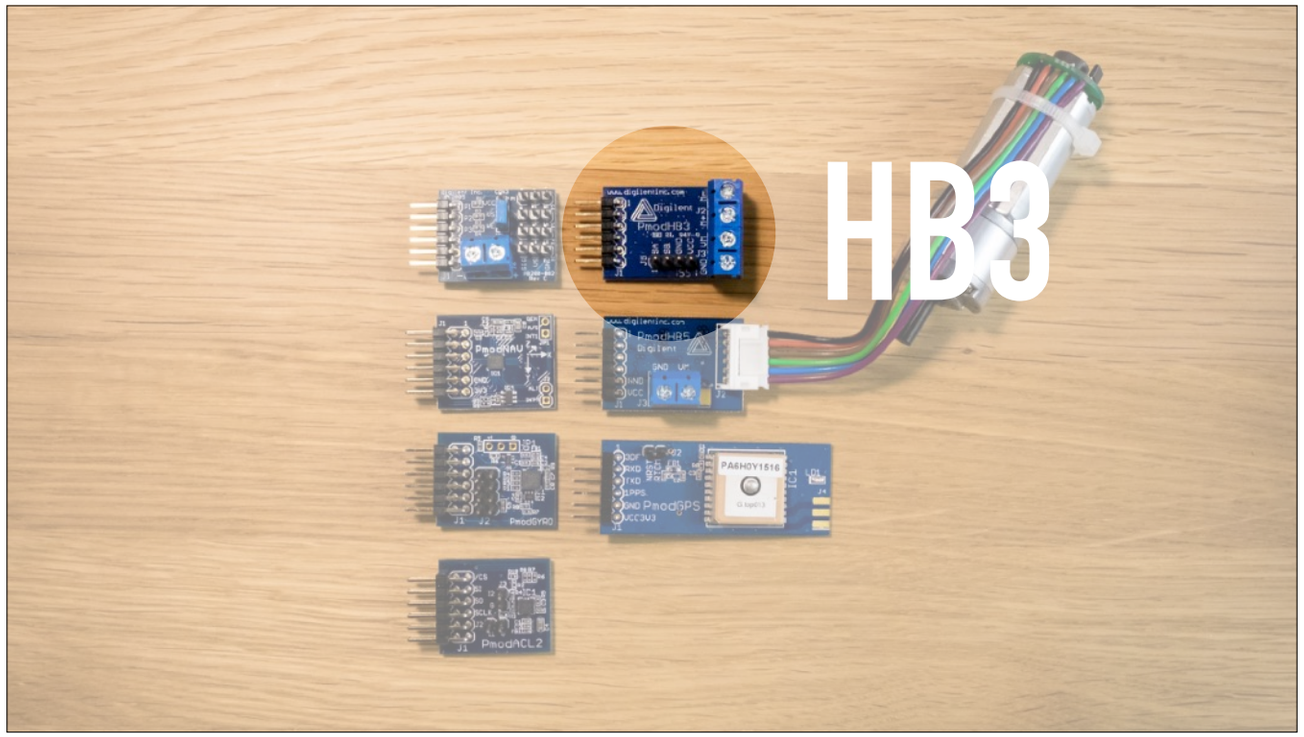
SPI

3-axis Digital Gyroscope



SPI

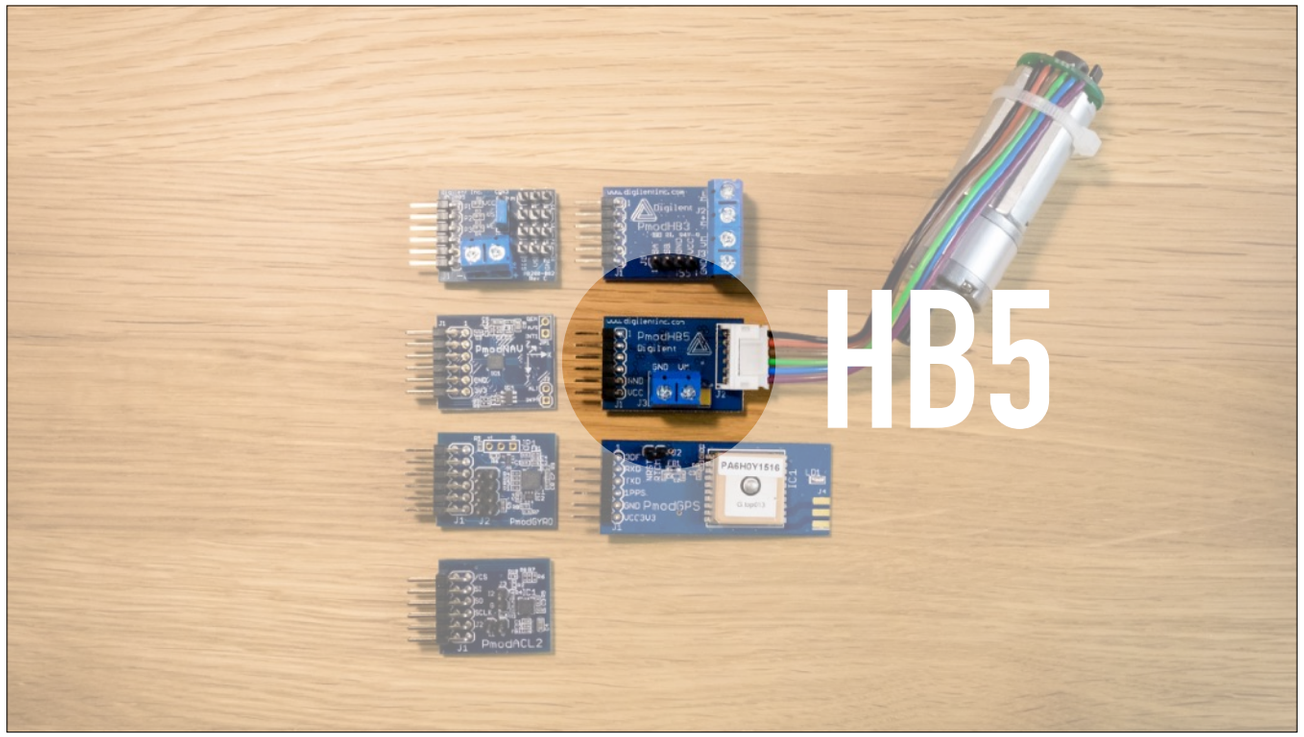
3-axis Microelectromechanical System (MEMS) Accelerometer



GPIO

H-bridge Driver with Feedback Inputs

Drive a DC motor with operation voltage up to 12V

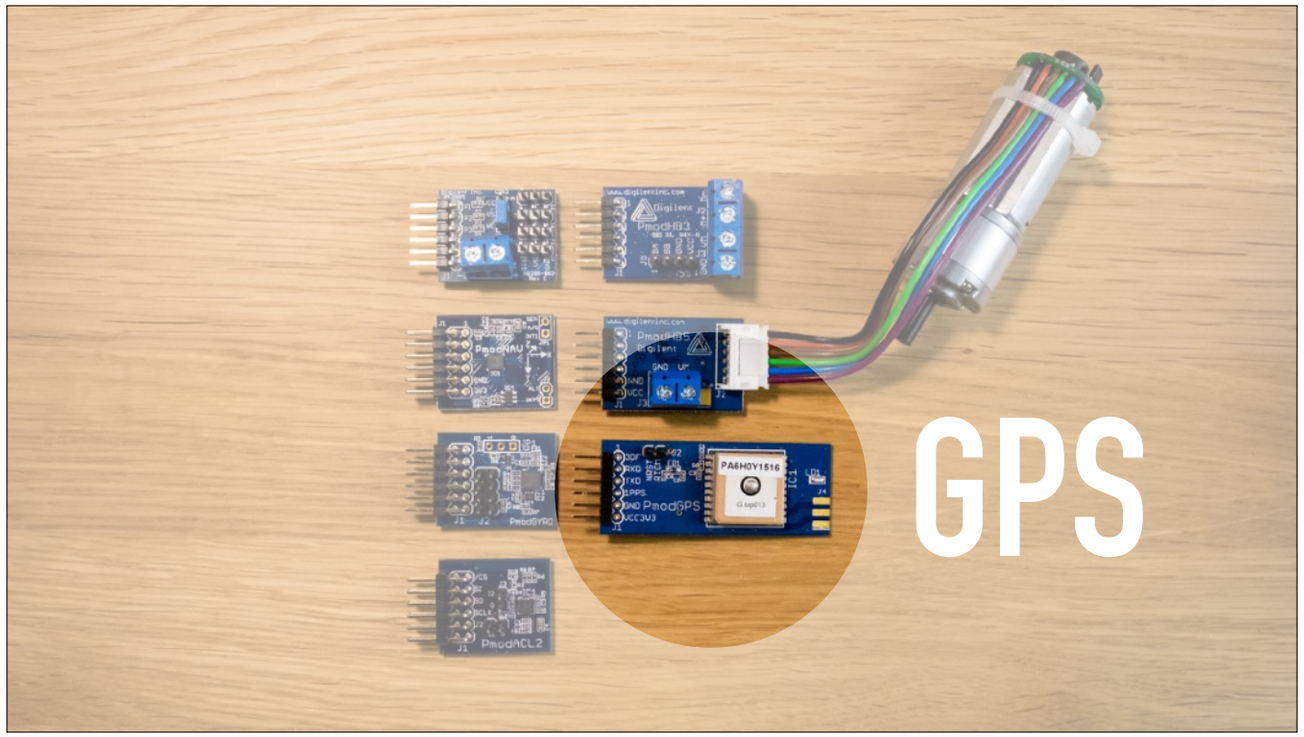


GPIO

H-bridge Driver with Feedback Inputs

6-pin JST connector for direct connection to Digilent motor/gearboxes

Drive a DC motor with operation voltage up to 12V



UART
GPS Receiver
3m 2D satellite positioning accuracy

DEMO

PmodACL2
Accelerando?

TOOLCHAIN,
OS
& RUNTIME

SOFTWARE

RTEMS

RTOS

“OS-AS-A-LIBRARY”

POSIX

- Real-Time Executive for Multiprocessor Systems
- Real Time Operating System (RTOS)
- Free & open source
- “OS-as-a-library”
- Supports open standard APIs (e.g. POSIX)

PERFORMANT

SMP

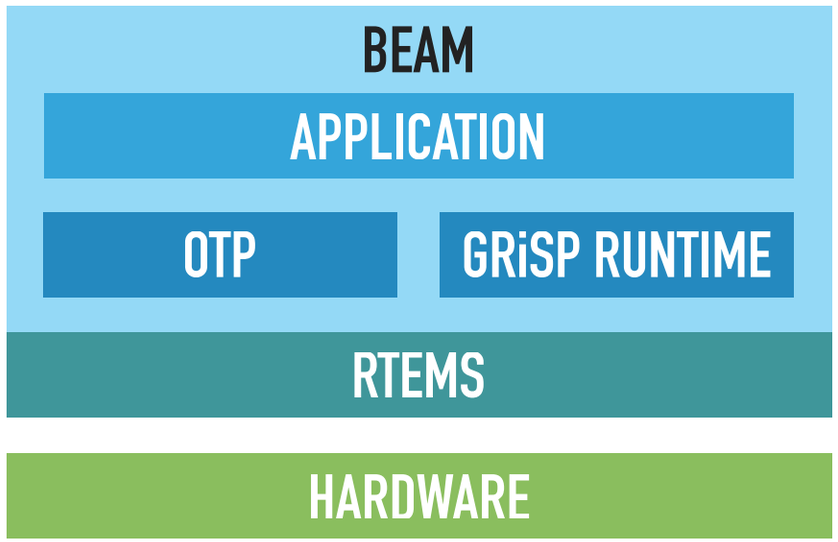
PROCESSES VIA THREADS

FREEBSD NETWORKING

- Scalable timer and timeout support
- Uses fine-grained locking
- Processes emulated by threads
- SMP support
- Uses the FreeBSD networking stack

BEAM COMPILED WITH RTEMS STARTS FROM BOOTLOADER OS APIS PROVIDED BY RTEMS

- We compile BEAM with RTEMS headers and libraries
- The VM can be started directly from the boot loader
- The OS APIs that the VM needs are implemented by RTEMS



GRiSP RUNTIME

HARDWARE ABSTRACTION

LOW LEVEL DRIVERS

HIGH LEVEL DRIVERS

- Erlang application and linked-in drivers
- Interface to interact with the GRiSP hardware and devices
- Low-level drivers for SPI & GPIO
- High-level drivers
  - LEDs
  - DIP switches
  - PMODs

EXAMPLE

SPI DRIVER

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SPI DRIVER (C)

```c
void grisp_spi_output
(ErlDrvData drv_data, char *buf, ErlDrvSizeT len)
{
    // …

    // Grab first byte as chip select
    cs = buf[0];
    buf++;
    len -= 1;
```

SPI DRIVER (C)

```
    // …
    msg.cs = cs;
    msg.tx_buf = buf;
    msg.rx_buf = res;
    msg.len = len;
    rv = ioctl(grisp_spi_data.fd, SPI_IOC_MESSAGE(1),
               &msg);
    assert(rv == 0);
    driver_output(grisp_spi_data.port, res, len);
}
```

SPI DRIVER (ERLANG)

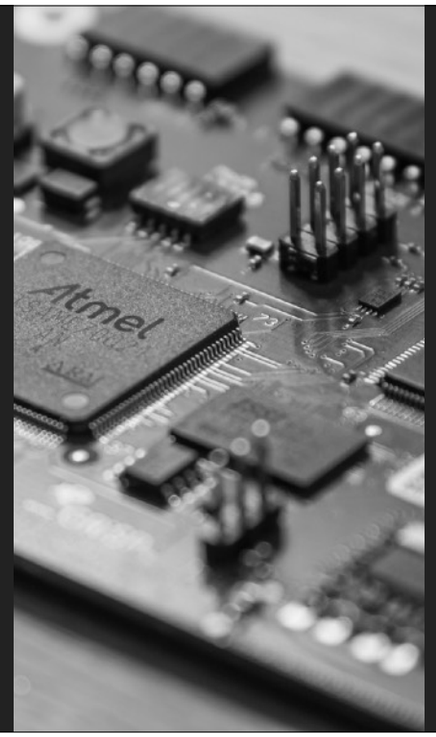
```
-module(grisp_spi_drv).
-export([open/0, command/3]).

open() ->
    open_port({spawn_driver, "grisp_spi_drv"},
              [binary]).

command(Port, Slot, Command) ->
    Slot = slave_select(Slot),  # gpio1 -> 2
    Command = <<Slot, Command/binary>>,
    Port ! {self(), {command, Command}}.
```

slave_select is a function that maps the slot name to a number

SPI DRIVER (SHELL)

```
1> Command = <<16#0B, 16#0E>>.
<<16#0B, 16#0E>>
2> Raw = <<Command/binary, 0>>.
<<16#0B, 16#0E, 0>>
3> grisp_spi_drv:command(Port, spi1, Raw).
{<0.132.0>,{command,spi1,<<11,14,0>>}}
4> flush().
Shell got {<0.127.0>,{data,<<0,0,172>>}}
ok
5> grisp_spi:send_recv(spi1, Command, 2, 1).
<<"¬">>
```

Motor
Robot?



WHAT WE'RE WORKING ON

THE FUTURE

ISSUES

FULL WIFI SUPPORT

MICROSD SPEED

CLOCK SPEED “OFF”

- Direct memory access (DMA)
- Some low-lever time mechanism used by Erlang has the wrong time

LIGHTKONE

Lightweight computation for networks at the edge

IOT

SYNCHRONIZATION-FREE PROGRAMMING

HYBRID GOSSIP PROTOCOLS

DPL PAVEL PEER STRITZINGER GMBH

ROADMAP

ERLANG 19/20

REBAR3 TOOLING

PMOD DRIVERS & WIFI

DIPL.-INFO. PEER STRITZINGER GMBH

- Rebar3 tooling (releases, cross compiling custom VM build)
- More high-level PMOD drivers
- Wi-Fi connection management
- Upgrade to Erlang 19/20

grisp.org
github.com/grisp
stritzinger.com

THANK YOU!

QUESTIONS?