Daisy Chain Protocol Development in Force-Guiding Particle Chains for Shape-Shifting Displays

Developmet Board Implementation

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What this session covers

physical network structure
MCU selection
development board

Underlying work

Force-Guiding particle Chains for Shape-Shifting Displays[1]

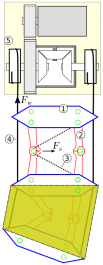


Figure 1: *particle chain*

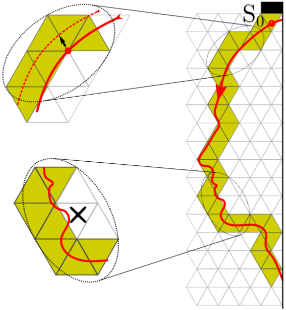


Figure 2: *folding a shape*

chain is stretched in natural state
shape Memory Alloy used as actuator (3)
joints unlocked by actuators (2)
force F_s folds chain

Approach & limitation

current particle implements 1-Wire via power supply wires
energy must be buffered before communication starts
power must be switched off/on
automatic chain position detection is costly

Idea

decouple communication from power supply (4)
using a daisy-chain protocol, and
actuator wires (3)

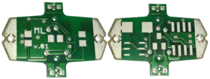


Figure 3: *particle PCB*

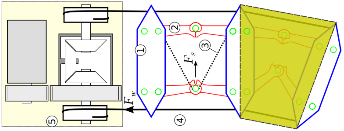


Figure 4: *particle chain*

Project extent

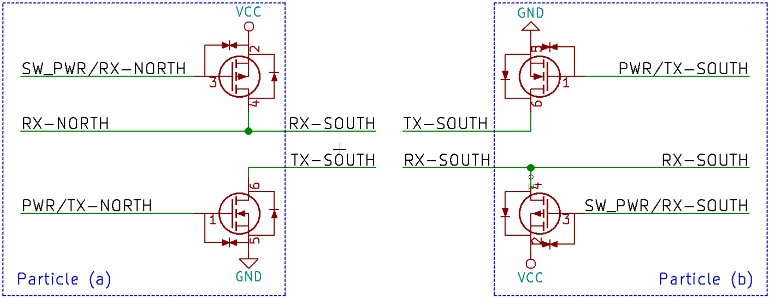
- particle board development
- easy accessible test points and transmission wires
- flexible and fast network assembly

Project constraints

- reasonable low level MCU
- minimize number of components on particle PCB
- communication:
  - exploit SMA wires
  - decouple from power supply
- small MCU package in final productive particle
- single communication entry point to the network

Network approach - I

exploit actuator wires
also for communication



Network approach - II

linear network

daisy chained participants

Advantages

\+ simple to implement

\+ no media access control

\+ no loops

\+ no dynamic routes

Disadvantages

\- error detaches segment

\- no recovery for segment

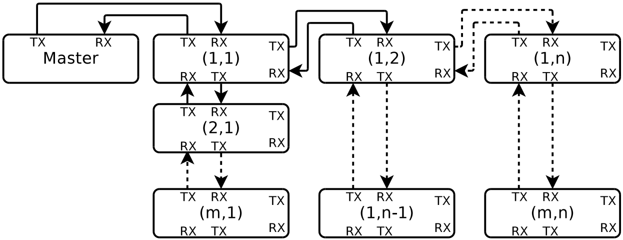


Figure 5: *network topology*

MCU requirements - capabilities

- three separate external interrupts
- self programmable EEPROM
  - for firmware replication (future work)
- package size
  - small package for productive particle
  - bigger package for development board

MCU memory requirements - upper bound estimation

Flash

expected max. firmware size:	$\sim 4k$ SLOC
estimated object code bytes per SLOC [2]	$\sim 4.0B$
flash usage estimation:	
$4k * 4B =$	**$\sim$16kB**

SRAM

tx/rx buffers: 3 ports, 8byte	
$3 * 8B * 2 =$	$16B$
Manchester code decoding buffer	
with 2 flank time stamps per bit	
$3 * 8 * 2 * sizeof(uint16\_t)B * 0.75 =$	$576B$
other global variables	$200B$
stack: max. 50 nested void function	
calls with $\sim (1 * uint8\_t)$ argument	
$50 * (1 + 2)B =$	$150B$
SRAM estimation:	**$\sim$950B**

Candidates

candidates are all ATTiny20 family MCUs having

- $\geq 16kB$ flash and
- $\geq 1kB$ SRAM

Comparison of used MCUs

	ATTiny20 (proof of concept)	**ATTiny1634**
# pin change int.	sufficient	sufficient
EEPROM	no	yes
flash	$2kB$	$16kB$
SRAM	$128B$	$1kB$
small package	$3mm \times 3mm$	$4mm \times 4mm$
alternative pkg.	no	yes, SOIC

The prototype

- not satisfying new requirements
- too small/unhandy for development

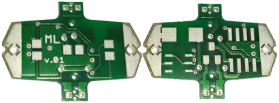


Figure 6: *prototype*

Version 1.0

linear chain of development particles
+ not mounted in chain mechanics
- but still time consuming assembly

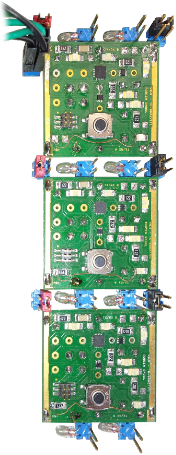


Figure 7: *Version 1.0*

Version 1.1

Advantages

+ repetitive design
+ configurable network shape

Disadvantages

- costly soldering
- expensive connectors
- one faulty particle breaks whole PCB

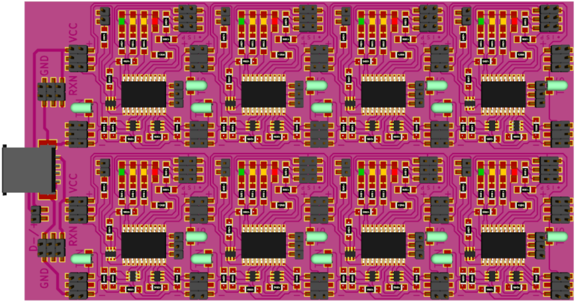


Figure 8: *Version 1.1 - particle array PCB*

Version 1.21

configurable network dimension
easy extensible network
faulty particles can be replaced
cheaper
higher particle density

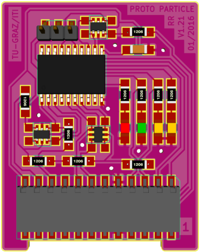


Figure 9: *pluggable particle*

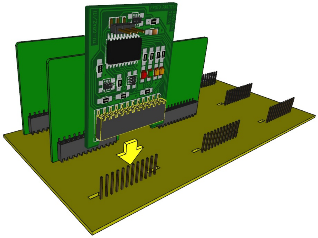


Figure 10: *grid board*

Results

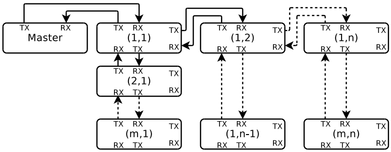


Figure 11: *network structure*

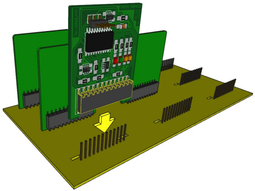
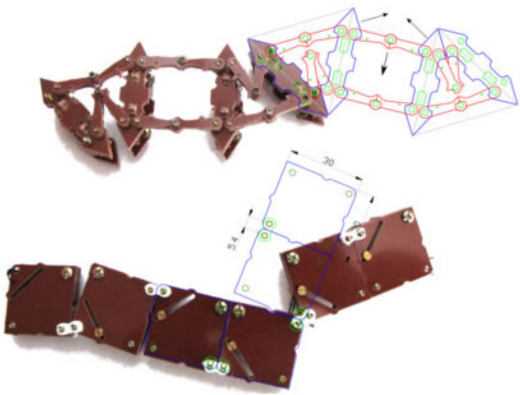


Figure 12: *pluggable particle module*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Future work

- hardware
  - simplify development board
  - enhance grid board
- communication protocol
  - Physical Layer: implement coding
  - Data Layer: fault detection
  - Network Layer: self enumeration, addressing,
    - synchronization, clock compensation
    - task scheduling (TDM of communication and tasks)
- runtime compensation of RC-oscillator discrepancy
- firmware replication: customize boot loader

M. Lasagni and K. Römer, "Force-guiding particle chains for shape-shifting displays," *CoRR*, vol. abs/1402.2507, 2014.

J. Ganssle, *Embedded systems*. Amsterdam Boston: Elsevier/Newnes, 2008.