The Powered Up serial link protocol

Curious to see how the dialog between Powered Up elements and hubs were communicating, I hooked a logical analyzer to the cable between them. Here is what I found...

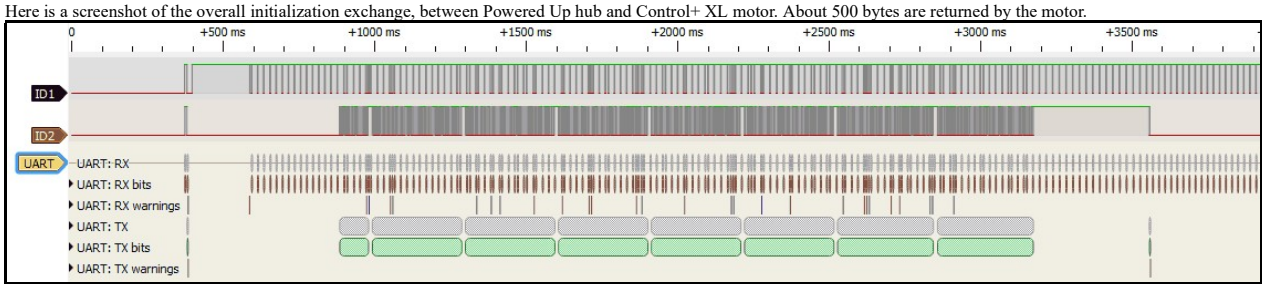
- Communication occurs on pin 5 and 6 of Powered Up connector (ID1/ID2 lines). ID1 (pin 5) transmits data from hub to device, ID2 (pin 6) transmits data from device to hub.
- Communication uses asynchronous serial protocol (UART).
- When the devices are powered on, there is an initialization sequence that occurs at 2400 bits/s.
- After the initialization, serial link switches to 115200 bits/s for "data mode", during which the device sends data and receives polling and commands to the hub.

Next to this icon you'll be able to find analyzer capture files for a few devices/situations. With them, you'll be able to perform your own protocol reverse engineering! To explore these captures, you'll need Sigrok/Pulseview open source signal analysis software.

Initialisation phase

I haven't spent too much time trying to understand what happens during this phase that occurs after power on of the system. During this phase, communication occurs at 2400 bits per second. Strangely enough, I get framing errors in hub to device direction. It could be using a 9 bits format... Anyway, data is mostly sent in device to hub direction.

Here is a screenshot of the overall initialization exchange, between Powered Up hub and Control+ XL motor. About 500 bytes are returned by the motor.



 Control+ XL motor initialization phase

 Control+ L motor initialization phase

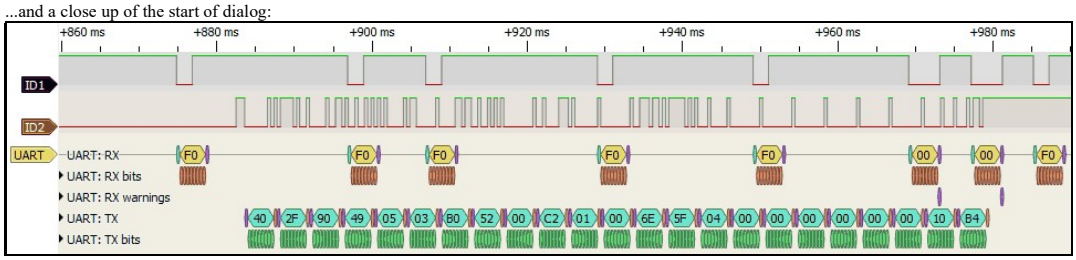
 WeDo2 tilt sensor initialization phase

 WeDo2 distance sensor initialization phase

 Boost motor initialization phase

 Boost color sensor initialization phase

...and a close up of the start of dialog:



Looking at device data in ASCII mode reveals some text strings that seems to indicate that the device sends a description of data that will be available during data phase.

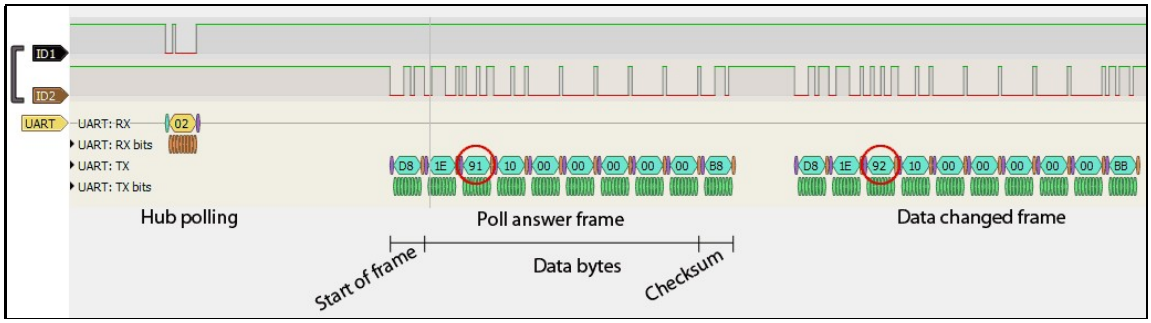
Device	Strings						
Control+ XL motor	STATS MIN	CALIB CAL	APOS DEG	POS DEG	SPEED PCT	POWER PCT	G836660
Control+ L motor	STATS MIN	CALIB CAL	APOS DEG	POS DEG	SPEED PCT	POWER PCT	G834061

Boost motor	TEST TST	POS DEG	SPEED PCT	POWER PCT							
WeDo 2 distance sensor	LPF2-CAL RAW	LPF2-COUNT CNT	LPF2-DETECT								
WeDo 2 tilt sensor	LPF2-CAL CAL	LPF2-CRASH CNT	LPF2-TILT DIR	LPF2-ANGLE DEG							
Boost color sensor	CALIB	DEBUG	SPEC	IR	RGB RAW	COL IDX	AMBI PCT	REFLT PCT	COUNT CNT	PROX DIS	COLOR IDX

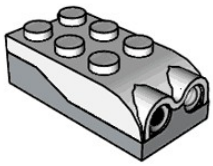
Data phase

After the initialization phase, the serial link switches to a much higher speed, 115200 bits/s. The host polls the device every 100 ms (sending a single 0x02 byte), the device answers with data frame. If device value(s) change between polls, the device sends a data frame without solicitation from the hub. Data frame contains a start of frame byte (depending on device), then data byte(s) and a checksum byte (Checksum8, NOT(XOR of previously transmitted bytes)). Multi-byte values are sent low byte first (in the example below, accumulated angle is 0x1091 = 4241).

As an example, here is an exchange between hub and Boost motor.



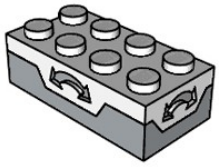
WeDo distance sensor



Example frame	Data type	Contents	Range
C0	Byte	Start of frame	
01	Unsigned byte	Distance	0..9
3E	Byte	Checksum	

"Distance" is actually an indication of reflected light. 0 is no reflected light, 9 can be reached with the sensor placed 5mm above a white paper.

WeDo tilt sensor



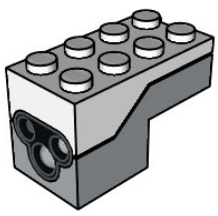
Example frame	Data type	Contents	Range
C8	Byte	Start of frame	
02	Signed byte	X tilt angle (degrees)	-45..+45
2D	Signed byte	Y tilt angle (degrees)	-45..+45
18	Byte	Checksum	

X direction is the rotation around long side of the brick. Value is clipped at +/-45°.


WeDo 2 tilt sensor data phase.

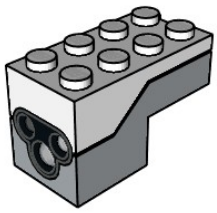
Boost color and distance sensor

This has a more complex behavior: not only it accepts commands from the hub to control LED color, but after poll it answers with a 3 bytes frame (0x46, 0x08, 0xB1), immediately followed by the true data frame returning data. This data frame is also sent (alone) when sensor values change.



Command	Example frame	Data type	Contents	Range
	46	Byte	Start of frame	
	08 B1 D0 00 00	Bytes	??? Unknown meaning	
	03	Byte	LED color	0, 3, 5, 9, 0x0A
	00	Byte	??? Unknown meaning	
	2F	Byte	Checksum	


Boost color sensor data phase during LED color change.

Data	Example frame	Data type	Contents	Range
	D0	Byte	Start of frame	
	0A	Byte	Detected color	0, 3, 5, 9, 0x0A, 0xFF
	01	Byte	Distance	0..10
	03	Byte	LED current color	0, 3, 5, 9, 0x0A
	59	Byte	Reflected light	0..5F
	2F	Byte	Checksum	

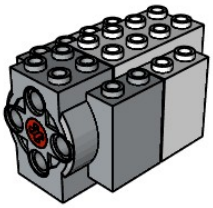
Color codes:

00	Black / LED off
03	Blue
05	Green
09	Red
0A	White
FF	No object

Note that reflected light value is scaled to a 0..10 range in Powered Up app by dividing by about 9 the value returned by sensor.

 Boost color sensor data phase during color detection.

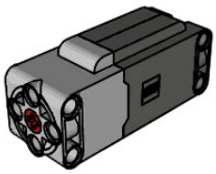
Boost motor

Data	Example frame	Data type	Contents	Range
	D8	Byte	Start of frame	
	1E	Signed byte	Rotation speed (%)	-125..125
	00001091	Signed Dword	Accumulated angle (degrees)	+/- 2.10^9
	0000	Word	0	
	00	Byte	0	
	B8	Byte	Checksum	

Rotation speed is calibrated to 100% when the motor is powered at full speed with nominal voltage (9V). You can reach higher values (up to 125%) by manually turning the motor shaft. According to the strings in initialization phase, last data byte might be power in %, but this byte is always 0, and anyway the motor has no way to know the power applied to it. Reserved for future use?

 Boost motor data phase during manual rotation of hub.

Control+ motors (L and XL)

Data	Example frame	Data type	Contents	Range
	D8	Byte	Start of frame	
	D7	Signed byte	Rotation speed (%)	-125..125
	FFFFFDBA	Signed Dword	Accumulated angle (degrees)	+/- 2.10^9
	FFCF	Signed Word	Absolute angle position (degrees)	-180..179
	00	Byte	0	
	B8	Byte	Checksum	

The data frame is the same as the Boost motor, with added absolute angle position derived from a magnetic angle sensor placed on the output shaft.

 Control+ XL motor data phase during speed ramp-up

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