Communication Developer Kit

LEGO® MINDSTORMS® EV3 Communication Developer Kit

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1 Hardware specifications for MINDSTORMS EV3 Programmable brick

LEGO MINDSTORMS EV3 programmable brick is the central processing unit within the new LEGO MINDSTORMS platform. The programmable brick consists of various advanced electronics to enable its wide range of functionalities.

Below list is a summary of the hardware specifications for the EV3 Programmable brick.

Main processor:	32-bit ARM9 processor, Texas Instrument AM1808 - 300 MHz - OS: LINUX
Memory:	64 MB DDR RAM 16 MB FLASH 256 KB EEPROM
Micro SD-Card interface	SDHC standard, 2 – 32 GB
Bluetooth wireless communication	Bluetooth V2.1 EDR, Panasonic PAN1325 module - Texas Instrument CC2550 chip - BlueZ Bluetooth stack - Primary usage, Serial Port Profile (SPP)
USB 2.0 Communication, Client interface	High speed port (480 MBit/s)
USB 1.1 Communication, Host interface	Full speed port (12 MBit/s)
4 input ports	6 wire interface supporting both digital and analog interface - Analog input 0 – 5 volt - Support Auto-ID for external devices - UART communication o Up to 460 Kbit/s (Port 1 and 2) o Up to 230 Kbit/s (Port 3 and 4)
4 output ports	6 wire interface supporting input from motor encoders
Display	178x128 pixel black & white dot-matrix display - Viewing area: 29.9 x 41.1 mm
Loudspeaker	Diameter, 23 mm
6 Buttons User interface	Surrounding UI light
Power source	6 AA batteries - Alkaline batteries are recommended - Rechargeable Lithium Ion battery, 2000 mAH
Connector	6-wire industry-standard connector, RJ-12 Right side adjustment

2 Communication interfaces

This section will document the protocol used for communicating between various types of masters (hosts) and the LEGO MINDSTORMS EV3 brick. The EV3 support multiple communication interfaces Bluetooth, USB and WiFi. The EV3 protocol is the same for all 3 transport technologies.

Besides running user programs the VM (Virtual machine) is able to execute direct commands sent through one of the above mentioned technologies. Direct commands are composed as small programs build of regular byte codes, please reference the LEGO MINDSTORMS EV3 Firmware developer kit for more details on the individual byte codes. These direct commands (program snippets) are executed in parallel with the running user program.

Special care MUST be taken when composing these direct commands. There is NO restriction in using "dangerous" codes and constructions (E.g. Dead-locking loops in a direct command are allowed). However a “normal” running program will continue working normal – it is only the Direct Command part of the VM which will be “dead-locked” by such a dead-locking loop.

Because of the header only containing the 2 bytes for variable allocation, direct commands are limited to one VMTHREAD only – I.e. SUBCALLs and BLOCKs is of course not possible.

Direct commands with data response can place return data in the global variable space. The global variable space is “equal to” the communication response buffer. The composition of the direct command defines at which offset the result is placed (global variable 0 is placed at offset 0 in the return buffer).

Offset in the response buffer (global variables) must be aligned (float/32bits first and 8 bits last).

Besides direct command the EV3 also support system command, which are more general terms commands which are used for downloading and upload of data to/from the embedded EV3 system.

3 System Command

```
#define     SYSTEM_COMMAND_REPLY        0x01    // System command, reply required
#define     SYSTEM_COMMAND_NO_REPLY     0x81    // System command, reply not require
```

System Command Bytes:

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8

Byte 0 – 1: Command size, Little Endian. Command size not including these 2 bytes

Byte 2 – 3: Message counter, Little Endian. Forth running counter

Byte 4: Command type. See defines above:

Byte 5: System Command. See the definitions below:

Byte 6 – n: Depends on the System Command given in byte 5.

System Commands:

```
#define     BEGIN_DOWNLOAD              0x92    // Begin file download
#define     CONTINUE_DOWNLOAD           0x93    // Continue file download
#define     BEGIN_UPLOAD                0x94    // Begin file upload
#define     CONTINUE_UPLOAD             0x95    // Continue file upload
#define     BEGIN_GETFILE               0x96    // Begin get bytes from a file (while writing to the file)
#define     CONTINUE_GETFILE            0x97    // Continue get byte from a file (while writing to the file)
#define     CLOSE_FILEHANDLE            0x98    // Close file handle
#define     LIST_FILES                  0x99    // List files
#define     CONTINUE_LIST_FILES         0x9A    // Continue list files
#define     CREATE_DIR                  0x9B    // Create directory
#define     DELETE_FILE                 0x9C    // Delete
#define     LIST_OPEN_HANDLES           0x9D    // List handles
#define     WRITEMAILBOX                0x9E    // Write to mailbox
#define     BLUETOOTHPIN                0x9F    // Transfer trusted pin code to brick
#define     ENTERFWUPDATE               0xA0    // Restart the brick in Firmware update mode
```

3.1 System command replies

```
#define      SYSTEM_REPLY                0x03    // System command reply OK
#define      SYSTEM_REPLY_ERROR          0x05    // System command reply ERROR
```

System Reply Bytes:

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8

Byte 0 – 1: Reply size, Little Endian. Reply size not including these 2 bytes

Byte 2 – 3: Message counter, Little Endian. Equals the Direct Command

Byte 4: Reply type. See defines above

Byte 5: System Command which this is reply to.

Byte 6: System Reply Status – Error, info or success. See the definitions below:

Byte 7 – n: Further System Reply bytes depending of the the System Command and the System Reply Status

SYSTEM command Reply Status codes:

```
#define      SUCCESS                     0x00
#define      UNKNOWN_HANDLE              0x01
#define      HANDLE_NOT_READY            0x02
#define      CORRUPT_FILE                0x03
#define      NO_HANDLES_AVAILABLE        0x04
#define      NO_PERMISSION               0x05
#define      ILLEGAL_PATH                0x06
#define      FILE_EXITS                  0x07
#define      END_OF_FILE                 0x08
#define      SIZE_ERROR                  0x09
#define      UNKNOWN_ERROR               0x0A
#define      ILLEGAL_FILENAME            0x0B
#define      ILLEGAL_CONNECTION          0x0C
```

3.2 Downloading data to the EV3 programmable brick

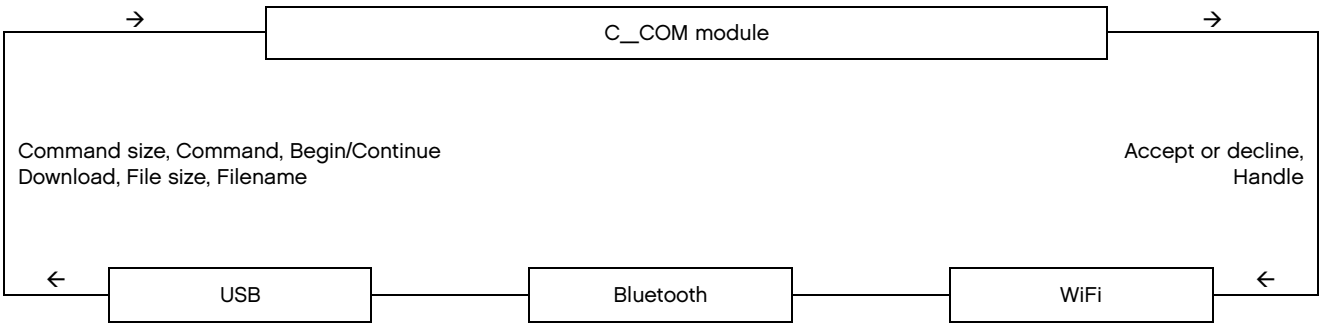
Downloading large files can be time consuming, so the download of files can be done in 2 different ways.

1. Downloading the file in largest possible chunks i.e. using the largest packet size as possible (total command size excl. Length bytes = 65534 bytes). If the total message size can be kept below 65534 bytes then all data could fit into the ***begin download*** command and that would be the fastest way to download that file. This is the fastest way to download but the system is also locked for this amount of time.

2. Splitting the file download into smaller portions i.e. one ***begin download*** followed by a number of ***continue download*** commands will increase the total download time, but it will also leave space (time-slice) for other commands (with higher priority) to be interleaved between the continued ***continue download*** commands.
   This is the slowest way to download files, but gives the possibility of interleaving other commands in between the ***continue download*** messages.

Since there is no stop or other synchronizes byte in the packets - it is essential that a message is not interrupted by other messages. I.e. when the brick has received the command size (2 first bytes of a message) ALL remaining bytes has to be transmitted and received uninterrupted. The reply (from the brick) for this very message should also be transmitted and received before any new message can be sent and processed by the brick.

The example below is build around the host application (X3 software) that wants to send a file to a P-Brick:



Command size, Command type, Begin D/L, File size, Filename	------>	
	<------	Command size, Command type, Handle
Command size, Command type, Continue D/L, Handle, Pay load	------>	
	<------	Command size, Command type
Command size, Command type, Continue D/L, Handle, Pay load	------>	
	<------	Command size, Command type
Command size, Command type, Continue D/L, Handle, Pay load	------>	

3.2.1 File DownLoad

- Destination filename path is addressed relative to *"lms2012/sys"*
- Destination folders are automatically created from filename path
- First folder name must be: *"apps"*, *"prjs"* or *"tools"* (*see lref UIdesign*)
- Second folder name in filename path must be equal to byte code executable name

3.2.2 File Upload (File read)

- BEGIN__UPLOAD and CONTINUE__UPLOAD closes automatically the file handle when file has been uploaded.
- BEGIN__GETFILE and CONTINUE__GETFILE does not close the file handle when EOF has been reached
- CONTINUE__GETFILE does also return the complete file size

3.2.3 Directory upload

- LIST__FILES work as long as list does not exceed 1014 bytes.

3.3 System command, communication examples

In the following a sample of system command communication examples will be document to help document the interface.

3.3.1 File download

Download file "../apps/tst/tst.rbf"

BEGIN_DOWNLOAD:

Bytes sent to brick:

1C00xxxx0192xxxxxxxx2E2E2F617070732F7473742F7473742E72626600 (Hex)
bbbbmmmmttsslllllllnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnnn

bbbb = bytes in message
mm = message counter
tt = type of command
ss = system command
lllllll = file length
nn.. = filename zero terminated.

Bytes received from brick:

0600xxxx03920000 (Hex)
bbbbmmmmttssrrhh

bbbb = bytes in message
mm = message counter
tt = type of command
ss = system command
rr = return status
hh = handle to file

CONTINUE_DOWNLOAD:

Bytes sent to brick:

```
xxxxxxxx819300xxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxxx     (Hex)
bbbbmmmmttsshhpppppppppppppppppppppppppppppppppppppppppppp
```

bbbb = bytes in message
mm = message counter
tt = type of command
ss = system command
hh = handle to file (returned in the BEGIN_DOWNLOAD)
pp.. = pay load

Bytes received from brick:

```
0600xxxx03930000    (Hex)
bbbbmmmmttssrrhh
```

bbbb = bytes in message
mm = message counter
tt = type of command
ss = system command
rr = return status
hh = handle to file

3.3.2 File Upload

BEGIN_UPLOAD:

Bytes send to the brick:

xxxxxxxx0194xxxxxxx
bbbbmmmmttsslllnnn...

bbbb = bytes in message
mmmm = message counter
tt = type of command
ss = system command
llll = bytes to read
nnn... = filename incl. path

Bytes received form the brick:

xxxxxxxx039400xxxxxxxx00xxx
bbbbmmmmttssrrllllllllhhppp...

bbbb = bytes in massage
mmmm = message counter
tt = type of command
ss = system command
rr = return status
llllllll = file size
hh = file handle
ppp... = payload

CONTINUE_UPLOAD:

Bytes send to the brick:

0700xxxx019500xxxx
bbbbmmmmttsshhllll

bbbb = bytes in the message
mmmm = message counter
tt = type of command
ss = system command
hh = file handle
llll = bytes to read

Bytes send to the PC:

xxxxxxxx03950000xxx
bbbbmmmmttssrrhhppp...

bbbb = bytes in the message
mmmm = message counter
tt = type of command
ss = system command
rr = return status
hh = handle
pppp.. = payload

3.3.3 Getting file content

Used to upload datalog files - file handle is only closed when file-pointer reaches EOF and the file is not open for writing.

BEGIN_GETFILE:

Bytes send to the brick:

xxxxxxxx0196xxxxxxx
bbbbmmmmttsslllnnn...

bbbb = Bytes in message
mmmm = message counter
tt = type of command
ss = system command
llll = max bytes to read
nnnn.... = path

Bytes send to the PC:

xxxxxxxx039600xxxxxxxx00xxx
bbbbmmmmttssrrllllllllhhppp...

bbbb = bytes ion message
mmmm = message counter
tt = type of command
ss = system command
rr = return status
llllllll = file size
hh = handle
ppp... = payload

CONTINUE_GETFILE:

Bytes send to the brick:

0700xxxx019700xxxx
bbbbmmmmttsshhllll

bbbb = bytes in message
mmmm = message counter
tt = type of command
ss = system command
hh = handle
llll = max bytes to read

Bytes send to the PC:

xxxxxxxx039700xxxxxxxx00xxx
bbbbmmmmttssrrllllllllhhppp...

bbbb = bytes in massage
mmmm = message counter
tt = type of command
ss = system command
rr = return status
llllllll = file size
hh = handle
ppp... = payload

3.3.4 Listing files and folders

LIST_FILES:

The new line delimited list is formatted as:

If it is a file:
32 chars (hex) of MD5SUM + space + 8 chars (hex) of filesize + space + filename + new line

If it is a folder:
foldername + / + new line

Bytes send to the brick:

xxxxxxxx0199xxxxxxx
bbbbmmmmttsslllnnn...

bbbb = bytes in message
mmmm = message counter
tt = type of message
ss = system command
llll = max. bytes to read
nnn.. = path name

Bytes send to the PC:

xxxxxxxx0399xxxxxxxxxxxxxxx
bbbbmmmmttssrrllllllllhhnnn...

bbbb = bytes in message
mmmm = message counter
tt = type of message
ss = system command
rr = return status
llllllll = list size
hh = handle
nnn.. = the new line delimited lists

CONTINUE_LIST_FILES:

Bytes send to the brick:

0700xxxx019Axxxxxx
bbbbmmmmttsshhllll

bbbb = bytes in message
mmmm = message counter
tt = type of command
ss = system command
hh = handle
llll = max bytes to read

Bytes send to the PC:

xxxxxxxx039Axxxxxxx
bbbbmmmmttssrrhhppp...

bbbb = bytes in message
mmmm = message counter
tt = type of command
ss = system command
rr = return status
hh = handle
ppp... = payload

3.3.5 Closing file handle

CLOSE_FILEHANDLE:

Bytes send to the brick:

xxxxxxxx019800xxxxxxxxxxxxxxxx
bbbbmmmmttsshhpppppppppppppppp

bbbb = bytes in the message
mmmm = message counter
tt = type of message
ss = system command
hh = handle
ppp... = hash

Bytes send to the PC:

0500xxxx039800
bbbbmmmmttssrr

bbbb = bytes in message
mmmm = message counter
tt = type of message
ss = system command
rr = return status

3.3.6 Create a directory

CREATE_DIR:

Bytes to send to the brick:

xxxxxxxx019Bxxxxxx...
bbbbmmmmttsppppppp...

bbbb = bytes in message
mmmm = message counter
tt = type of message
ss = system command
pp = null terminated string containing full path of directory to create

Bytes send to the PC:

0500xxxx039Bxx
bbbbmmmmttssrr

bbbb = bytes in message
mmmm = message counter
tt = type of message
ss = system command
rr = return status

3.3.7 Deleting a file

DELETE_FILE:

Bytes to send to the brick:

xxxxxxxx019Cxxxxxx...
bbbbmmmmttsppppppp...

bbbb = bytes in message
mmmm = message counter
tt = type of message
ss = system command
pp = null terminated string containing the full path of the file to delete

Bytes send to the PC:

0500xxxx039Cxx
bbbbmmmmttssrr

bbbb = bytes in message
mmmm = message counter
tt = type of message
ss = system command
rr = return status

3.3.8 Get a list of open handles

LIST_OPEN_HANDLES:

Bytes to send to the brick:

xxxxxxxx019D
bbbbmmmmttss

bbbb = bytes in message
mmmm = message counter
tt = type of message
ss = system command

Bytes send to the PC:

xxxxxxxx039Dxxxxxx....
bbbbmmmmttssrrpppp....

bbbb = bytes in message
mmmm = message counter
tt = type of message
ss = system command
rr = return status
pppp = bits indicating whether handles are busy (open) or not.

3.3.9 Write to a mailbox

WRITEMAILBOX:

Bytes sent to another brick:

Mailbox name has to be zero terminated while the name length has to be the number of chars excluding the zero termination!

```
xxxxxxxx819Exxxxxxxxxxxxxxxxxxxxx
bbbbmmmmttssllaaaaa...LLLLppp...
```

bbbb = bytes in the message
mmmm = message counter
tt = type of message
ss = system command
ll = name Length
aaa... = name
LLLL = payload length
ppp... = payload

Reply received from another brick:

Not valid

3.3.10 Set the Bluetooth PIN code

BLUETOOTHPIN:

This command can only be sent by USB for safety reasons and should be formatted as:

- Bluetooth address does not contain colons
- Bluetooth MAC address is a zero terminated string type
- Bluetooth pin code is a zero terminated string type

Bytes sent to the brick:

```
0E00xxxx019F06xxxxxxxxxxxx04xxxx
bbbbmmmmttssllaaaaaaaaaaaaLLpppp
```

bbbb = bytes in the message
mmmm = message counter
tt = type of message
ss = system command
ll = MAC Length
aaa.. = MAC address of PC
LL = pin length
ppp... = pin code

Bytes send to the PC:

```
0F00xxxx039Fxx06xxxxxxxxxxxx04xxxx
bbbbmmmmttssrrllaaaaaaaaaaaaLLpppp
```

bbbb = bytes in message
mmmm = message counter
tt = type of message
ss = system command
rr = return status
ll = MAC length
aaa.. = MAC address of PC
LL = pin length
ppp... = pin code

3.3.11 Force the EV3 Programmable brick into Firmware update mode

This command is used to force the brick into Firmware update mode. The command will not send any response back to the host. The file-system will not be updated when closing (shut down) the Linux OS.

ENTERFWUPDATE:

Bytes send to the brick:

0400xxxx81A0
bbbbmmmmttss

bbbb = bytes in massage
mmmm = message counter
tt = type of message
ss = system command

4 Direct Commands

```
#define      DIRECT_COMMAND_REPLY         0x00      // Direct command, reply required
#define      DIRECT_COMMAND_NO_REPLY      0x80      // Direct command, reply not require
```

Direct Command Bytes:

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8

Byte 0 – 1: Command size, Little Endian. Command size not including these 2 bytes

Byte 2 – 3: Message counter, Little Endian. Forth running counter

Byte 4: Command type. See defines above

Byte 5 - 6: Reservation (allocation) of global and local variables using a compressed format (globals reserved in byte 5 and the 2 lsb of byte 6, locals reserved in the upper 6 bits of byte 6) – see below:

Byte 7 – n: Byte codes as a single command or compound commands (I.e. more commands composed as a small program)

Locals = "l" and Globals = "g"

```
          Byte 6:             Byte 5:
Bit no:   76543210            76543210
Var size: llllllgg            gggggggg

gg gggggggg          Global vars reservation 0 – (2^10 – 1) 0..1023 bytes
llllllxx             Local  vars reservation 0 – (2^6 – 1)  0....63 bytes
```

4.1 Direct Replies

```
#define      DIRECT_REPLY                 0x02      // Direct command reply OK
#define      DIRECT_REPLY_ERROR           0x04      // Direct command reply ERROR
```

Direct Reply Bytes:

Byte 0	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8

Byte 0 – 1: Reply size, Little Endian. Reply size not including these 2 bytes

Byte 2 – 3: Message counter, Little Endian. Equals the Direct Command

Byte 4: Reply type. See defines above

Byte 5 - n: Resonse buffer. I.e. the content of the by the Command reserved global variables. I.e. if the command reserved 64 bytes, these bytes will be placed in the reply packet as the bytes 5 to 68.

4.2 Direct command, communication examples

In the following a sample of direct command communication examples will be document to help illustrate the interface more detailed. The high-level macros used are documented below.

Parameter encoding at a higher level:

To make it a bit easier to use the parameter encoding some macros defined in the ***"bytecodes.h"*** are use (See also the Parameter encoding on page 9 – *3.4 Parameter Encoding* in the document "LEGO *MINDSTORMS EV3 - Firmware Developer Kit*" range shown encoded as signed integer:

LCS	Long variable type	Length bytes	STRING zero terminated
LC0(v)	Short constant(value)	single byte	+/- 31
LC1(v)	Long constant(value)	one byte to follow (2 bytes)	+/- 127
LC2(v)	Long constant(value)	two bytes to follow (3 bytes)	+/- 32767
LC4(v)	Long constant(value)	four bytes to follow (5 bytes)	+/- 2147483647
LV0(i)	Short LOCAL variable(adr)	single byte at adr	+/- 31
LV1(i)	Long LOCAL variable(adr)	one byte to follow at adr (2 bytes)	+/- 127
LV2(i)	Long LOCAL variable(adr)	two bytes to follow at adr (3 bytes)	+/- 32767
LV4(i)	Long LOCAL variable(adr)	four bytes to follow at adr (5 bytes)	+/- 2147483647
GV0(i)	Short GLOBAL variable(adr)	single byte at adr	+/- 31
GV0(i)	Long GLOBAL variable(adr)	one byte to follow at adr (2 bytes)	+/- 127
GV0(i)	Long GLOBAL variable(adr)	two bytes to follow at adr (3 bytes)	+/- 32767
GV0(i)	Long GLOBAL variable(adr)	four bytes to follow at adr (5 bytes)	+/- 2147483647

4.2.1 Start program "Demo" on EV3 brick

Load and run an app byte code file. This example also shows a compound direct command – i.e. two or more direct commands in one single packet. Here we load the byte code image: ***"../prjs/BrkProg_SAVE/Demo.rpf"*** into slot 1 – the user slot. Immediate followed by the start program in slot 1 command. Remember this is a compound command and cannot be interleaved. **REMARK:** The file-extension is "rpf" and NOT "rbf". The file is a built-in "on-brick program file".

Bytes sent to the brick:

```
opFILE,LC0(LOAD_IMAGE),LC2(USER_SLOT),LCS,'.','.','/','p','r','j','s','/',
'B','r','k','P','r','o','g',
'_','S','A','V','E'/','D','e','m','o','.','r','p','f',0,GV0(0),GV0(4),opPROGRAM_START,
LC0(USER_SLOT),GV0(0),GV0(4),LC0(0)
```

opFILE	Opcode file related
LC0(LOAD_IMAGE)	Command encoded as single byte constant
LC2(USER_SLOT)	User slot (1 = program slot) encoded as single constant byte
LCS	Encoding: String to follow (zero terminated)
"../prjs/BrkProg_SAVE/Demo.rpf"	File path and name. ".." is the "moving 1 folder up from current"
0x00	Zero termination of string above
GV0(0)	Return Image Size at Global Var offset 0. Offset encoded as single byte.
GV0(4)	Return Address of image at Global Var offset 4. Offset encoded as single byte.
opPROGRAM_START	Opcode
LC0(USER_SLOT)	User slot (1 = program slot) encoded as single byte constant
GV0(0)	Size of image at Global Var offset 0.
GV0(4)	Address of image at Global Var offset 4.
LC0(0)	Debug mode (0 = normal) encoded as single byte constant

```
30000000800800C008820100842E2E2F70726A732F42726B50726F675F534156452F44656D6F2E72706600
bbbbmmmmtthhhhccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccccc

60640301606400
ccccCCCCCCCCCC
```

bbbb = bytes in message 48 excl. packet length bytes
mmmm = message counter
tt = type of command - Direct command no reply
hhhh = header – variable alloc*).
cc/CC = byte codes.

*)hhhh = 10 least significant bits are number of globals, 6 most significal bits are locals

4.2.2 Start motor B & C forward at power 50 for 3 rotation and braking at destination

This example uses the special OUTPUT__STEP__SPEED motor command. This command sets the speed (setpoint) for the motors in the motor-list. The command includes a ramp-up and ramp-down portion. Especially the ramp-down is usefull for getting a more precise final destination. The motor brakes when the 3 rotations (3 * 360 degrees) are finished.

```
opOUTPUT_STEP_SPEED,LC0(LAYER_0),LC0(MOTOR_A + MOTOR_B),LC1(SPEED_50),LC0(0),LC2(900),
LC2(180),LC0(BRAKE)
```

opOUTPUT__STEP__SPEED	Opcode
LC0(0)	Layer 0 – encoded as single byte constant
LC0(MOTOR__A + MOTOR__B)	Motor B & C (motor list) encoded as single byte constant
LC1(SPEED__50)	Speed 50% encoded as one constant byte to follow
LC0(0)	No STEP1 i.e. full speed from beginning – encoded as single byte constant.
LC2(900)	STEP2 for 2.5 rotation (900 degrees) – encodes as two bytes to follow.
LC2(180)	STEP3 for 0.5 rotation (180 degrees) for better precision at destination – encoded as two bytes to follow.
LC0(BRAKE)	Brake (1) – encoded as single byte constant.

Bytes sent to the brick:

```
1200xxxx800000AE000681320082840382B40001
Bbbbmmmmtthhhhccccccccccccccccccccccccc
```

bbbb = bytes in message 21 excl. packet length bytes
mmmm = message counter
tt = type of command - Direct command no reply
hhhh = header – variable alloc*).
cc/CC = byte codes.

*)hhhh = 10 least significant bits are number of globals, 6 most significal bits are locals

4.2.3 Read light sensor value on sensor port 3

This direct command will read the light-sensor connected to the input port 3 on the brick. The mode is explicitly set to mode 0 (zero) i.e. the native mode 0 for a Light Sensor (0 – 100 pct.). The returned value is a 32 bit float encoded as SI 0-100 pct.

Default 32 bit float (SI 0-100 pct.)

```
opINPUT_DEVICE,LC0(READY_SI),LC0(LAYER_0),LC0(SENSOR_PORT_3),LC0(DO_NOT_CHANGE_TYPE),
LC0(MODE_0),LC0(ONE_DATA_SET),LCO(GLOBAL_VAR_INDEX0)
```

opINPUT__DEVICE	Opcode input related
LC0(READY__SI)	Command (READY__SI) encoded as single byte constant
LC0(LAYER__0)	Layer number (0 = this very brick) encoded as single byte constant
LC0(SENSOR__PORT__3)	Sensor connected to port 3 (1-4 / 0-3 internal) encoded as single byte constant
LC0(DO__NOT__CHANGE__TYPE)	If set to 0 (zero) = don't change type - encoded as single byte constant
LC0(MODE__0)	Mode 0 - encoded as single byte constant
LC0(ONE__DATA __SET)	Count of datasets (Mode 0 has only 1 (pct)) - encoded as single byte constant
LC0(GLOBAL__VAR__INDEX0)	Place returned value in Global var at index 0 (zero) - encoded as single byte constant

Bytes sent to the brick:

```
0D00xxxx000400991D000200000160
BbbbmmmmtthhhhCCCCCCCCCCCCCCCC
```

bbbb = bytes in message 13 excl. packet length bytes
mmmm = message counter
tt = type of command - Direct command with reply
hhhh = header – variable alloc. Here 4 bytes reserve in Global Vars*).
CC/cc/CC/cc = byte codes.

*)hhhh = 10 least significant bits are number of globals, 6 most significal bits are locals

4.2.4 Read the light sensor connected to port 1 as COLOR

This direct command will read the light-sensor connected to the input port 1 on the brick. The mode is explicitly set to mode 2 “COLOR mode”. The sensor will return a value between 0-8 (both included) i.e. the color of the object in front of the sensor. The returned value is a 32 bit float encoded as 0-8.

opINPUT_DEVICE,LC0(READY_SI),LC0(LAYER_0),LC0(SENSOR_PORT_1),LC0(DO_NOT_CHANGE_TYPE), LC0(MODE_2),LC0(ONE_DATA_SET),LCO(GLOBAL_VAR_INDEX0)

opINPUT__DEVICE	Opcode input related
LC0(READY__SI)	Command (READY__SI) encoded as single byte constant
LC0(LAYER__0)	Layer number (0 = this very brick) encoded as single byte constant
LC0(SENSOR__PORT__1)	Sensor connected to port 1 (1-4 / 0-3 internal) encoded as single byte constant
LC0(DO__NOT__CHANGE__TYPE)	If set to 0 (zero) = don’t change type - encoded as single byte constant
LC0(MODE__2)	Mode 2 - encoded as single byte constant
LC0(ONE__DATA __SET)	Count of datasets (Mode 0 has only 1 (pct)) - encoded as single byte constant
LC0(GLOBAL__VAR__INDEX0)	Place returned value in Global var at index 0 (zero) - encoded as single byte constant

Bytes sent to the brick:

0D00xxxx000400991D000000020160
BbbbmmmmtthhhhCCCCCCCCCCCCCCCC

bbbb = bytes in message 13 excl. packet length bytes
mmmm = message counter
tt = type of command - Direct command with reply
hhhh = header – variable alloc. Here 1 byte reserve in Global Vars*).
CC/cc/CC/cc = byte codes.

*)hhhh = 10 least significant bits are number of globals, 6 most significal bits are locals

4.2.5 Play a 1Kz tone at level 2 for 1 sec.

opSOUND,LC0(TONE),LC1(2),LC2(1000),LC2(1000)

opSOUND	Opcode sound related
LC0(TONE)	Command (TONE) encoded as single byte constant
LC1(2)	Sound-level 2 encoded as one constant byte to follow
LC2(1000)	Frequency 1000 Hz. encoded as two constant bytes to follow
LC2(1000)	Duration 1000 mS. encoded as two constant bytes to follow

Bytes sent to the brick:

0F00xxxx80000094018102 82E80382E803
Bbbbmmmmtthhhhccccccccccccccccccc

bbbb = bytes in message 15 excl. packet length bytes
mmmm = message counter
tt = type of command - Direct command no reply
hhhh = header – variable alloc*).
cc/CC = byte codes.

*)hhhh = 10 least significant bits are number of globals, 6 most significal bits are locals

4.2.6 Show a picture in the display

Clears the screen and draws the bmp-image “mindstorms.rgf” on the display at the coordinates(x = 0, y = 50. First the screen is cleared by the FILLWINDOW sub-command, then the bmp-image file is loaded by the sub-command BMPFILE. Nothing happens on the screen before the UPDATE sub-command is issued.

```
opUI_DRAW,LC0(FILLWINDOW),LC0(BG_COLOR),LC2(0),LC2(0),opUI_DRAW,LC0(BMPFILE),
LCO(FG_COLOR),LC2(0),LC2(50),LCS,'u','i','/','m','i','n','d', 's','t','o','r','m','s',
'.','r','g','f',0,opUI_DRAW,LC0(UPDATE)
```

opUI__DRAW	Opcode drawing related
LC0(FILLWINDOW)	Command (FILLWINDOW) encoded as single byte constant
LC0(BG__COLOR)	Color set to background color – i.e. clear screen encoded as single byte constant
LC2(0)	Start y (zero means all the screen) encoded as single byte constant
LC2(0)	End y (zero means all the screen) encoded as single byte constant
opUI__DRAW	Opcode drawing related
LC0(BMPFILE)	Command (BMPFILE) encoded as single byte constant
LC0(FG__COLOR)	Color set to forground color encoded as single byte constant
LC2(50)	Start at y-coordinate 50 encoded as two bytes to follow
LC2(0)	Start at x-coordinate 0 encoded as two bytes to follow
LCS	Encoding: String to follow (zero terminated)
“ui/mindstorms.rgf”	File path and name.
0	Zero-termination of string.
opUI__DRAW	Opcode drawing related
LC0(UPDATE)	Command (UPDATE) “do all the graphical stuff” encoded as single byte constant

Bytes sent to the brick:

```
2C00000080000084130082000082000084 1C018200008232008475692F6D696E6473746F726D7
BbbbmmmmtthhhhCCCCCCCCCCCCCCCCCCccccccccccccccccccccccccccccccccccccccccccccc

32E726766008400
ccccccccccCCCC
```

bbbb = bytes in message 44 excl. packet length bytes
mmmm = message counter
tt = type of command - Direct command no reply
hhhh = header – variable alloc*).
CC/cc/CC/cc = byte codes.

*)hhhh = 10 least significant bits are number of globals, 6 most significal bits are locals