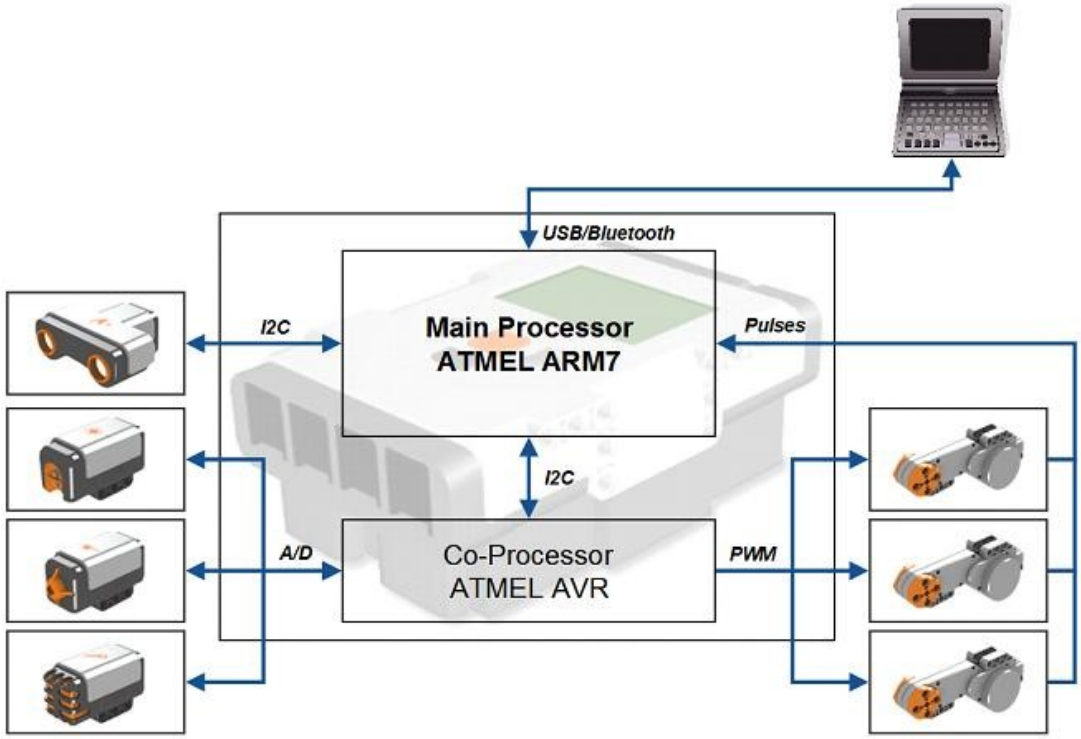
System architecture of LEGO MINDSTORMS NXT:

The below figure provides a graphical overview of LEGO MINDSTORMS NXT system architecture according to LEGO MINDSTORMS NXT Hardware Developer Kit.



This figure tells that communication between the main ARM7 processor (ATMEL AT91SAM7S256) and Sensors/Servo Motors is done via the co-processor (ATMEL AVR) except for the Ultrasonic Sensor and acquisition of Servo Motor revolutions. For nxtOSEK, most important factor to access Sensors/Servo Motors is the communication with the co-processor via I2C serial bus. This system architecture definitely influences on the software run-time environment of nxtOSEK. The main ARM7 processor accesses to Sensors (to read sensor A/D value) and Servo Motors (to set PWM duty ratio and breake mode) independently every 2 msec through a 1 msec periodical Interrupt Service Routine (ISR) of LEJOS NXJ platform. Servo Motors revolutions are directly captured by pulse triggered ISRs of LEJOS NXJ platform. Ultrasonic Sensor has its brain to directly communicate with the main ARM7 processor via another I2C communication channel.

TOPPERS ATK1 API:

TOPPERS ATK1 is similar to the following version of OSEK OS/OIL according to TOPPERS project. OSEK API Reference and detailed information are described in the documents at the OSEK/VDX site:
OSEK OS Version 2.2.1
OSEK OIL Version 2.5

nxtOSEK restricts several TOPPERS ATK1 features due to the system architecture. User should not use ISR definitions and Interrupt handling API. For those who can understand Japanese, under nxtOSEK\toppers_osek\doc directory, there are detailed documents written in Japanese about TOPPERS ATK1.

ECRobot API:

ECRobot API consists of low level device API and ECRobot wrapper API (prefix of the API is ecrobot_) that is designed for real-time control application programming. Gray colored wrapper API in the below tables has duplicated feature of the original low level device API, so it is better to use the original API to reduce the run time overhead. When you use ECRobot API, you need to include `ecrobot_interface.h` in your source code.

Accessing to the Servo Motor is a bit complicated. NXT uses I2C communication between the ARM7 and the AVR to set Motor PWM value and brake

mode. However, acquisition of the Motor count is done by pulse input capture of the ARM7 directly.

Servo Motor API	Description
int nxt_motor_get_count(U32 *n*)	gets Servo Motor revolution count in degree. Parameters: *n*: NXT_PORT_A, NXT_PORT_B, NXT_PORT_C Returns: Servo Motors revolution in degree
void nxt_motor_set_count(U32 *n*, int *count*)	sets Servo Motor revolution count in degree. Parameters: *n*: NXT_PORT_A, NXT_PORT_B, NXT_PORT_C *count*: Servo Motor revolution value Returns: none
void nxt_motor_set_speed(U32 *n*, int *speed_percent*, int *brake*)	sets Servo Motor PWM value and brake mode. Parameters: *n*: NXT_PORT_A, NXT_PORT_B, NXT_PORT_C *speed_percent*: -100 to 100 *brake*: 0(float), 1(brake) Returns: none
S32 ecrobot_get_motor_rev(U8 port_id)	gets Servo Motor revolution value in degree. Wrapper of nxt_motor_get_count. Parameters: *port_id*: NXT_PORT_A, NXT_PORT_B, NXT_PORT_C Returns: Servo Motors revolution in degree
void ecrobot_set_motor_speed(U8 port_id, S8 speed)	sets Servo Motor PWM value. Wrapper of nxt_motor_set_speed, but brake mode is fixed as brake. Parameters: *port_id*: NXT_PORT_A, NXT_PORT_B, NXT_PORT_C *speed*: -100 to 100 Returns: none
void ecrobot_set_motor_mode_speed(U8 port_id, S32 mode, S8 speed)	sets Servo Motor brake mode and PWM value. Wrapper of nxt_motor_set_speed Parameters: *port_id*: NXT_PORT_A, NXT_PORT_B, NXT_PORT_C *mode: 0(float), 1(brake)* *speed*: -100 to 100 Returns: none

NXT uses I2C communication between the ARM7 and the AVR to access the Light Sensor. The AVR uses 10bit A/D converter to get Light Sensor data.

Light Sensor API	Description
void ecrobot_set_light_sensor_active(U8 *port_id*)	turns on infra-red light of Light Sensor. This function should be implemented in the device initialize hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none
void ecrobot_set_light_sensor_inactive(U8 *port_id*)	turns off infra-red light of Light Sensor. This function should be implemented in the device terminate hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns:

	none
U16 ecrobot_get_light_sensor(U8 *port_id*)	gets Light Sensor raw A/D data. Greater value means darker (or lower reflection). Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: 0 to 1023

NXT uses I2C communication between the ARM7 and the AVR to access the Touch Sensor. The AVR uses 10bit A/D converter to get Touch Sensor data. In ecrobot_get_touch_sensor API, A/D data is converted to be 0/1.

Touch Sensor API	Description
U8 ecrobot_get_touch_sensor(U8 *port_id*)	gets Touch Sensor status. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: 0(not touched), 1(touched)

NXT uses I2C communication between the ARM7 and the AVR to access the Sound Sensor. The AVR uses 10bit A/D converter to get Sound Sensor data.

Sound Sensor API	Description
U16 ecrobot_get_sound_sensor(U8 *port_id*)	gets Sound Sensor raw A/D data. Smaller value means louder sound. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: 0 to 1023

Ultrasonic Sensor has its brain to communicate with the ARM7 via another I2C communication channel. ecrobot_get_sonar_sensor sends a protocol data to communicate with the Ultrasonic Sensor. However, actual data transaction between the ARM7 and the Ultrasonic Sensor is done by an ISR triggered by this function call, so there is one execution cycle delay to achieve consistent data acquisition.

Ultrasonic Sensor API	Description
void ecrobot_init_sonar_sensor(U8 *port_id*)	initializes a port for I2C communication for Ultrasonic Sensor. This function should be implemented in the device initialize hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none
S32 ecrobot_get_sonar_sensor(U8 *port_id*)	gets Ultrasonic Sensor measurement data in cm via I2C. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: -1 to 255 (-1: not ready for measurement)
void ecrobot_term_sonar_sensor(U8 *port_id*)	terminates I2C communication used for Ultrasonic Sensor. This function should be implemented in the device terminate hook routine. Parameters:

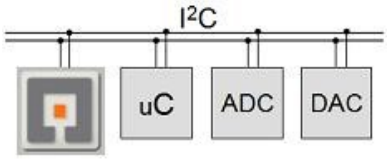
	port_id: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none

NXT Color Sensor can be used as a Color Sensor or a Light Sensor with lamps of several colors. It needs to run a background process to keep communicating with the sensor.

NXT Color Sensor API	Description
void ecrobot_init_nxtcolorsensor(U8 *port_id,* U8 *mode*)	initializes a port for NXT Color Sensor. This function should be implemented in the device initialize hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 *mode*: NXT_COLORSENSOR, NXT_LIGHTSENSOR_RED, NXT_LIGHTSENSOR_GREEN, NXT_LIGHTSENSOR_BLUE, NXT_LIGHTSENSOR_WHITE, NXT_LIGHTSENSOR_NONE, NXT_COLORSENSOR_DEACTIVATE Returns: none
void ecrobot_process_bg_nxtcolorsensor(void)	comunicates with the NXT Color Sensor repeatedly. This function should be executed in a background Task to keep communicating the sensor. (For more detailed information, see C/C++ samples) Parameters: none Returns: none
void ecrobot_set_nxtcolorsensor(U8 *port_id*, U8 *mode*)	sets the sensor mode. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 *mode*: NXT_COLORSENSOR, NXT_LIGHTSENSOR_RED, NXT_LIGHTSENSOR_GREEN, NXT_LIGHTSENSOR_BLUE, NXT_LIGHTSENSOR_WHITE, NXT_LIGHTSENSOR_NONE, NXT_COLORSENSOR_DEACTIVATE Returns: none
U8 ecrobot_get_nxtcolorsensor_mode(U8 *port_id*)	gets the sensor mode. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: sensor mode: NXT_COLORSENSOR, NXT_LIGHTSENSOR_RED, NXT_LIGHTSENSOR_GREEN, NXT_LIGHTSENSOR_BLUE, NXT_LIGHTSENSOR_WHITE, NXT_LIGHTSENSOR_NONE, NXT_COLORSENSOR_DEACTIVATE
U16 ecrobot_get_nxtcolorsensor_id(U8 *port_id*)	gets color ID. This API returns valid data when the sensor is in color sensor mode. Note that the color ID might be unmatch with the real color due to measurement conditions and each sensor characteristics. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: color ID: NXT_COLOR_BLACK, NXT_COLOR_BLUE, NXT_COLOR_GREEN, NXT_COLOR_YELLOW, NXT_COLOR_ORANGE, NXT_COLOR_RED, NXT_COLOR_WHITE, NXT_COLOR_UNKNOWN
void ecrobot_get_nxtcolorsensor_rgb (U8 *port_id*, S16 *rgb[3]*)	gets color RGB raw data. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 *rgb*: rgb[0] = Red, rgb[1] = Green, rgb[2] = Blue Returns: none

U16 ecrobot_get_nxtcolorsensor_light(U8 *port_id*)	gets light sensor A/D data. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: 0 - 1023 raw A/D data
void ecrobot_term_nxtcolorsensor(U8 *port_id*)	terminates the NXT Color Sensor. This function should be implemented in the device terminate hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none

RS485 API	Description
void ecrobot_init_rs485(U32 *baud_rate*)	initializes NXT sensor port 4 for RS485 communication. RS485 is configured as asynchronous mode, 8 bits character length, 1 stop bit and no parity check. This function should be implemented in the device initialize hook routine. Parameters: *baud_rate*: RS485 baud rate [bps]. LEGO dafault baud rate is 921600 [bps] Returns: none
U32 ecrobot_send_rs485(U8* *buf*, U8 *off*, U32 *len*)	send RS485 data. Maximum length of send data is 64 [bytes]. Parameters: *buf*: buffer containing data to send *off*: buffer offset *len*: length of the data to be sent Returns: Number of sent data
U32 ecrobot_read_rs485(U8* *buf*, U8 *off*, U32 *len*)	receive RS485 data. Maximum length of receive data is 64 [bytes]. Parameters: *buf*: buffer to receive data *off*: buffer offset *len*: length of the data to be received Returns: Number of received data
void ecrobot_term_rs485(*void*)	terminates RS485 communication. This function should be implemented in the device terminate hook routine. Parameters: none Returns: none



I2C API	Description

void ecrobot_init_i2c(U8 *port_id* U8 *type*)	initializes a NXT sensor port for I2C communication. This function should be implemented in the device initialize hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 *type*: LOWSPEED_9V/LOWSPEED Returns: none
SINT ecrobot_send_i2c(U8 *port_id*, U32 *address*, SINT *i2c_reg*, U8 **buf*, U32 *len*)	send I2C data. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 *address*: 0x01 to 0x7F Note that addresses are from 0x01 to 0x7F not even numbers from 0x02 to 0xFE as given in some I2C device specifications. They are 7-bit addresses not 8-bit addresses. *i2c_reg*: I2C register e.g. 0x42 *buf*: buffer containing data to send *len*: length of the data to send Returns: 1(success)/0(failure)
SINT ecrobot_read_i2c(U8 *port_id*, U32 *address*, SINT *i2c_reg*, U8 **buf*, U32 *len*)	read I2C data. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 *address*: 0x01 to 0x7F Note that addresses are from 0x01 to 0x7F not even numbers from 0x02 to 0xFE as given in some I2C device specifications. They are 7-bit addresses not 8-bit addresses. *i2c_reg*: I2C register e.g. 0x42 *buf*: buffer to return data *len*: length of the return data Returns: 1(success)/0(failure)
void ecrobot_term_i2c(U8 *port_id*)	terminates a NXT sensor port used for I2C communication. This function should be implemented in the device terminate hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none

Inside of the NXT, there is a Bluecore chip to handle Bluetooth communication. The ARM7 uses UART to communicate with the Bluecore chip. In LEGO MINDSTORMS NXT Bluetooth Developer Kit, standard LEGO firmware supports a lot of communication protocols, however, ECRobot API does not support all LEGO standard communication protocol (i.e. no direct control, no diagnosis...).
- In case of NXT-PC Bluetooth communication, A Windows application program (NXT GamePad) is available to remotely control a NXT and acquire the NXT internal data (data logging).
- In case of NXT-NXT, only one NXT to one NXT communication is supported. Device configurations for a Bluetooth connection needs to be implemented in the code.

Bluetooth API	Description
void ecrobot_init_bt_master(const U8 **bd_addr*, const CHAR **pin*)	initializes NXT as the Bluetooth master device and establish a connection with a slave NXT. Bluetooth Device Address (BD_ADDR) consists of 48 bits, however, NXT requires additional 8 bits (total 7 bytes), so the last 8 bits should always be 0x00. This API needs to be implemented in a loop (e.g. ecrobot_device_initialize or a background Task). Parameters: *bd_addr:* Slave NXT's Bluetooth Device Address. If a slave NXT had 00:16:53:04:F1:B3 BD_ADDR, *bd_addr* should be defined such as: `const U8 bd_addr[7] = {0x00,0x16,0x53,0x04,0xF1,0xB3,0x00};` *pin*: pin code string. Maximum character length is 16. (e.g. "LEJOS-OSEK") Returns: none

void ecrobot_init_bt_slave(const CHAR *_pin_)	initializes NXT as the Bluetooth slave device and establish a connection with a master device (PC, master NXT). This API needs to be implemented in a loop (e.g. ecrobot_device_initialize or a background Task). Parameters: *pin*: pin code string. Maximum character length is 16. (e.g. "LEJOS-OSEK") Returns: none
void ecrobot_init_bt_connection(void)	initializes Bluetooth device and establish a connection with PC. PINCODE for the connection is pre-fixed as "MATLAB". This API needs to be implemented in a loop (e.g. ecrobot_device_initialize or a background Task). Parameters: none Returns: none
U8 ecrobot_get_bt_device_name(CHAR* *bd_name*)	get Bluetooth friendly device name. Parameters: *bd_name*: Friendly name of the device Returns: 1(succeeded)/0(failure)
U8 ecrobot_set_bt_device_name(const CHAR* *bd_name*)	sets Bluetooth friendly device name. Note that this API should be used only when Bluetooth is NOT connected. Note that user specified friendly device name using this function seems to be appeared in the Windows Bluetooth device dialog only when NXT BIOS is used as the firmware. Parameters: *bd_name*: Friendly name of the device(max. 16 characters string) Returns: 1(succeeded)/0(failure)
SINT ecrobot_get_bt_status(void)	gets the status of Bluetooth device. To communicate with other device, Bluetooth device status has to be BT_STREAM. Parameters: none Returns: Bluetooth device status BT_NO_INIT (device is not initialized) BT_INITIALIZED (device is initialized) BT_CONNECTED (device is connected through pairing process) BT_STREAM (device is ready for read/send user data)
S16 ecrobot_get_bt_signal_strength(void)	gets Bluetooth signal strength. Parameters: none Returns: Signal strength -1 to 255. Higher value means the link quality is better. -1 means that the Bluetooth is not connected.
U32 ecrobot_send_bt_packet(U8 **buf*, U32 *bufLen*)	sends data packet to a Bluetooth device (PC, master/slave NXT). Parameters: *buf:* Bluetooth send data buffer *bufLen*: size of sending data (max. 254 bytes) Returns: number of sent data in bytes
U32 ecrobot_send_bt(const void* *buf*, U32 *off,* U32 *len*)	[**RECOMMENDED TO USE**] sends data to a Bluetooth device (PC, master/slave NXT). Parameters: *buf:* Bluetooth send data buffer *off:* Bluetooth send data buffer offset *len*: size of sending data (max. 256 bytes) Returns: number of sent data in bytes

U32 ecrobot_read_bt_packet(U8 **buf*, U32 *bufLen*)	reads data packet from a Bluetooth device (PC, master/slave NXT). Parameters: *buf*: Bluetooth receive data packet *bufLen*: size of receive data buffer (max. ~~254~~126 bytes) Returns: number of return data in bytes
U32 ecrobot_read_bt(void* *buf*, U32 *off,* U32 *len*)	[**RECOMMENDED TO USE**] reads data from a Bluetooth device (PC, master/slave NXT). Parameters: *buf*: Bluetooth receive data buffer *off*: Bluetooth receive data buffer offset *len*: size of the data buffer (max. 128 bytes) Returns: number of return data in bytes
U8 ecrobot_set_bt_factory_settings(void)	resets all settings in the persistent settings in the BlueCore chip. The BlueCore chip should be restarted (may need to remove the battery) after calling this function. Otherwise old values can be floating around the BlueCore chip causing unexpected behavior. Parameters: none Returns: none
void ecrobot_term_bt_connection(void)	terminates Bluetooth connection with a device (PC, master/slave NXT). Parameters: none Returns: none
void ecrobot_bt_data_logger(S8 data1, S8 data2)	sends pre-fixed NXT internal status data. Data packet size is 32bytes and the following NXT internal status data is sent to PC via Bluetooth. This API is designed for NXT GamePad and NXT GamePad will save all data as a CSV file. data packet 0-3bytes: system tick in msec, data type U32 data packet 4bytes: data1 (i.e. left analog stick input), data type S8 data packet 5bytes: data2 (i.e. right analog stick input), data type S8 data packet 6-7bytes: battery voltage in mV, data type U16 data packet 8-11bytes: Servo Motor revolution at Port A, data type S32 data packet 12-15bytes: Servo Motor revolution at Port B, data type S32 data packet 16-19bytes: Servo Motor revolution at Port C, data type S32 data packet 20-21bytes: Analog Sensor value at Port S1, data type S16 data packet 22-23bytes: Analog Sensor value at Port S2, data type S16 data packet 24-25bytes: Analog Sensor value at Port S3, data type S16 data packet 26-27bytes: Analog Sensor value at Port S4, data type S16 data packet 28-31bytes: I2C Sensor value, data type S32 Parameters: *data1*: user selected data (i.e. left analog stick input) *data2*: user selected data (i.e. right analog stick input) Returns: none

~~nxtOSEK uses LibUsb and LibNXT for USB host application program. Under samples directory, a USB target example (usbtest) and a USB host example (usbhost) are available. Currently, only one NXT can be communicated with a host via USB.~~

January, 2009: The new nxtOSEK v2.05 uses LEGO Fantom driver for USB host application program and USB communication protocol becomes more consistent(i.e. explict connect/disconnect) and provides more functionalities(i.e. ~~multiple NXT connections with a host~~) compared to the previous version. For more detailed information about nxtOSEK USB API, see samples\usbtest directory. On the host side programming, see also samples\usbtest\usbhost directory.

USB API	Description

void ecrobot_init_usb(void)	initializes USB functionality in the NXT. This function must be invoked in ecrobot_device_initialize. Parameters: none Returns: none
SINT ecrobot_set_name_usb(U8* *name*)	sets name to the NXT. By default, "nxt" is set as the device name in ecrobot_init_usb. Parameters: *name*: device name of the NXT (character length is up to 16) Returns: 1(success)/0(failure)
U8 ecrobot_process1ms_usb(void)	USB process handler to establish a connection with a host. This function must be invoked every 1msec. (i.e. in a loop with 1msec wait, OSEK/JSP 1msec peiodical Task) Parameters: none Returns: status of USB(USB_NO_INIT/USB_INIT/USB_CONNECTED)
SINT ecrobot_read_usb(U8* *buf,* U32 *off*, U32 *len*)	reads USB data from host after a USB connection was established. Parameters: *buf*: data buffer *off*: offset in the buffer *len*: length of data to read (length is up to 64) Returns: length of read data
SINT ecrobot_send_usb(U8* *buf,* U32 *off*, U32 *len*)	sends USB data to host after a USB connection was established. Parameters: *buf*: data buffer *off*: offset in the buffer *len*: length of data to send(length is up to 64) Returns: length of sent data
SINT ecrobot_disconnect_usb(void)	disconnects a current connection with host. This API enables to implement connect/disconnect sequence in application. This function makes USB device name being default, so it needs to invoke ecrobot_set_name_usb to change the device name to be user specified device name. Parameters: none Returns: 1(success)/0(failure)
void ecrobot_term_usb(void)	terminates USB functionality in the NXT. Parameters: none Returns: none

nxtOSEK supports for monochrome BMP files to draw graphics in the LCD display. User can design LCD graphics in BMP editor on PC and the BMP image can be displayed in the LCD on the NXT. GCC provides objcopy which enables to link BMP files to a nxtOSEK binary executable. Under samples directory, there are two BMP file examples (anime and bmptest).

LCD display API	Description
SINT ecrobot_bmp2lcd(const CHAR **file*, U8 **lcd*, S32 *width*, S32 *height*)	converts a monochrome BMP file image to a BMP array data. Parameters:

	file: `BMP_DATA_START(BMP file name)` macro has to be assigned. BMP file name should NOT contains file extension (.bmp) *lcd*: LCD array buffer (maximum data size is 800) *width*: LCD data width in bits (maximum width is 100) *height*: LCD data height in bits (maximum height is 64) Returns: 1: BMP file could be converted. 0: BMP file conversion was failed.
void display_bitmap_copy(const U8 **data*, U32 *width*, U32 *depth*, U32 *x*, U32 *y*)	displays a BMP array data to LCD. Parameters: *data*: Start address of a BMP array data *width*: BMP array data width in bits (maximum width is 100) *depth*: BMP array data height in bytes (maximum height is 8) *x*: BMP array data horizontal postion in bits (0 - 100) *y*: BMP array data vertical position in bytes (0 - 8) Returns: none
void display_update(void)	updates LCD display. Parameters: none Returns: none
void display_clear(U32 *updateToo*)	clears LCD display buffer. Parameters: *updateToo*: 0 (not update LCD display), 1(update LCD display after clearing the buffer) Returns: none
void display_goto_xy(int *x*, int *y*)	specifies text display position. Top left is (0,0). Parameters: *x*: horizontal position (0 to 15) *y*: vertical position (0 to 7) Returns: none
void display_string(const char **str*)	stores string into LCD display buffer. Parameters: *str*: supported ASCII characters are 0x00 to 0x7F Returns: none
void display_hex(U32 *val*, U32 *places*)	stores integer value into LCD display buffer to display hex expression. Parameters: *val*: integer value to be displayed *places*: number of characters to be reserved Returns: none
void display_unsigned(U32 *val*, U32 *places*)	stores unsigned integer value into LCD display buffer. Parameters: *val*: unsigned integer value to be displayed *places*: number of characters to be reserved Returns: none
void display_int(int *val*, U32 *places*)	stores signed integer value into LCD display buffer. Parameters: *val*: signed integer value to be displayed *places*: number of characters to be reserved Returns: none
void ecrobot_status_monitor(const CHAR **target_name*)	displays NXT internal status (application name, system tick, battery voltage, raw A/D data, motor revolutions, Bluetooth connection status, and Ultrasonic Sensor data) on the LCD. It is recommended to invoke this API in a low speed periodical Task (i.e. 500msec).

	Parameters: *target_name*: target name string Returns: none

nxtOSEK supports for 8bit monoral PCM WAV file to play a sound. WAV file sound (e.g. music, voice...) can be directly played in the NXT. GCC provides objcopy which enables to link WAV files to a nxtOSEK binary executable. Under samples directory, there is a WAV file example (wavtest).

Sound API	Description
SINT ecrobot_sound_tone(U32 *freq*, U32 *ms*, U32 *vol*)	plays a tone, given its frequency, duration and volume. Frequency is audible from about 31 to 2100 Hertz. The duration argument is in hundreds of a seconds (centiseconds, not milliseconds) and is truncated at 256, so the maximum duration of a tone is 2.56 seconds. Parameters: *freq*: frequency of a tone in Herz. *ms*: duration of a tone in hundreds of a second. *vol*: sound volume (0 - 100). 0 means mute. Returns: 1: sound tone is playing
SINT ecrobot_sound_wav(const CHAR **file*, U32 *length*, S32 *freq*, U32 *vol*)	plays a 8bit monoral PCM WAV sound file. Parameters: *file*: `WAV_DATA_START(WAV file name)` macro has to be assigned. WAV file name should NOT contains file extension (.wav) *length*: `WAV_DATA_SIZE(WAV file name)` macro has to be assigned. WAV file name should NOT contains file extension (.wav) *freq*: sampling frequency in Herz. (2000Hz - 22050Hz. -1: use WAV file original sampling frequency) *vol*: sound volume (0 - 100). 0 means mute. Returns: 1: WAV file is playing. 0: Sound resouce is busy. -1: non-supported WAV file.
void sound_freq(U32 *freq*, U32 *ms*)	plays a tone, given its frequency and duration. Frequency is audible from about 31 to 2100 Hertz. The duration argument is in hundreds of a seconds (centiseconds, not milliseconds) and is truncated at 256, so the maximum duration of a tone is 2.56 seconds. Parameters: *freq*: frequency of the tone in Herz. *ms*: duration of the tone in hundreds of a second. Returns: none

NXT internal API	Description
U8 ecrobot_is_ENTER_button_pressed(void)	returns the status of ENTER (ENTR) button. Parameters: none Returns: Status of ENTER (ENTR) button 1: button is pressed 0: button is not pressed
U8 ecrobot_is_RUN_button_pressed(void)	returns the status of RUN button. Parameters:

	none Returns: Status of RUN button 1: button is pressed 0: button is not pressed
U16 ecrobot_get_battery_voltage(void)	gets battery voltage data. Parameters: none Returns: battery voltage in mV. (i.e. 9000 = 9.000V)
U32 systick_get_ms(void)	gets system tick in msec. system tick is started when the NXT is turned on (not started when an application begins) Parameters: none Returns: system tick in msec
U32 ecrobot_get_systick_ms(void)	gets system tick in msec. Wrapper of systick_get_ms. Parameters: none Returns: system tick in msec
void systick_wait_ms(U32 *ms*)	waits for specified msec. Parameters: *ms*: wait time in msec Returns: none

NXT acquires three axes acceleraton data from the HiTechnic Acceleration Sensor (NAC1040) via I2C communication. However, actual data transaction between the ARM7 and the Acceleration Sensor is done by an ISR triggered by a function call, so there is one execution cycle delay to achieve consistent data acquisition. According to HiTechnic, data reflesh rate on the Sensor is approximately 100 times per second and acceleration is measured in the range of ?2g to +2g with scaling of approximately 200 counts per g.
For more detailed information about Acceleration Sensor, please visit HiTechnic Web site.

HiTechnic Acceleration Sensor API	Description
void ecrobot_init_accel_sensor(U8 *port_id*)	initializes a port for I2C communication for Acceleration Sensor. This function should be implemented in the device initialize hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none
void ecrobot_get_accel_sensor(U8 *port_id*, S16 *buf*[3])	gets acceleration data in three axes. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 *buf*: acceleration data in three axes (buf[0]: x axis, buf[1]: y axis, buf[2]: z axis) Returns: none
void ecrobot_term_accel_sensorr(U8 *port_id*)	terminates I2C communication used for Acceleraton Sensor. This function should be implemented in the device terminate hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none

NXT uses I2C communication between the ARM7 and the AVR to access the HiTechnic Gyro Sensor (NGY1044). The AVR uses 10bit A/D converter to get Gyro Sensor data. According HiTechnic, The Gyro Sensor can measure up to +/- 360° per second of rotation and the rotation rate can be read up to approximately 300 times per second. For more detailed information about Gyro Sensor, please visit HiTechnic Web site.

HiTechnic Gyro Sensor API	Description
U16 ecrobot_get_gyro_sensor(U8 *port_id*)	gets Gyro Sensor raw A/D data. The sensor data has offset value (approximately 600). Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none

NXT acquires direction and intesity data from the HiTechnic IR Seeker (NSK1042) via I2C communication. However, actual data transaction between the ARM7 and the IR Seeker is done by an ISR triggered by a function call, so there is one execution cycle delay to achieve consistent data acquisition. For more detailed information about IR Seeker, please visit HiTechnic Web site.

HiTechnic IR Seeker API	Description
void ecrobot_init_ir_seeker(U8 *port_id*)	initializes a port for I2C communication for IR Seeker. This function should be implemented in the device initialize hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none
void ecrobot_get_ir_seeker(U8 *port_id*, S16 *buf*[6])	gets direction and intensity data. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 *buf*: infrared data (buf[0]: direction, buf[1]: intesity1, ... buf[5]: intesity5) Returns: none
void ecrobot_term_ir_seeker(U8 *port_id*)	terminates I2C communication used for IR Seeker. This function should be implemented in the device terminate hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none

NXT acquires magnetic heading in degree from the HiTechnic Compass Sensor (NMC1034) via I2C communication. However, actual data transaction between the ARM7 and the Compass Sensor is done by an ISR triggered by a function call, so there is one execution cycle delay to achieve consistent data acquisition. For more detailed information about Compass Sensor, please visit HiTechnic Web site.

HiTechnic Compass Sensor API	Description
void ecrobot_init_compass_sensor(U8 *port_id*)	initializes a port for I2C communication for Compass Sensor. This function should be implemented in the device initialize hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none

void ecrobot_cal_compass_sensor(U8 *port_id*)	calibrates the Compass Sensor. There is a detailed description about calibration of the Compass Sensor at HiTechnic Web site. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none
S16 ecrobot_get_compass_sensor(U8 *port_id*)	gets magnetic heading in degree(0 to 359). South is 180 degrees. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: heading data in degree (0 to 359)
void ecrobot_term_compass_sensor(U8 *port_id*)	terminates I2C communication used for Compass Sensor. This function should be implemented in the device terminate hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none

NXT acquires Red/Green/Blue color raw data from the HiTechnic Color Sensor (NCO1038) via I2C communication. However, actual data transaction between the ARM7 and the Color Sensor is done by an ISR triggered by a function call, so there is one execution cycle delay to achieve consistent data acquisition. For more detailed information about Color Sensor, please visit HiTechnic Web site.

HiTechnic Color Sensor API	Description
void ecrobot_init_color_sensor(U8 *port_id*)	initializes a port for I2C communication for the Color Sensor. This function should be implemented in the device initialize hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none
void ecrobot_get_color_sensor(U8 *port_id*, S16 *buf*[3])	gets Red/Green/Blue color raw data. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 *buf*: color data (buf[0]: Red, buf[1]: Green, buf[2]: Blue) Returns: none
void ecrobot_term_color_sensor(U8 *port_id*)	terminates I2C communication used for the Color Sensor. This function should be implemented in the device terminate hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none

NXT communicates with a HiTechnic Prototype Sensor (NPS1055) via I2C communication. However, actual data transaction between the ARM7 and the Prototype Sensor is done by an ISR triggered by a function call, so there is one execution cycle delay to achieve consistent data acquisition. For more detailed information about the Prototype Sensor, please visit HiTechnic Web site.

HiTechnic Prototype Sensor API	Description
void ecrobot_init_prototype_sensor(U8 *port_id*, U8 *rate*, U8 *dir*)	initializes a port for I2C communication for the Prototype Sensor. This function should be implemented in the device initialize hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 *rate*: sensor sampling rate (forcing into the range of 4 - 100 msec) *dir*: direction of the six digital I/O ports. A 1 bit in position i (0<= i<=5) indicates the port i is configured for output. A 0 bit indicates the port is configured for input. Returns: none
void ecrobot_get_prototype_analog_sensor(U8 *port_id*, S16 *buf[5]*)	gets the Prototype Sensor analog data. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 *buf*: analog 5 channel data buffer Returns: none
U8 ecrobot_get_prototype_digital_sensor(U8 *port_id*)	gets the Prototype Sensor digital data. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: digital data (0 - 5 bits)
void ecrobot_send_prototype_digital_sensor(U8 *port_id*, U8 *data)*	sends the Prototype Sensor digital data. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 *data*: digital data (0 - 5 bits) to be sent Returns: none
void ecrobot_term_prototype_sensor(U8 *port_id*)	terminates I2C communication used for the Prototype Sensor. This function should be implemented in the device terminate hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none

RCX Active Sensor (e.g. Light Sensor) on NXT requires power source to drive the sensor. RCX Active Sensor API may be used for other RCX Active Sensors (not tested all).

RCX Active Sensor API	Description
void ecrobot_set_RCX_power_source(U8 *port_id*)	supplies power source to RCX Active Sensor. This function should be implemented in the device initialize hook routine. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none
S16 ecrobot_get_RCX_sensor(U8 *port_id*)	gets RCX Active Sensor raw data. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: sensor raw data
void ecrobot_term_RCX_power_source(U8 *port_id*)	stops power source to RCX Active Sensor. This function should be implemented in the device terminate hook routine. Parameters:

	port_id: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: none

RCX Touch Sensor is compatible with NXT A/D Sensors such as NXT Touch Sensor. This API is implemend to just dinstiguish those RCX/NXT Touch Sensors. (ecrobot_get_touch_sensor also could be used to access RCX Touch Sensor)

RCX Touch Sensor API	Description
U8 ecrobot_get_RCX_touch_sensor(U8 *port_id*)	gets Touch Sensor status. Parameters: *port_id*: NXT_PORT_S1, NXT_PORT_S2, NXT_PORT_S3, NXT_PORT_S4 Returns: 0(not touched), 1(touched)

nxtOSEK Hook routines:

nxtOSEK provides 3 hook routines for user. These hook routines have to be defined in the user code. ecrobot_main.c file of NXTway sample is useful to understand how to use these hook routines.

- `void ecrobot_device_initialize(void)`: This hook routine is invoked when the NXT was turned on. User can implement device initialize functions in this function.

```
void ecrobot_device_initialize(void)
{
    /* Initialize ECRobot used devices */
    ecrobot_set_light_sensor_active(NXT_PORT_S1);
    ecrobot_set_light_sensor_active(NXT_PORT_S3);
    ecrobot_init_sonar_sensor(NXT_PORT_S2);
    ecrobot_init_bt_connection();
}
```

- `void ecrobot_device_terminate(void)`: This hook routine is invoked when STOP or EXIT button was pressed. User can implement device terminate functions in this function.

```
void ecrobot_device_terminate(void)
{
    /* Terminate ECRobot used devices */
    ecrobot_set_light_sensor_inactive(NXT_PORT_S1);
    ecrobot_set_light_sensor_inactive(NXT_PORT_S3);
    ecrobot_set_motor_speed(NXT_PORT_B, 0);
    ecrobot_set_motor_speed(NXT_PORT_C, 0);
    ecrobot_term_sonar_sensor(NXT_PORT_S2);
    ecrobot_term_bt_connection();
}
```

- `void user_1ms_isr_type2(void)`: This hook routine is invoked from a 1msec periodical ISR in category 2. For example, user can implement an OSEK Alarm counter for Rate Monotonic Scheduling in this hook routine.

```
#include "kernel.h"
#include "kernel_id.h"

void user_1ms_isr_type2(void)
{
    StatusType ercd;

    /* Increment System Timer Count */
    ercd = SignalCounter(SysTimerCnt);
```

```
    if (ercd != E_OK)
    {
        ShutdownOS(ercd);
    }
}
```