Design Manual

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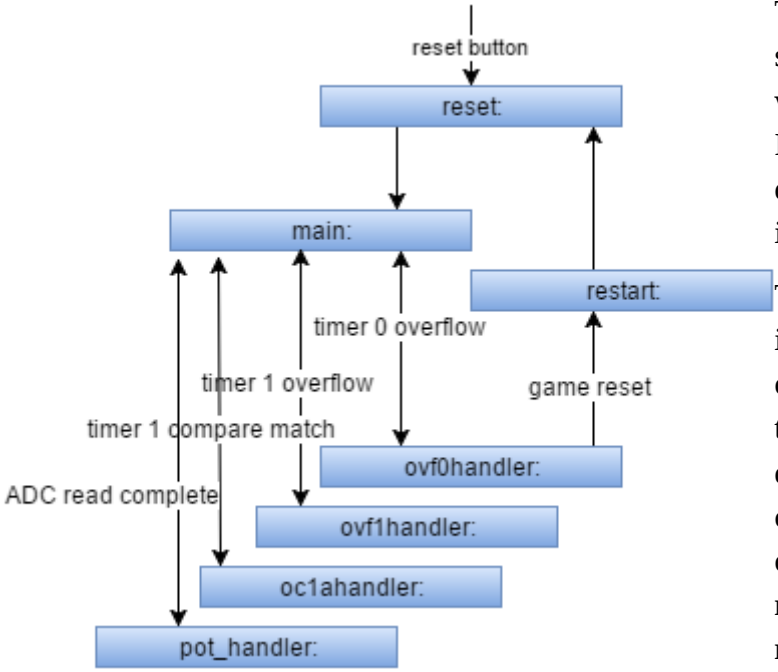
System Flow Control

The safe cracker is split into a main file, `cracker.asm`, and helper files which provide functions, macros and interrupt service routines to interact with the AVR board's inputs and outputs. The helper files are described in the 'Modules' section.

The main file, `cracker.asm` implements the flow of game.



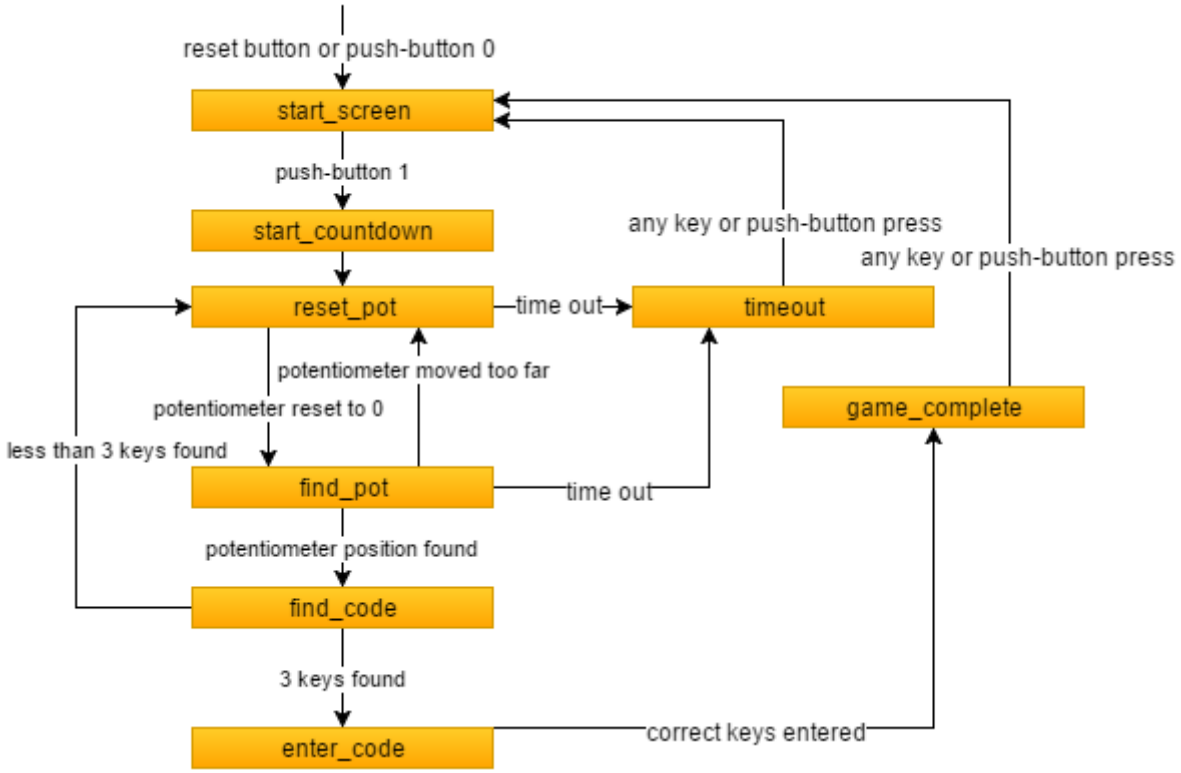
The game is initialised by the reset interrupt service routine. It then enters the main loop which does nothing but wait for interrupts. Interrupts are shown in the diagram with double ended arrows representing the interrupt and return from interrupt.

The interrupt service routine which implements the overall game flow is ovf0handler, the interrupt service routine for the timer 0 overflow interrupt. It executes different sections of code based on the current stage of the game. When the game is over, or if push-button 0 is pushed, it calls restart to restart the game. Otherwise it returns from interrupt to main.

ov1handler and oc1ahandler are interrupt service routines for timer 1 overflow and timer 1 compare match interrupts respectively. These are used to implement LCD fading.

pot_handler is the interrupt service routine for the ADC read complete interrupt, used to implement reading from the potentiometer.

ovf0handler implements the game flow by executing different sections of code based on the stage of the game. The game flow is simply as described by the project specifications.



Data Structures

Bytes are 8-bit integers. *Words* are 16-bit (or 2-byte) integers. *Characters* are (represented as, and can be considered as) bytes. *Booleans* are stored as bytes.
Key presses and the difficulty level are represented as a character. Letters in this case are represented as capitals (eg the lowest difficulty is `'A'`).

cracker.asm

Registers

`timer0_parity` is `r11`, it flips between `1` and `0` on each timer 0 overflow interrupt. It is used to control the fade speed of the LCD.

`fade_dir` is r12, it stores `-1`, `0` or `1` to control whether the LCD fades in or out.

`lcd_brightness` is `r13`, it stores the current LCD brightness from `0x00` for off to `0xff` for full brightness.

`cur_code_char` is `r14`, it stores the index of the current character being entered in the enter_code stage.

`game_iter` is `r15`, it stores how many rounds have been won/how many secret keys have been found.

`tmp` is `r16`, it is used as a miscellaneous temporary variable.

`do_display` is `r22`, it stores `1` if the display needs to be refreshed and `0` otherwise.

`stage` is `r23`, it stores which stage the stage is at, the stages are defined as constant integer symbols.

`tmp_wordl` is `r24` and `tmp_wordh` is `r25`, they are used as a miscellaneous word temporary variable.

Compiler constant symbols

`ticks_per_sec` is the approximate number of timer 0 overflows per second.

`lcd_fade_time` is the number of timer 0 overflows to wait before beginning to fade the LCD.

`pot_eps` is a small value, below which any potentiometer readings are essentially `0`.

`start_screen`, `start_countdown`, `reset_pot`, `find_pot`, `find_code`, `enter_code`, `game_complete` and `timeout` are given the values `0` through `7`.

Data segment variables

`diff_time` is a byte that stores the number of seconds the user has to find the correct potentiometer position in the current difficulty.

`diff_level` is a character that stores the current difficulty level (`'A'` to `'D'`).

`timer_cd` is word that stores the number of timer 0 overflow interrupts until a second has passed.

`timer_cnt` is a byte that stores the number of seconds left on the timer.

`pot_cd` is a word that stores that number of timer 0 overflow interrupts remaining until the potentiometer has been held in the correct position for long enough.

`pot_targ` is a word that stores the secret target value for the potentiometer.

`key_targ` is a character that stores the secret target value for the keypad.

`key_cd` is a word that stores the number of timer 0 overflow interrupts remaining until the secret key has been held for long enough.

`key_code` is 3 characters that stores the 3 letter code.

`strobe_cd` is a word that stores the number of timer 0 overflow interrupts remaining until the strobe should be toggled.

`lcd_off_cd` is a word that stores the number of timer 0 overflow interrupts remaining until the lcd should begin fading.

`random_timer` is a byte that increments on each timer 0 overflow interrupt and is used to seed the random number generator.

Program memory constants

The fixed display strings, as specified in the project specifications, are stored as program memory constants. In addition, strings to display each difficulty level, `“ (?)”` (with `?` replaced by the

difficulty level as a character) are also stored as program memory constants.

Modules

The interface to the following helper files is described under 'Modules'. The algorithms used are described in 'Algorithms'. In this section, the data structures used are described.

keypad-util.asm

`pressed_char` is a character storing the last pressed character for debouncing purposes.

`key_db` is a byte storing the remaining debounce duration.

lcd-fader.asm

LCD fading implicitly stores the LCD brightness in the compare interrupt value for timer 1.

pot-util.asm

`pot` is a word that stores the potentiometer reading.

`potav` is a boolean which stores whether a new potentiometer reading is available.

rand.asm

`rand_cur` is a byte that stores the current random value for use in the linear congruential generator.

speaker-util.asm

`speaker_what` is a byte that stores `0` or `1` for whether the pin is currently high or low.

`speaker_len` is a word that stores the remaining speaking duration.

Algorithms

cracker.asm

Le todo

Modules

The interface to the following helper files is described under 'Modules'. The data structures used are described in 'Data Structures'. In this section, the non-trivial algorithms used in the helper files are described.

keypad-util.asm

`read_key` is implemented simply by looping over each row of the keypad and then over the columns of that row.

`read_key_db` implements debouncing by storing the last key pressed, and keeping a counter of how many times a different key or no key needs to be pressed to register new key presses. Once the counter reaches 0, new key presses will be registered.

lcd-fader.asm

LCD brightness is implemented by turning the LCD on and off, but at small intervals so that the LCD appears to just be dimmer. The greater the proportion of time the LCD is on, the brighter it appears.

Specifically, `set_lcd_level` sets the proportion of each timer 1 overflow that the LCD will be on. If the level is 5 or lower, the brightness is effectively 0 so the LCD is turned off. Otherwise, each time timer 1 overflows, the LCD is turned on. And each time timer 1 reaches the set level, the LCD is turned off. (Thus a higher LCD brightness level will cause the LCD to be on for a larger proportion of each overflow.)

lcd-util.asm

`print_int` is implemented by printing each digit in order: the hundreds digit, then the tens digit then the ones digit, taking care to ignore leading 0s but not non-leading 0s.

pot-util.asm

`pot_handler` is the interrupt service routine for the ADC read complete interrupt. It stores potentiometer readings and whether a new reading is available. Then, `pot_read` simply returns the value of the new reading if one is available (and an invalid value otherwise) and then requests a new reading if needed.

rand.asm

`rand` is implemented using a simple linear congruential generator. To create different starting values, the generator is seeded with a timer value when the user begins a new game. Since the timer overflows very often, the seed value is generally random enough.

speaker-util.asm

Speakers are implemented by simply storing the remaining beep duration. `speaker_set_len` sets the remaining duration. Then, `speaker_speak` is run on each timer0 overflow interrupt and switches the pin only if the current beep is not complete.

Modules

In addition to the main file, a number of helper files define functions, macros and interrupt service routines to interact with the AVR board's inputs and outputs. Only functions, macros and interrupt service routines used in `cracker.asm` are described.

Macro arguments are referred to as `@x` (as in avr assembly). `a:b` represents a pair of registers representing a word, where `a` is the more significant byte.

keypad-util.asm

`keypad_init` (macro): Initialises the keypad.

`read_key` (function): Returns a key which is currently pressed as a character in `r16`. If no key is pressed, it returns `'?'`.

`read_key_db` (function): Returns a key which is currently pressed as a character in `r16` with debouncing. If no key is pressed (or not pressed enough to pass debouncing) it returns `'?'`.

lcd-fader.asm

`lcd_fade_init` (macro): Sets up the LCD for fading.

`set_lcd_level` (function): Sets the brightness level of the lcd based on `r16`. When `r16` is `0x00` brightness is lowest, when `r16` is `0xff` brightness is highest.

`ovf1handler` (interrupt service routine): Interrupt service routine for timer 1 overflow interrupt for LCD fading.

`oc1ahandler` (interrupt service routine): Interrupt service routine for timer 1 compare match interrupt for LCD fading.

lcd-util.asm

`do_lcd_data` (macro): Prints immediate character `@0` to the LCD.

`lcd_row2` (macro): Moves printing on the LCD to the second row.

`lcd_clear` (macro): Clears the LCD (and moves printing to the first row).

`lcd_init` (macro): Initialises the LCD.

`rip` (function): Prints `'*'` and infinite loops. Should never be called.

`print_int` (function): Prints `r16` as an integer to the LCD.

led-util.asm

`set_led` (macro): Displays the lowest 10 bits of immediate `@0` on the LEDs. An LED is turned on if the corresponding bit is set (if the bit is `1`). The most significant bit is displayed on the top LED.

motor-util.asm

`motor_init` (macro): Initialises the motor.

`set_motor_speed` (macro): Turns the motor off if immediate `@0` is `0`, otherwise turns the motor to full speed.

pb-util.asm

`ispb0` (macro): Sets the Z flag to `1` if push-button 0 is pressed. Otherwise sets it to `0`.

`ispb1` (macro): Sets the Z flag to `1` if push-button 1 is pressed. Otherwise sets it to `0`.

`is_any_keys` (function): Sets the Z flag to `1` if push-button 1 is pressed or any key on the keypad is pressed. Otherwise sets it to `0`.

pot-util.asm

`pot_req` (function): Initialises the potentiometer. (Used internally to request a reading from the potentiometer.)

`pot_read` (function): Returns the potentiometer reading in `r17:r16`. If no reading is available, it returns `0xffff`.

`pot_handler` (interrupt service routine): Interrupt service routine for ADC read complete interrupt for reading the potentiometer.

print-string.asm

`puts` (macro): Prints the string at immediate program memory *word* address `@0` to the LCD.

rand.asm

`srand` (macro): Seeds the random number generator with `r16`.

`rand` (function): Returns a pseudo-random 8-bit integer in `r16`.

`rand_char` (function): Returns a (pseudo-)random character on the keypad.

speaker-util.asm

`speaker_init` (macro): Initialises the speaker.

`speaker_speak` (macro): Switches the speaker pin between high and low while the current beep is not completed.

`speaker_set_len` (macro): Sets the remaining beep duration.

util.asm

`read_word` (macro): reads a word from immediate data memory address `@2` to registers `@0:@1`.

`write_word` (macro): writes a word from registers `@0:@1` to immediate data memory address `@2`.

`write_const_word` (macro): writes immediate word `@1` to immediate data memory address `@2`.

`subi_word` (macro): subtracts immediate byte `@2` from registers `@0:@1`. Neither register can be `r16`.

`dec_word` (macro): decrement from registers `@0:@1`. Neither register can be `r16`.

`def_string` (macro): places immediate string `@0` in program memory with correct padding.