Universidad de Alcalá

Project description

Development of a remote-controlled rolling platform

Digital Electronic Systems

(22-09-2025)

Degree In Electronics Engineering and Industrial Automation

University of Alcalá

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3dr Year – First Semester

Index

1 PROJECT OVERVIEW

In this document, it is proposed the design of an embedded system based on microcontroller LPC1768 (Cortex-M3) to implement a small differential rolling platform capable of performing previously established routes based on straight lines and turns without displacement (thanks to its holonomic design).

This robot movement should have the following characteristics:

- We will start with a mechanical platform that includes two DC motors to provide power to the front wheels and a third freewheel (or *Roller Ball*) that gives stability to the platform.
- The two motors will be driven by non-linear H-bridge amplifiers, through the corresponding PWM signals, that modulate the relative value of the H-bridge power supply that is applied to each motor.
- Motors integrate a magnetic quadrature encoder that will be used to measure the distance traveled, so that we will always know if the robot movement is correct.
- There will be a potentiometer to monitor the H-bridge power supply.
- When advancing, the rolling platform will emit an intermittent beep informing the user.
- Such movements to be performed will be programmed through a serial port.

On the other hand, the rolling platform may also include the other two capabilities:

- An ambience sensor will inform about different variables through a serial port (I2C/SPI).
- Non-holonomic and reverse movements, and non-straight turns could also be programmed.
- Platform movements could be specified wirelessly from a smartphone using a Bluetooth connection.

Figure 1 shows a block diagram of the embedded system that will enable the functionality described.

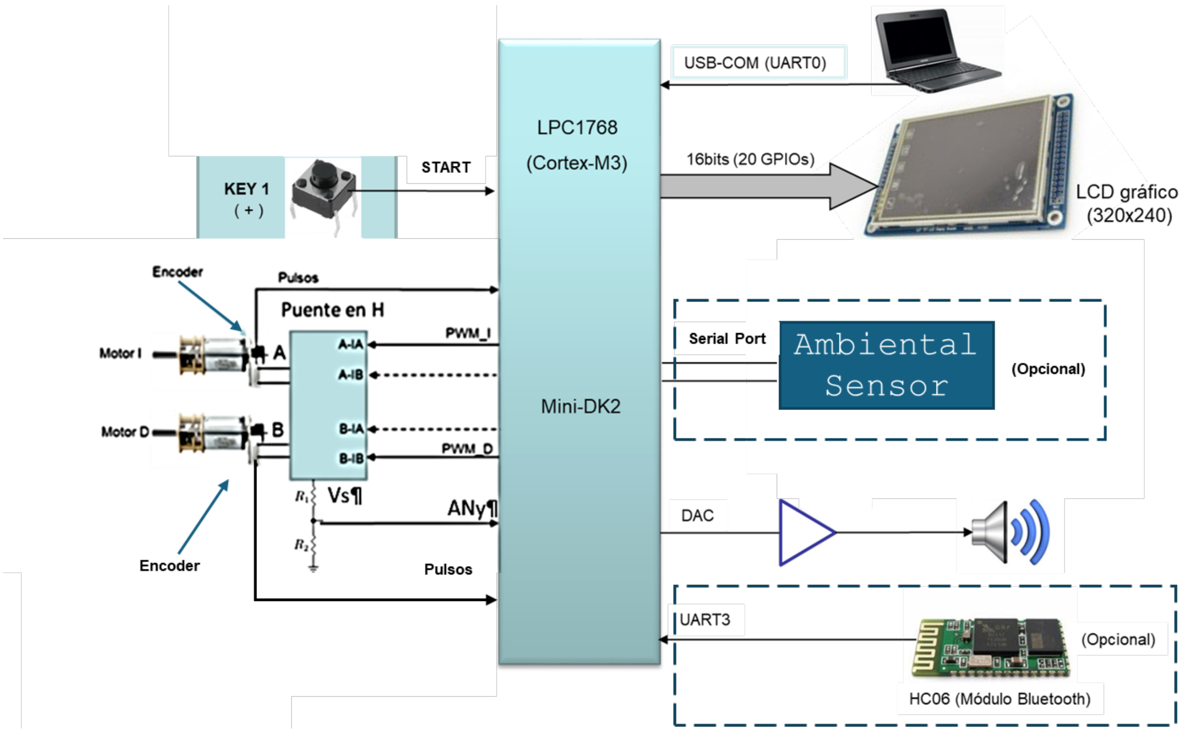


Figure 1. Block diagram of the rolling platform with differential drive

2 SYSTEM SPECIFICATIONS

The operating mode of the system must meet the specifications listed below:

1. The robot must perform predefined paths based on straight lines and 90º turns.

2. The sequence of movements is loaded from a PC via serial port into the Mini-DK2, as follows:

   a. A string of ASCII characters terminated by the character "return" (ASCII "0x0D") is used.
   b. The string syntax is the following:

      VxxFxxLxxRxx...[0x0D]

      V: percentage of maximum speed desired for the movement.
      F: advance Forward xx cm
      R: turn 90º Right and advance forward xx cm
      L: turn 90º Left and advance forward xx cm

   Optionally, a sequence with reverse and non-holonomic turning movements, and with non-straight turns, could be specified.

   Optionally the same sequence can be sent from a smartphone via Bluetooth, including to that aim, in the Mini-DK2 serial port, an external module.

   Optionally, it can be included a sensor to measure ambience variables and show them in the display.

3. The H-bridge power supply must be continuously monitored.

4. The measurement of the distance traveled in cm and turns in °, as well as the power supply voltage in V will be updated on the display of the Mini-DK2 continuously.

5. A push-button on the Mini-DK2 has to be pressed to start the movement of the stored sequence of movements, once the speed potentiometer is monitored. Such sequence may be modified in any moment through the corresponding serial port.

6. In addition, an acoustic signal must be given when the vehicle moves forward, with an intermittent acoustic signal ("Beep").

   Optionally, the intermittent acoustic signal can be programmed so that its frequency (in pulses per minute) is equal to the percentage of movement speed.

   Figure 3 shows the time diagram of the acoustic signal to be generated for the sequence: `V60A90[0x0D]`

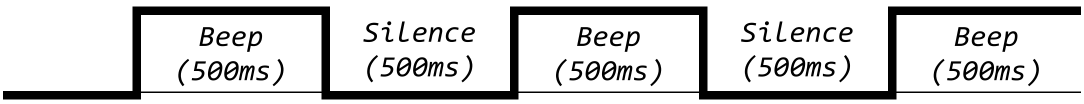


Figure 3. Example of a 90cm forward movement at 60% of maximum speed (V60).

3 DESCRIPTION OF DEVICES

3.1 Rolling platform or chassis

The mechanical platform should be appropriate to include different: two DC motors with gear reduction, three wheels (2 drive wheels and one freewheel), Mini-DK2 board, a battery case and some electronic circuits.

It should be made of any type of material with a surface area slightly larger than that of the Mini-DK2. A good choice would be methacrylate, foam or plywood (laminated wood) between 2mm and 3mm thick. A pair of examples of the rolling platform final aspect is shown in Figure 2.

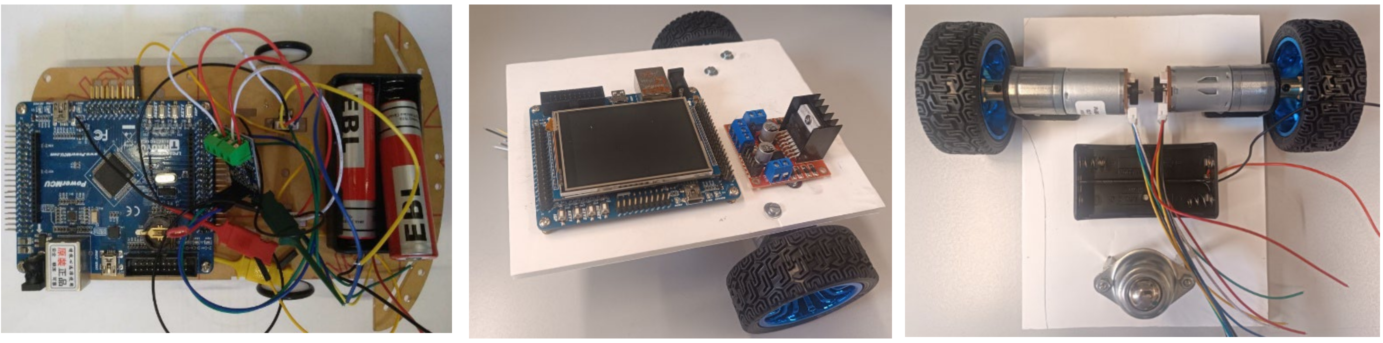


Figure 2. Examples of the rolling platform final aspect.

Two supports are necessary to hold the motors to the platform, the wheels, and the freewheel which gives stability to the system. Figure 3 shows these elements' appearance and dimensions, where it has to be highlighted the wheels diameter of 67mm, in order to calculate the distance traveled.

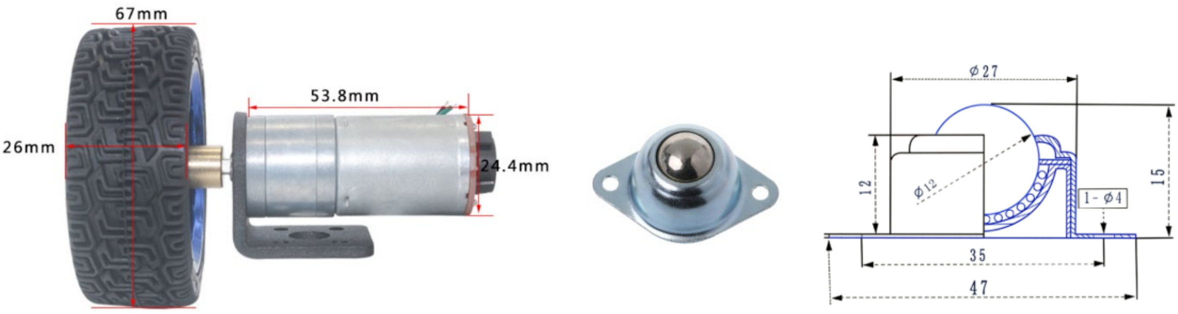


Figure 3. Appearance of the wheels, support for the motors and freewheel.

References:
https://es.aliexpress.com/item/1005001279982165.html?
https://es.aliexpress.com/item/32890317145.html?

3.2 Motors with encoder

The motor to be used is the JGA25-370 DC model. It is powered with nominal voltages of 6V and incorporates an incremental encoder on the motor shaft that allows the position of the motor shaft to be determined.

To do this, it has two Hall effect sensors that, together with the corresponding conditioning circuit, provide two digital quadrature signals (90º out of phase). These signals correspond to the two channels (A and B) of the encoder. The phase shift between both signals allows the motor direction of rotation to be determined, while its rotation speed is proportional to the frequency of either of them, and the amount of movement (motor revolutions) can be obtained through the number of pulses.

Figure 4 shows the appearance of the motor attached to the wheel and its connection diagram, where it is also pointed out that its encoder gives 11 pulses per revolution ($N = 11ppr$).

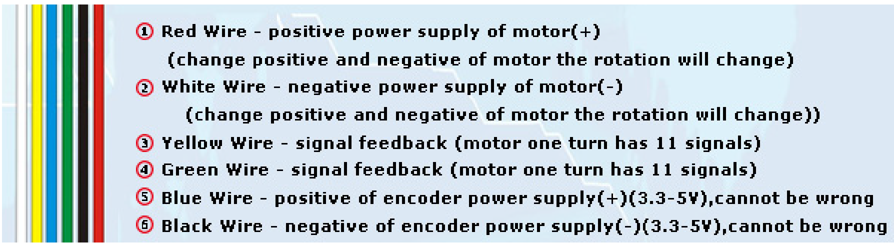


Figure 4. Appearance and connection diagram of the JGA25-370 DC motor with encoder.

It must be highlighted that the incremental encoder is mounted on the motor shaft, not on the gearbox or wheel shaft. This fact must be considered when calculating the wheel movement based on the pulses detected in the A or B quadrature signals, that therefore will be $\theta_{motor} = \frac{encoder\_pulses}{N} rev$ by the reduction ratio, i.e. $\theta_{wheel} = \frac{encoder\_pulses}{35 \cdot N} rev$

Table 1 shows the motor characteristics of the 6V version with various gearboxes offered by the manufacturer. The one proposed to be used in the project is the 6V/170 rpm model without load, i.e. that moves at a speed $\omega_{wheel} = \frac{170}{6} = 28{,}3\ rpm/V$ without load, implying already the reduction.

Table 1. JGA25-370 DC motor versions with different gearboxes and electrical-mechanical characteristics with and without load

Reduction ratio	Rated Volt	No Load		AT Load			STALL		Gearbox
		SPEED	CURRENT	Torque	SPEED	Current	TOGQCE	CURRENT	Length
	V	RPM	mA	KG.cm	RPM	A	KG..CM	A	mm
4.4	6	1360	100	0.1	1000	0.45	0.35	1.8	17
9.6	6	620	100	0.22	450	0.45	0.75	1.8	17
21.3	6	280	100	0.5	220	0.45	1.7	1.8	19
35	6	170	100	0.8	130	0.45	2.8	1.8	21
46	6	130	100	1	100	0.45	3.6	1.8	21
78	6	77	100	1.8	60	0.45	6.2	1.8	23
103	6	60	100	2.4	46	0.45	8.2	1.8	23
171	6	35	100	4	27	0.45	9	1.8	25
226	6	26	100	5.2	20	0.45	9	1.8	25
377	6	16	100	8.4	12	0.45	9	1.8	27
500	6	12	100	9	9	0.45	9	1.8	27

Figure 5 shows the output signals of a quadrature encoder with its internal electronic diagram.

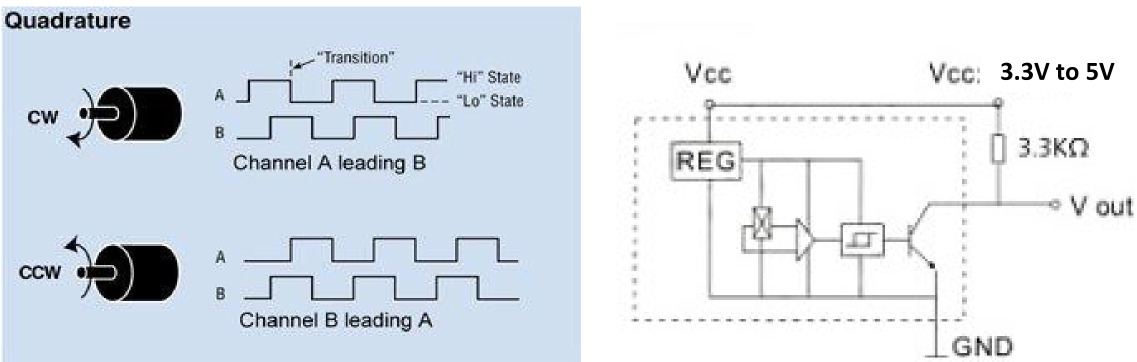


Figure 5. Internal diagram and functionality of the encoder.

References:

https://es.aliexpress.com/item/1005001279982165.html?

3.3 Motor drivers

It is proposed to use the L298N non-linear integrated amplifier for driving two small DC motors. This is a device that incorporates a double H-bridge (with bipolar transistors) that, when connected to a motor, allows its speed and direction to be modified.

As shown in the block diagram in Figure 6, each of the bridges A and B uses 3 control digital inputs: an enable one (En), and two digital ones (Inx) to drive branch x.

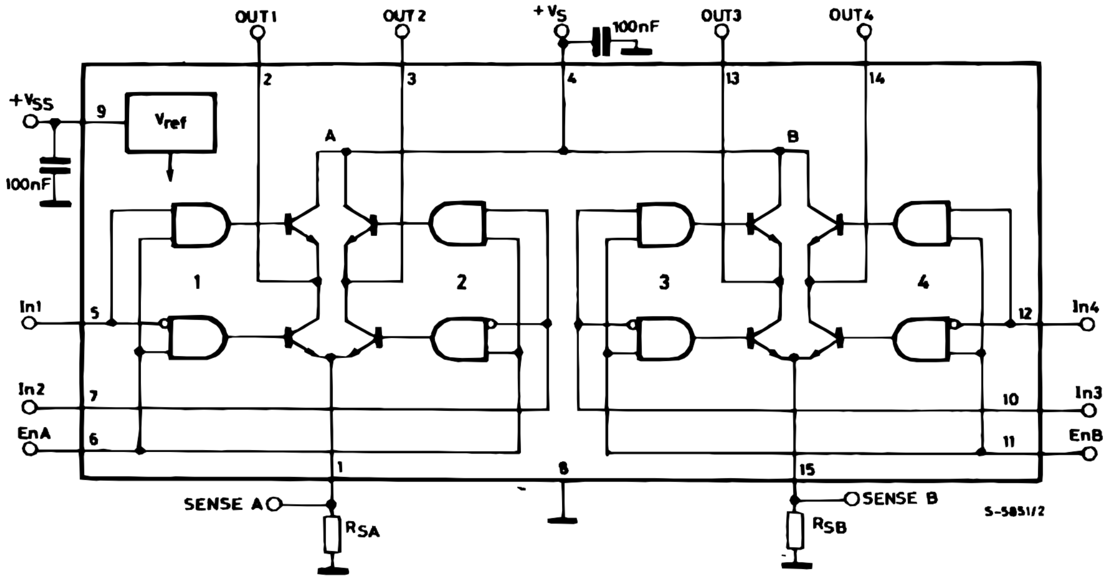
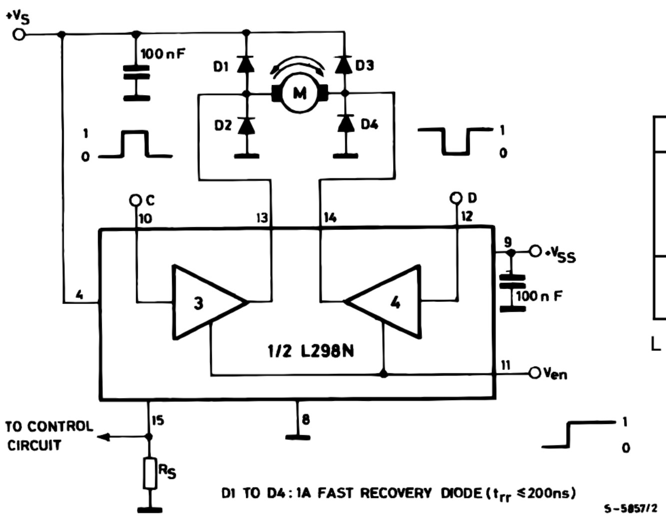


Figure 6. Internal diagram of the non-linear amplifier L298N.

Enable input (EnA and EnB) enables the bridge transistors, so that if it is set to low level, all transistors will remain off and therefore the motor will not be powered (regardless the value of Inx). On the other hand, if the bridge is enabled (EnA or EnB at high level), setting the Inx input to high level will conduct the upper transistor of the associated branch and setting it to low level, the lower one.

Therefore, to drive the motor, the pair of Inx must take complementary values, so that if In1 is high and In2 is low, the motor will rotate in one direction (e.g. clockwise or forward), similarly, if In1 is set to low and In2 is high, the motor will rotate in the other direction (e.g. counterclockwise or reverse). In fact, if both Inx signals have the same value the motor is short-circuited, causing it to stop quickly.

Figure 7 shows one bridge operation with the corresponding truth table.



Inputs		Function
V_{en} = H	C = H ; D = L	Forward
	C = L ; D = H	Reverse
	C = D	Fast Motor Stop
V_{en} = L	C = X ; D = X	Free Running Motor Stop

L = Low H = High X = Don't care

Figure 7. H-bridge operation with its inputs' truth table.

As the motor DC speed is proportional to the voltage across its terminals (in our case rpm/V) and considering that a non-linear amplifier is used, in order to modify the voltage applied to the motor a PWM (Pulse Width Modulation) signal is used, so that the percentage of the amplifier power V_S driven to the motor is encoded in the PWM signal duty cycle, while its period can remain constant. Therefore, the power driven to the motor and thus its speed will be proportional to the PWM signal mean value, i.e. its duty cycle d, $V_{motor} = d \cdot V_S$.

Thanks to the explained behavior, H-bridge driving with a PWM can be performed in two different ways:

- By inserting a PWM signal through Enx to set the motor speed, and use Inx to set its direction.
- By setting Enx to high, inserting a PWM signal through one of Inx signals to set the motor speed and use the other Inx signal to set its direction.

In the last case, it must be considered that, when changing motor direction, the PWM signal must be complemented to get the same speed. Figure 8 describes graphically such last functionality.

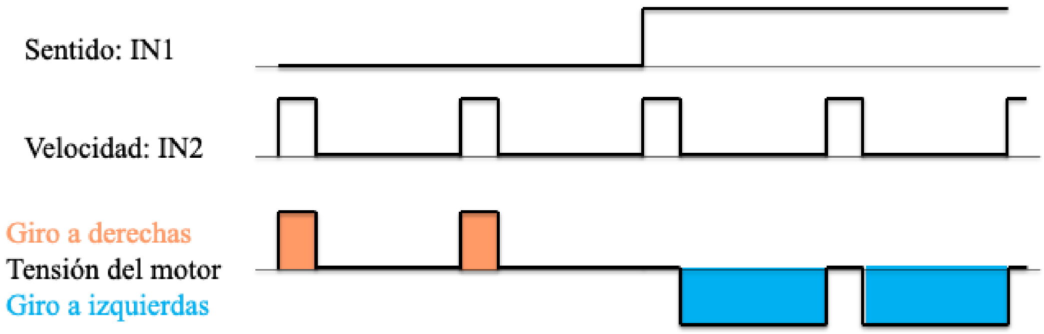


Figure 8. Diagram of H-bridge drive in this application, with Enx set to high, and with IN1 and IN2 to set speed and direction.

H-bridges are also manufactured within modules that include connectors and passive components to facilitate its use. Figure 9 shows the one proposed to be used in this project, based on a L298N, with its schematics. Moreover, its main electrical features can also be found below

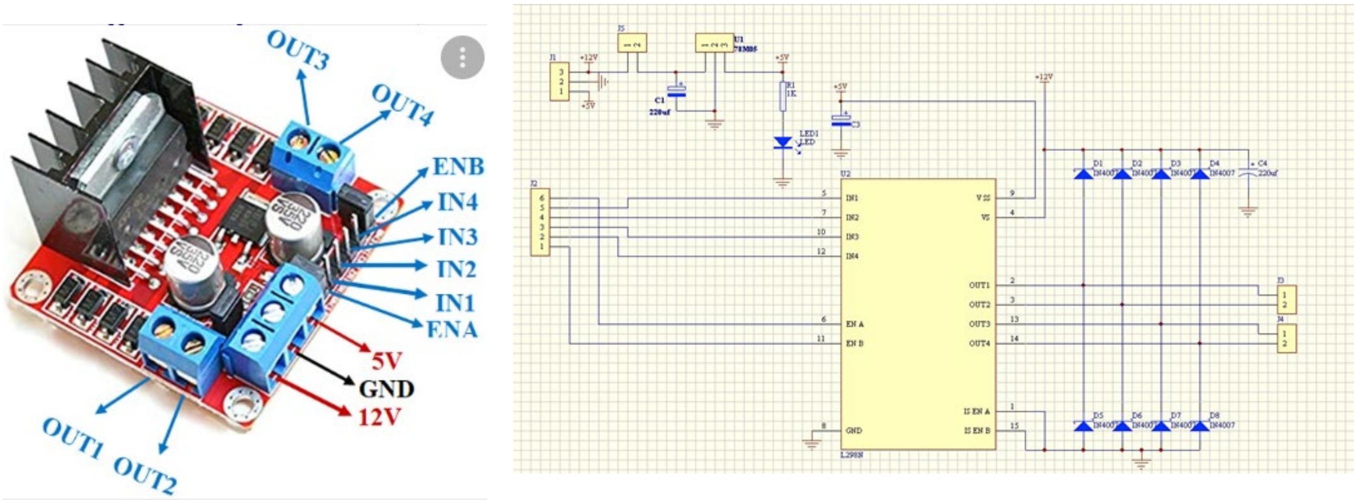


Figure 9. L298N module: physical appearance and schematic.

Referencias:
https://es.aliexpress.com/item/1005004177699678.html?

Features & Specifications

- Driver Model: L298N 2A
- Driver Chip: Double H Bridge L298N
- Motor Supply Voltage (Maximum): 46V
- Motor Supply Current (Maximum): 2A
- Logic Voltage: 5V
- Driver Voltage: 5-35V
- Driver Current:2A
- Logical Current:0-36mA
- Maximum Power (W): 25W
- Current Sense for each motor
- Heatsink for better performance
- Power-On LED indicator

3.4 Audio amplifier and speaker

To reproduce an acoustic alarm signal when the temperature exceeds a certain threshold, it is necessary to generate a sinusoidal signal (a tone) within the audible spectrum that excites a speaker. This waveform can be easily generated by a DAC (e.g. the one included in the microcontroller) but this output cannot provide the necessary power to generate an audible signal in a speaker, as it demands a high current, so an amplifier will be needed that can provide more current before applying it to the speaker.

To do this, a power operational amplifier can be used that has adequate bandwidth (audible spectrum) and can provide the output current necessary to drive a speaker with a low impedance (typically 4Ω or 8Ω). An interesting alternative power amplifier in the audio band is the LM386, a linear one of class AB. In addition, there are PCBs that incorporate this chip, such as that shown in Figure 10, which facilitates assembly.

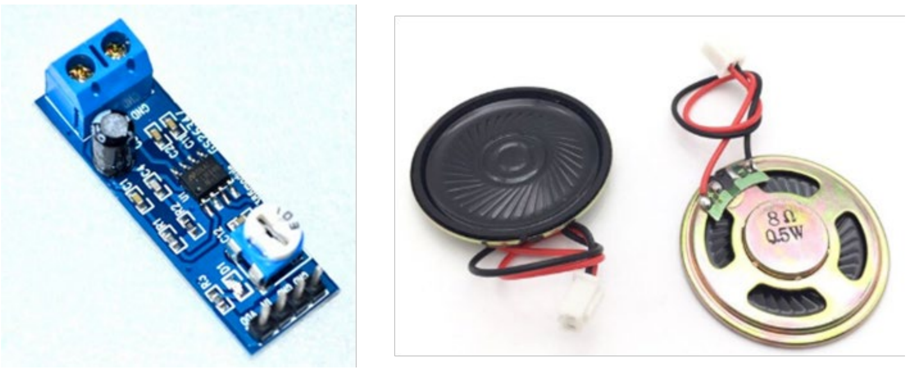


Figure 10. Audio amplifier in PCB based on the LM386 (left) and speaker (center and right).

Another type of amplifier of interest that, due to its low cost and high performance (being a class D) can be used to attack a speaker of this type, is the PAM8402. For the latter, there are also PCBs on which the amplifier is already mounted to facilitate wiring, since it is a surface mount or SMD chip. Figure 11 shows an example of a PCB with this PAM8402 amplifier and another with the PAM8303 (its stereo version).

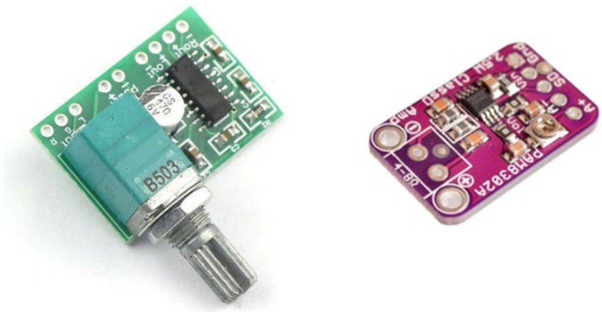


Figure 11. Audio amplifier in PCB based on the PAM8403 (stereo, left) and PAM8302 (mono, right)

References:

https://www.ti.com/lit/ds/symlink/lm386.pdf?ts=1636985530144&ref_url=https%253A%252F%252Fwww.google.com%252F
https://www.electrosmash.com/es/analisis-lm386
https://amplificadores.info/amplificadores-de-audio/lm386
https://es.aliexpress.com/item/32686434452.html
https://es.aliexpress.com/item/1084746279.html
https://es.aliexpress.com/item/32923423569.html

3.5 Graphical display (HY28A/B)

The 2.8" display module HY28A/B is the graphical TFT color touchscreen display included in the Mini-DK2. Its resolution is 320x240 pixels and its functionality is based on the ILI9320/5 controller.

The module is sold mounted on a PCB that incorporates the touch interface circuits (XPT2046) and the backlight in two 20-pin connectors. The Mini-DK2 card incorporates 2 sockets to connect the module.

There are two ways to use the display controller: with a 16-bit parallel bus, through a SPI interface, being the main differences between them the number of microcontroller pins that are necessary in each case and the data update rate, i.e. with the SPI interface fewer pins are required but data transfers are slower.

The appearance of the HY28A module and its connection diagram to the Mini-DK2 are shown in Figure 12.

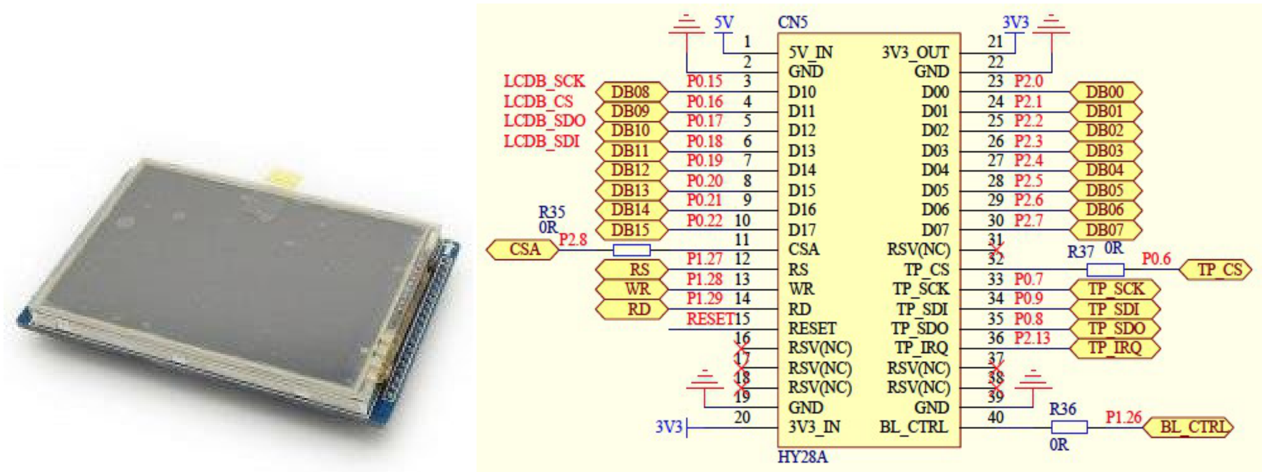


Figure 12. Graphical display HY28A/B and its connection diagram to Mini-DK2.

References:
http://www.hotmcu.com/28-touch-screen-tft-lcd-with-all-interface-p-63.html?cPath=6_16

3.6 Bluetooth to serial port adapter

The HC06 (or HC05) module is widely used to provide Bluetooth connectivity to a microcontroller via one of its asynchronous serial ports. The module has two operating modes, one for configuration and other for data transfers, that are selected with a control signal when connecting the power (Figure 15). The iOS compatible version is the HM-10.

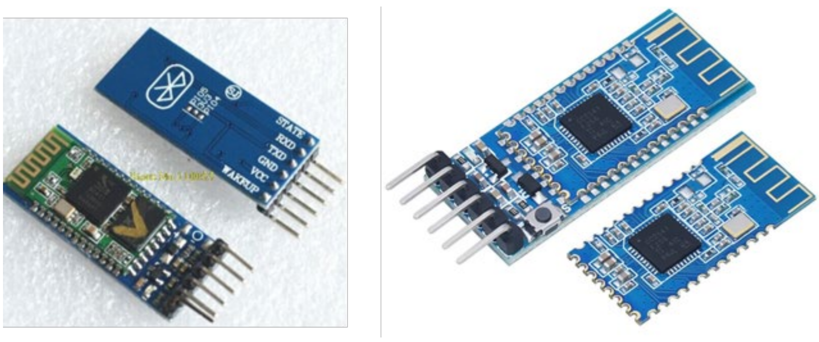


Figure 15. External appearance of the HC06 (left) and HM-10 (right) modules.

References:
https://es.aliexpress.com/store/product/HC-06-paso-a-trav-s-de-serie-Bluetooth-inal-mbrica-del-m-dulo-de-comunicaci/1326062_32857133517.html
https://es.aliexpress.com/item/32826166129.html

4 BUILDING THE PROJECT

The project should be carried out in pairs of students (or individually) whose evolution in the design of the system, through milestones and a final integration, will be evaluated in the laboratory (continuous assessment) and in a final test.

4.1 Project planning

To follow a work plan in which the implementation of the whole system will be addressed, it is proposed a set of guidelines or milestones to break down the entire project into several parts and gradually achieve the operation of the different parts in a modular fashion.

HW/SW development	Weeks
Designing the system. Block diagram indicating optimal LPC1768 resources use in Mini-DK2. Keil environment for programming and debugging.	2
1st Millestone: Driving motors. Generation of PWM signals to move motors in different directions. **Non-holonomic movements, non-straight turns, reverse movement.**	3
3rd Millestone: Measuring robot movements. Distance and path monitoring based on the encoder reading with TIMERs and GPIOs.	2
2nd Millestone: Analog inputs/outputs. ADC configuration and reading for monitoring power supply from battery. Generation of acoustic alarm with DAC. **Variable acoustic signal.**	2
4th Millestone: Asynchronous Serial Communications. Programming and monitoring the sequence of movements through the UART0. **Movements sequence sent via Bluetooth. Measuring ambience variables from a serial port.**	2
Software integration.	2

4.2 Project assessment

Thus, upon completion of the project a final face-to-face evaluation will be taken to assess the operation and design of the proposed solution. Moreover, the students must write a technical documentation describing the operation and limitations of the system, allowing a qualified person to build the entire system and make any hardware or software modifications on it.

This way, three tools will be considered in order to assess the project: **continuous assessment, face-to-face evaluation and project report**.

*A*s a sum of these three tools, completing the mandatory sections will provide the **70% of the laboratory grade.** The remaining optional sections may contribute with the remaining the 30% (each one with a 10%):

- Non-holonomic movements, non-straight turns, reverse movement.
- Variable acoustic signal.
- Movement sequence sent via Bluetooth.
- Measuring ambience variables from a serial port.
- Other improvements to be agreed with professors.

Obtaining the maximum score will depend on the **degree of achievement, correct functioning, quality of the report, clarity of the presentation, etc.**

4.3 Project report

The report must contain (at least) the following sections:

1. Cover: specifying the name of the group members.
2. Page index.
3. Introduction: brief description of the objectives and explanation of the complete system designed.
4. Hardware description:
    a. Block diagram, schematics and device connections duly justified.
    b. Complete schematic of the entire circuit.
5. Software description:
    a. Behavior modeling: Flowchart or state machine to describe the complete software design.
    b. Description of each of the modules (.c files) into which the project is divided.
    c. Description of each of the functions included in each module, explaining at least:
        - The goal of the function and the description of its input and output arguments.
        - Its internal operation when not obvious. Standard software description tools, such as state machines, flowcharts, pseudo code, etc., will be used here again.
        - Global variables used and justification for their use.
6. Conclusions: In this section, the technical ideas deduced after carrying out the practice must be described. Those aspects not foreseen at the beginning of the practice must be included, such as, for example: deviations of any of the components with respect to the theoretical behavior or the description provided by the manufacturer, etc. It cannot be limited in any case to a mere summary of the practice carried out or a simple subjective description of the degree of satisfaction obtained from carrying out said practice.
7. Annexes with commented source code (with CourierNew/Consolas font, with a maximum 8p size). It is important to format the code once exported to the document.

It is recommended to use source code editors such as Notepad++, capable of exporting the copied source code in rich text format (RTF). This allows the syntax highlighting of the source code to be maintained when pasted.

4.4 Project final assessment

The final project face-to-face evaluation will take place on a date proposed by the teachers.

Prior to the date of evaluation, students must send the technical report and the software project to their teacher. This documentation should match that presented on the evaluation day, or, if necessary, students shall indicate the added amendments to the professors on the evaluation day.

The day of the assessment all group members must give a presentation of their project to be assessed by the professors. The presentation can be given either individually or by the two group members, so that they can explain their project and answer questions asked by the professors.