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TOUCH SCREEN DEMO BOARD PROJECT

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ABSTRACT

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ABSTRACT

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This thesis work contains the planning of the demo board for the resistive panel type and also includes the schematic work for it. Usage in different environment is also studied to assess the behavior in real world usage. All common disturbances are included in the demo board feature list or at least the capability to create or add them is added. Software to demonstrate it on a PC display is also included

The resistive panel type was used due to it being cheap to manufacture and robust in use. It does not support the multi-touch but the users do not normally need that feature. The target of this project was to make a working demo board for a customer to study the resistive touch screen controller. It gave the opportunity to test it in real life and also allowed the customer to connect their own resistive panel. During the project, many new features were added in order to stress test the board and measure its real performance**.** A good overview was gained on how the different parameters affected the performance.

As the project progressed, many problems and drawbacks were encountered, but in the end, all of the obstacles were overcome. All the blocks that were designed for the demo board were tested with a real circuit. When the project was ready to enter the production phase, the actual printed circuit boards were ready to be orderd. Unfortunately, the project was canceled due to changing priorities and it never went into production.

1 INTRODUCTION

1.1 Touch screen panel types

The most common types of touch screens are resistive and capacitive. Both screen types have their own advantages. The capacitive screen is more expensive and can accept several fingers at the same time and can still follow each finger touch individually. A good touch requires a finger or a similar touch that can act like a finger. A capacitive panel type became familiar to the users after mobile manufactures started to use it in expensive phone models. The resistive panel is cheap and accepts only one touch at a time. A touch can be made by using a finger or anything which has a sharp enough edge. This hard touch can also destroy the panel. The resistive panel type was used in earlier and cheaper mobile phones.

1.2 Scope of this work

This thesis work contains the planning of the demo board for the resistive panel type and also includes the schematic work for it. Usage in different environment is also studied to assess the behavior in real world usage. All common disturbances are included in the demo board feature list or at least the capability to create or add them is added. Software to demonstrate it on a PC display is also included.

2 PLANNING OF THE DEMO BOARD

This chapter describes background of the project plan.

2.1 Purpose of the demo board

The main target of the demo board was to give the customer the possibility to test ST-Ericsson's new resistive touch screen controller with different pre-selected touch panels. It also has built in possibilities to test how it works in different kind of environments.

2.2 Demo board requirements

When starting to collect requirements for the demo board, it was already known in the beginning that the requirement list is going to grow during the planning and building phases. A list was compiled after a long study and also added to during the project. The requirement list started as follows:

1. Transient is coming from battery lines
    - This phenomenon is always present when there are other active devices connected to the same battery line.
2. Noise is present in all environments
    - All possible noise sources must be studied to understand what kind of disturbances there are in a mobile phone which seems to be the worst environment to use the touch screen. Modern mobile phone has small distances between active components and there are a many radiating components.
3. Drawing is the most important feature.
    - This is the most important feature because the customer can see what is happening.
4. Haptic feedback was needed to give fast feedback to the user that the touch has been recognized.

- When a touch is detected, the user can have immediate feedback that something is happening. The size of the haptic feedback is not so important.

5. The oscilloscope feature was needed to demonstrate to the customer what kind of noise signals was fed to the measurement and battery lines. The results can be seen immediately on the display.
6. I2C was needed to control the touch screen controller
   - Communication between the microcontroller and the touch screen controller is done with I2C. Read and write capabilities are required.
7. Usability
   - All errors and instability creates a need to explain why it did not work. To avoid this, testing must be comprehensive.
8. Possibility to get X,Y coordinate list (save)
   - The touch screen controller has a feature to use averaging when drawing is in use. With less averaging, the noise increases and with longer averaging the noise decreases. Averaging can be also done in the mobile phone but this used more computing power and that is why it is integrated into the touch screen controller.
9. Writing / reading register values
   - To avoid the situation where the customer is only reading manuals, the most important features are integrated with the PC's control panel.
10. Possibility to have default settings
    - This makes the starting easier and a secure feeling that everything works.
11. Only USB connector in use. No external power supplies or clock generators.
    - When the customer has the controller in their hands, no extra power supplies are required. This is to make the demo trials easier.
12. Possibility to connect different kind of touch panels
    - The Controller is not tied to only one panel. If the customer has their own special size and type panel, it is easy to connect to the

demo board. Different kinds of connectors are required to fulfill this requirement.

13. Signals and power supplies for the touch screen controller
    - The touch screen controller requires
        - 32768 Hz and 3.2 MHz clock signals with 1.8V amplitude
        - Power supplies 1.8V, 3.6V and 5V
14. Current consumption
    - According to the USB standard, maximum current consumption without hand shaking is only 100mA. In this case hand shaking is done by the MBED micro controller and after that maximum current consumption is 500mA. Short spikes which go over that limit are allowed if they are less than 800mA and take that amount of current less than 1 millisecond long.
15. Software
    - All features in this demo board need software to work properly. The required software must be easy to use and give a professional feeling to the user.

2.3 Work environment

Most of the studies and testing were done with an earlier demo board which was using a digital interface card and several external power supplies. In addition, all of the required clock signals were done with clock generators. The size and complexity of the environment meant it was too difficult to transport. All hardware blocks were tested in practice to minimize the risk when a real PWB was done.

The Schematics were done with ORCAD software. All of the demo board schematics were delivered in the pdf format to allow further copies for the printing should the originals be misplaced.

3 DISTURBANCES IN ENVIRONMENT

Most of the disturbance signals in a mobile phone can be classified as one of three kinds of signal types. These types are sinus, square and glitch based disturbances. These signals are emitted to a circuit and tested in three different ways. The first method is when the disturbance signals are emitted directly to the touch screen panel. One of the biggest creators of these signals is lighting and other electronic devices which have a transformer, though they can also come from power supply lines. These signals are attenuated signals because transients from the regulator’s output are not so big. Typically these are less than 30mV. Both sinus and glitches are possible waveforms in this case. The last method is disturbance coming from the battery line. These transients are bigger changes in line transient means and also strong glitches are then possible. Lighting causes big transients when they are turned on. Glitches can be more than 500 mV and line transients can be up to 300mV. Typically these line transients are visible when a charger is connected to device. When planning stimuli for disturbance measurements, these frequencies should be tested as known frequencies to avoid future problems. In addition, 10 different frequencies per decade should be tested to get a good enough idea about the quality of the design.

3.1 Sinus signals

Sinus based signals are common in all devices that are used in buildings or from devices with a power supply connected to a normal power line. Frequencies for these signals are 50 Hz in most of the European countries and 60 Hz in American countries. Also, a few harmonics (100 & 120 Hz) are often present. Frequencies in the 50 and 60 Hz range are normally caused by normal wall chargers and lighting. These two signals differ from other signals because these are sinus signals.

3.2 Square signals

Square based signals are mostly generated inside the device and the main source for these are different kinds of clocks or data lines. In this case, we do not concentrate on fast signals or fast data rates. One common signal should be tested and that would be the real time clock (RTC). Its frequency is 32768 Hz and all frequencies inside the device are based on that. When a device is battery based device which has a charger property it is common to use a slow PWM controlled charger to avoid the battery overheating. The frequency for this PWM is roughly 1.14Hz. In mobile phone environments there is also a GSM burst present. The Speed of this disturbance signal is 217 Hz. A square type signal with 300 mV amplitude change is called a line transient.

The 1.14 Hz disturbance signal is created by the charger. This situation occurs at the “end of charging” when the battery is almost full or when the battery temperature is rising too much. This will cause up to 300 mV changes in the battery voltage level. In figure 1 is example of the battery line during end of charging state. Both rising and falling times are about 0.8 milliseconds. Falling and rising type signals are tested with a sinus shape and levels are tested with square signal.

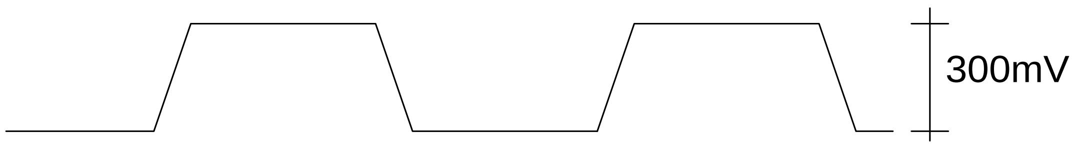

FIGURE 1. Line transient in mobile phone battery line

The SMPS ripple is shown in the figure 2. The period for this signal depends on the load current and size of the output capacitance. The ripple size is about 5-20 mV fast rise and slow ramp back to start point. Normally this is visible when the device current consumption is low. The rise edge is more critical than the falling slope. This signal type will be tested with a square signal. The signal is added to a Vcc level signal. In FIGURE **2**. SMPS regulator output ripple.

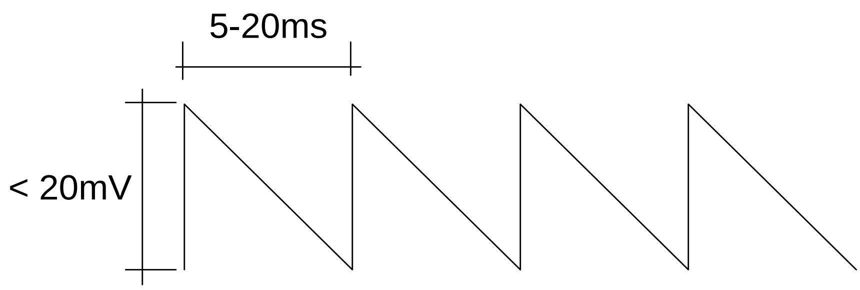

FIGURE 2. SMPS regulator output ripple

3.3 Glitch signals

Glitch based signals are come from square type signals. When clock edge is emitted from one line to another line, it is called crosstalk based disturbance. These glitches are also tested when testing square signals.

A 128 /256 Hz signal is emitted from the LED driver if the single coil technique is under use. The same coil is used for the keyboard and display branches. This is making a big current change if different amount of energy is used in the branches. This phenomenon is visible because it is using the same capacitance in output. If the display is using a 4 led combination and the keyboard has 2 leds, then the voltage level in the display branch is 14V and 7v in the keyboard branch. This difference always causes a glitch when the branch is changed. This basic frequency is also used in light dimmer switches. This will cause glitch in the battery. This PWM can be selectable due to the sensitivity of the display panel.

A 217 Hz signal can be found when GSM is in use. Because many of the digital ports are synchronized to the same clock, many of the ports are consuming energy at the same time. This causes glitches upwards and downwards.

32768 Hz is emitted by the real time clock. This signal is also routed to several IC’s to give the same clock to the state machine. Many times too aggressive rise and fall times can be seen in all regulators due to the internal spread in references. All type signals must be tested with this frequency.

4 TEST ENVIRONMENT

All needed blocks and devices are carefully planned to fulfill requirements. This project is basically divided in two different parts: hardware and software. The software is subdivided into three parts: the computer software, software to control the devices on the circuit board and software for the touch screen controller.

4.1 Test board

After a requirement list was created, it was easy to plan what kind of electrical block was needed to fulfill requirements. The possibility of using the same block for several purposes was also studied. Some requirements could be fulfilled with software.

The list of the different required blocks was as follows:

- Waveform generator
- Amplitude control
- Buffering
- Haptic feedback connector

The PWB requirements were as follows:

- All components are placed in top side.
- Holes in all corners for support.
- Silkscreen marking for all components to help the customer connect the right signals easier and to avoid wrong connections.

4.1.1 Programmable waveform generator

A waveform generator is needed to create the three different kinds of signals for noise creation purposes. The selected generator from Analog Devices, AD9833 IC (6) is made to output three different kinds of signals, Sinus, triangle and clock. The frequency is freely programmable by using the SPI protocol. The resolution is 10 bit and the frequency area is up to 1.6Mhz with a 3.2MHz clock frequency. The operating voltage is 2.3V to 5.5V. Because the output of the waveform generator is not adjustable, there was a need to use an external solution. The schematic is shown in the figure 3.

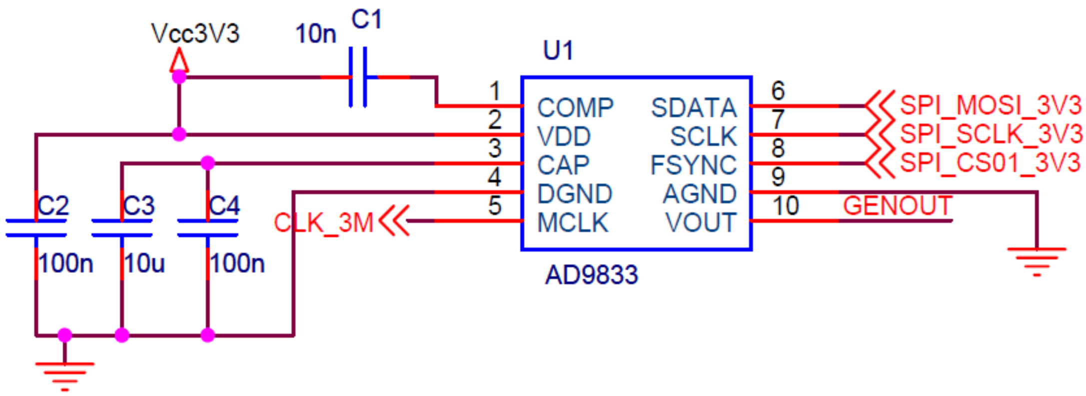

FIGURE 3. Waveform generator circuit.

Current consumption according to the specification is a maximum of 5.5 mA with a 25 MHz system clock. In this case, only 3.2MHz is used for the clock and the current consumption with a lower clock speed is less than 5.5mA. In the total current consumption calculations 5 mA is used to avoid problems.

4.1.2 Clock generator for 3.2MHz

FIGURE **4**. Oscillator for 3M2 clock and how the demo board main clock is done. The component values are selected according to the crystal in use. The oscillator chip includes strong buffering and the output voltage is according to VCC1V8. The schematic component values for other components are based on the manufacturer's recommendations (7).

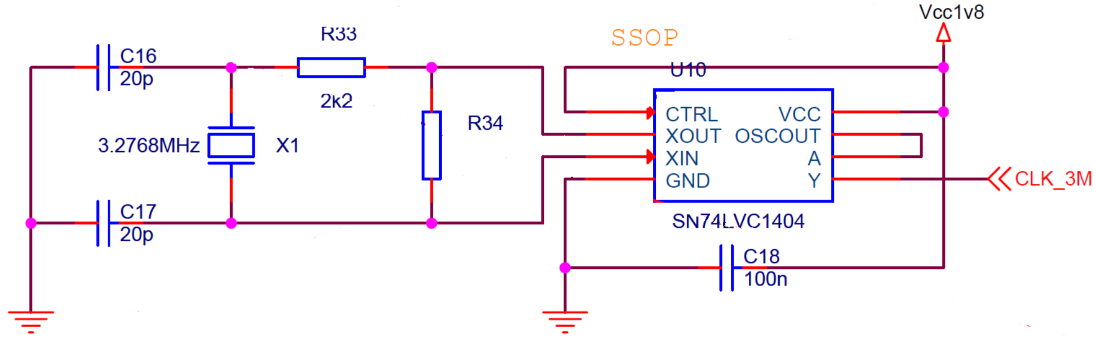

FIGURE 4. Oscillator for 3M2 clock

4.1.3 Clock generator for 32768 Hz real-time clock

The touch screen controller requires a real time clock as an input. The easiest way to make this signal was to use a real RTC component for it. There were only a few requirements. The clock edge must be fast enough, output should be 1.8Vpp and low current consumption. STCL132KR (8) made by STM was found to be good enough for this purpose. It is made to use 1.65V to 1.95V, and the output is 1.8Vpp. The rise and fall time is 10 ns. Only one external component was required to guarantee the proper work for the circuit. In addition the small form factor was a positive feature for layout purposes. As there was no requirement to stop the clock, the CE pin was pulled to VCC. To provide the possibility of stopping the clock, a resistor was connected between CE and VCC. The size of the capacitor between VCC and GND was copied from the datasheet. Figure 5 illustrates the circuit for the real time clock.

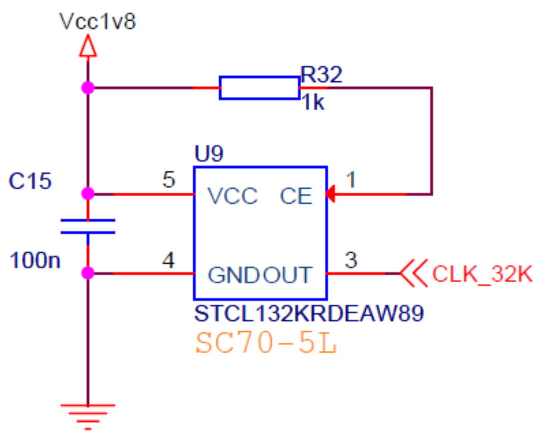

FIGURE 5. 32 kHz real-time clock circuit.

4.1.4 Analog switch

When looking for the right solution for an analog multiplexer, it was known at the start that low ON resistance was needed to give the opportunity to put extra filtering capacitance between the analog switch and the buffer if needed. After investigation, ADG706BRUZ (9) from Analog Devices was found. The features were good enough to add it to the test board. It had an operating voltage with single supply levels from 1.8V to 5.5V. It also had the needed 16 channels with low ON 2.5 ohm resistance. To control analog switch positions, all controls from A0 to A3 were connected to the microcontroller. The Enable signal (EN) could be connected directly to 3.3V to enable the circuit. The OFF state was not needed in this project. Required voltage levels for control lines were suitable without modifications. Figure 6 is the circuit for amplitude adjustment.

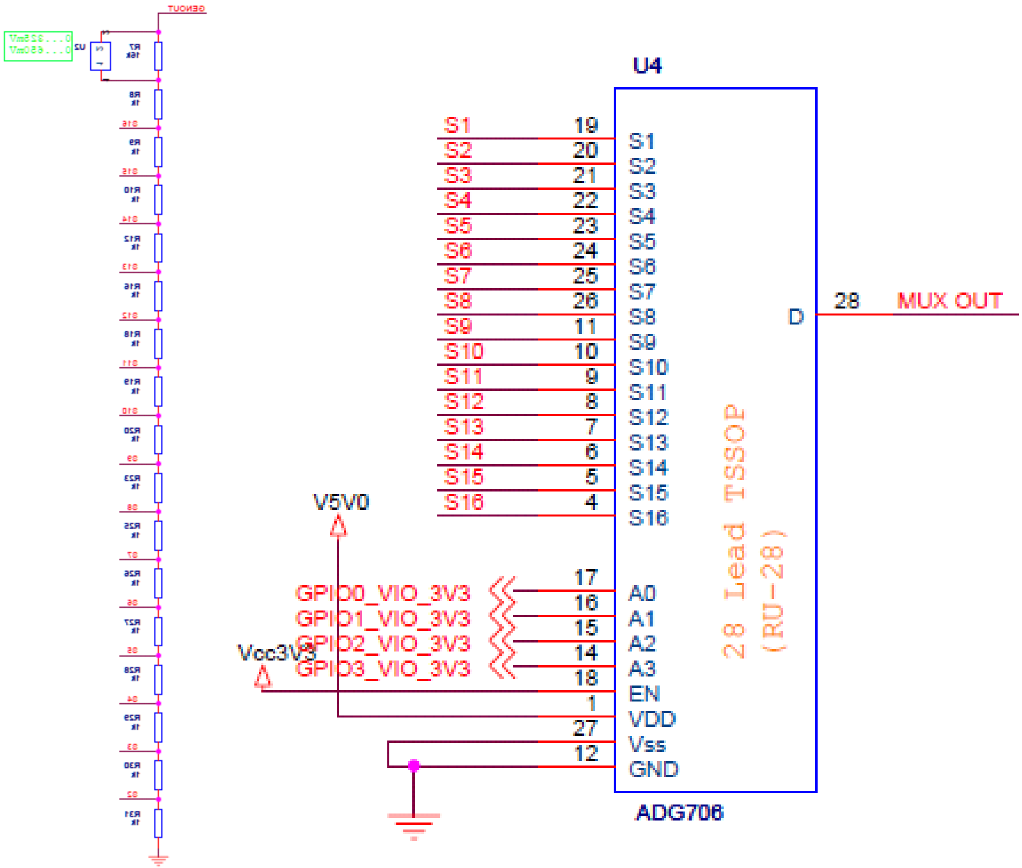

FIGURE 6. Analog multiplexer to adjust amplitude.

The resistors in the ladder are in serial and the size is 1kohm. There are 16 resistors in total. This give a 16 kohm load resistance to the waveform generator. Because the generator's output voltage is not adjustable, the maximum load is 650mV/16 komh = 41 uA. The multiplexer current consumption according specification is 1 uA.

The size of the smallest voltage adjustment step is 650mV /16 = 41mV

4.1.5 Operational amplifier

The requirements for the buffer were to have compatibility with a 5V power supply and to have as high as possible rail to rail capability. After a long search, the AD8018 (10) was found. It could drive the output to VCC- to 160mV with a small load. Output current can be 400mA and short circuit protection is 1A. Because the waveform generator was giving output voltages from 0mV to 650mV, an offset was needed. To avoid the buffer going too low and cutting the signal, an offset of more than 500mV was used. The easiest way make this offset is to use the diode's forward voltage property. In FIGURE 7. Operational amplifier as a buffer with offset shows how the amplifier is inserted into the schematics. Current is (5V -0.6V)/10kohm = 450uA. The selected operational amplifier takes a maximum of 10mA when driving rail to rail with 100MHz. In this case all 10mA are taken into the current calculation.

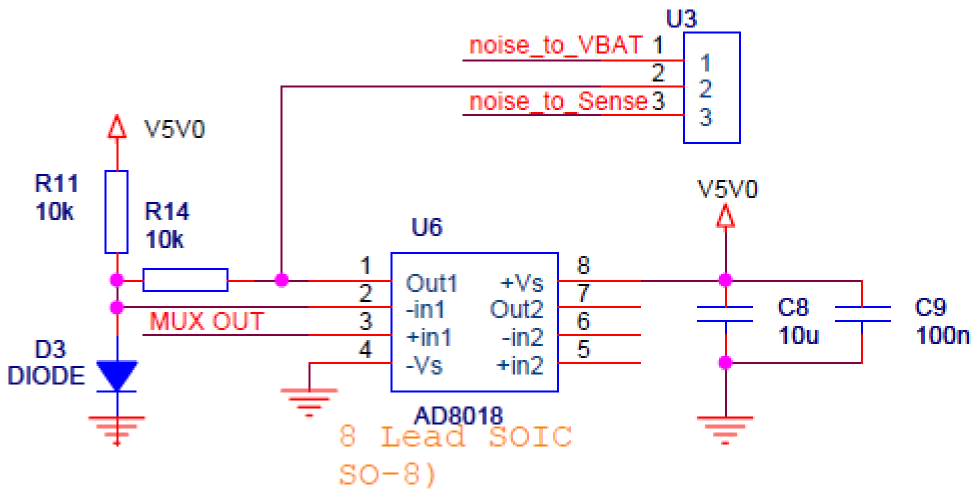

FIGURE 7. Operational amplifier as a buffer with offset

4.1.6 Line transient circuit

In FIGURE **8**. VBAT noise circuit, named noise_to_VBAT is connected to the LM217's feedback line thru C6. Capacitor C10 is connected to ground to give the same resistance as that in C6. Resistance is calculated by using the formula R=1/(2*Pi*f*C). In this case for one capacitor it gives 733 ohm with 217 Hz frequency and 5 ohm with 32768 Hz. Because the voltage level in the noise_to_VBAT line can rise up to 1.3V, it gives the current 1.3V/10 ohm = 130 mA. This calculated current gives requirement for buffer which drives the noise_to_VBAT line in the noise block. Resistors R13 and R17 are giving a basic voltage level for regulation. The formula to calculate the correct resistance values for these two resistors is from the LM217 datasheet. Because this connection gives transients to the VBAT_noise line, voltage level can rise up to the calculated value + transient. Because the LM217 does not have the feature to sink current, extra load was added to avoid the situation when a transient appears so that voltage levels stays high until the load is sinking extra power from the transient line.

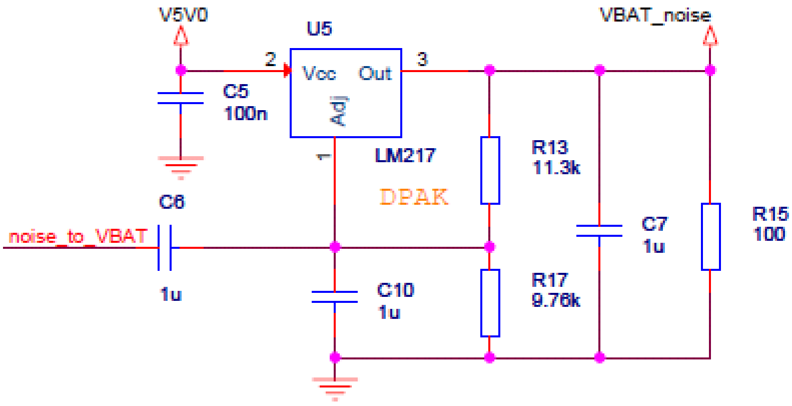

FIGURE 8. VBAT noise circuit

4.1.7 Haptic feedback motor

The Demo board is equipped with a connector that will give the opportunity to connect an external haptic feedback motor. The maximum load current is limited by the MBED and it is 50 mA. The motor is located in a small box and purpose is that, when the user holds it in same hand as that used to touch screen, it will use the motor for 20 milliseconds to give instant feedback that a screen touch has been detected.

4.1.8 Total current consumption

The current consumption in each block shows that it fits within the USB requirements without any problems. All current calculations are based on the worst case scenarios to make sure that there is no problem with power consumption. USB standards give the possibility to take 500 mA from USB port if no other high current device is connected at the same time to the same USB port. In table is current consumption estimates.

TABLE 1. Current consumption

Block	**current consumption [mA]**	**Power consumption [mW]**
VBAT indicator LED	2	10
VIO indicator LED	2	10
Waveform generator	5	25
Operational amplifier	10	50
Offset circuit for it	0.45	2.25
Latter for mux	1	5
Multiplexer	0.001	0.005
VBAT noise amplifier	1	5
load for it	30	150
Sense line amplifier	1	5
load for it	30	150
32kHz oscillator	0.8	4
3.2MHz oscillator	1	5
Regulator for 1v8	0.55	2.75
Regulator for 3v3	1	5
I2C level shifter	1	5
MBED controller	100	500
Level shifter for reset	0.004	0.02
total	**186.805**	**934.025**

4.2 FTDI micro controller

(1) The UM232H is a USB-to-serial/FIFO development module in the FTDI product range which utilizes the FT232H USB Hi-Speed (480Mb/s) single-port bridge chip to handle the USB signaling and protocols. The UM232H is ideal for development purposes to quickly prove functionality of adding USB to a target design. The UM232H is a module designed to plug into a standard 0.6” wide 28 pin DIP socket. The USB connection to a host system is via a mini-B USB connector.

FIGURE 9. FTDI microcontroller.

It also provides low level drivers to make I2C and SPI communication easier. All software is runs on a PC and it is not possible to use it without a PC and its software. All communication goes thru the USB port and the SW sees that as a COM port.

All C-code was done with Microsoft Visual C++ environment. The amount of c-code was huge. Several header files and many drivers made the work slow going and caused lots of instability. Finally it was possible make c-code that was capable of I2C writing. Then, another big problem appeared. At the protocol level, the FTDI was not fully compatible with the touch screen controller. The FTDI controllers start signal was 1 ns too short. That error was solved with one small capacitor in the clock line. Communication between the FTDI controller and the touch screen controller was still unstable because of the acknowledgement signal.

After hard debugging it became apparent that the SPI low level driver was not fully compatible with the I2C driver. Both drivers work only on port A. It was discovered that I2C must be located on port A and the SPI on port B. After a long debugging session, it was discovered that both low level drivers are using the same variables which were causing this problem. The only solution was to make new drivers or ask for support from FTDI. A long time was wasted and FTDI answered that “THIS CODE ABOVE IS NO LONGER ACTIVELY SUPPORTED BY FTDI”. After that comment development stopped with FTDI and to find another new solution started. After weeks of studies, MBED was selected. MBED is made by NXP. Their active support was suitable in this case.

4.3 MBED micro controller

MBED is a microcontroller which is designed for rapid prototype use. It has its own dedicated web page where all the users have own work space. In that workspace it is possible to make project. It also contains ready-made low level libraries to help programming. Some of the pins have a special usage to make progress faster.

The microcontroller is normally powered from a USB connector but it is also possible to make it as a standalone device by using the VIN pin. It is also possible to get out a regulated 3.3V from the VOUT pin. All blue pins (5-30) can be used as a digital in or out pin. The light green boxes present the ready-made support for SPI communication. Only chip select is needed to add in that case. Dark blue boxes present ready-made support for I2C communication. Currently only full speed I2C is supported. This will give a 400kbit writing speed. All analog in pins (15 to 20) have 3.3V range and ADC accuracy is 12 bit. Analog out pin number 18 has output voltage levels from 0.0V to 3.3V. The purple marked outputs have a built in PWM controller. The rest of the pins are not used in this demo board. More information can be found from mbed.org web page.

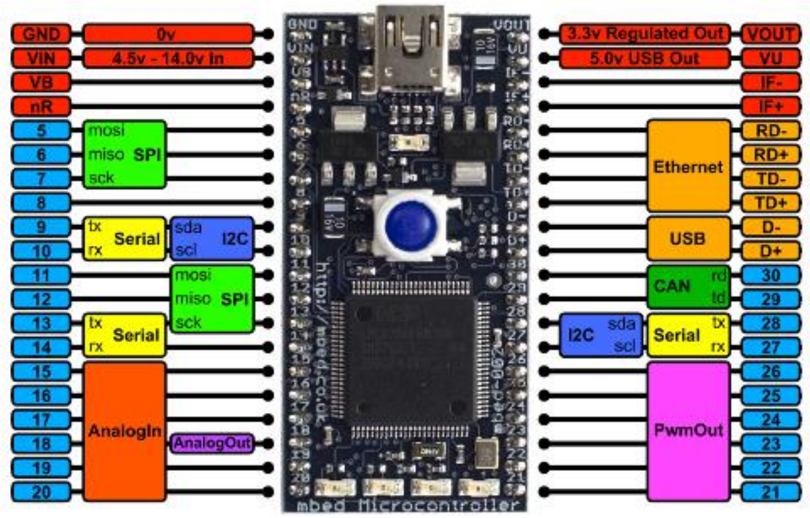

FIGURE 10. MBED microcontrolle pins.

In FIGURE **11**. MBED compiler web page. There is an example code on the web page and it is also compiled there. After successful compilation it gives the opportunity to save the binary file to the MBED if it is connected to a USB port. After saving to the MBED flash drive and resetting, it takes the new code into use. This means that it is possible to make software that runs independently in MBED and does not require PC to run. In that case power supply with +5V must be connected to the VIN pin. Otherwise it uses the USB connector as a power supply. Power supply out-take should be equipped with extra capacitors to filter unwanted noise from power lines that are connected to other IC’s.

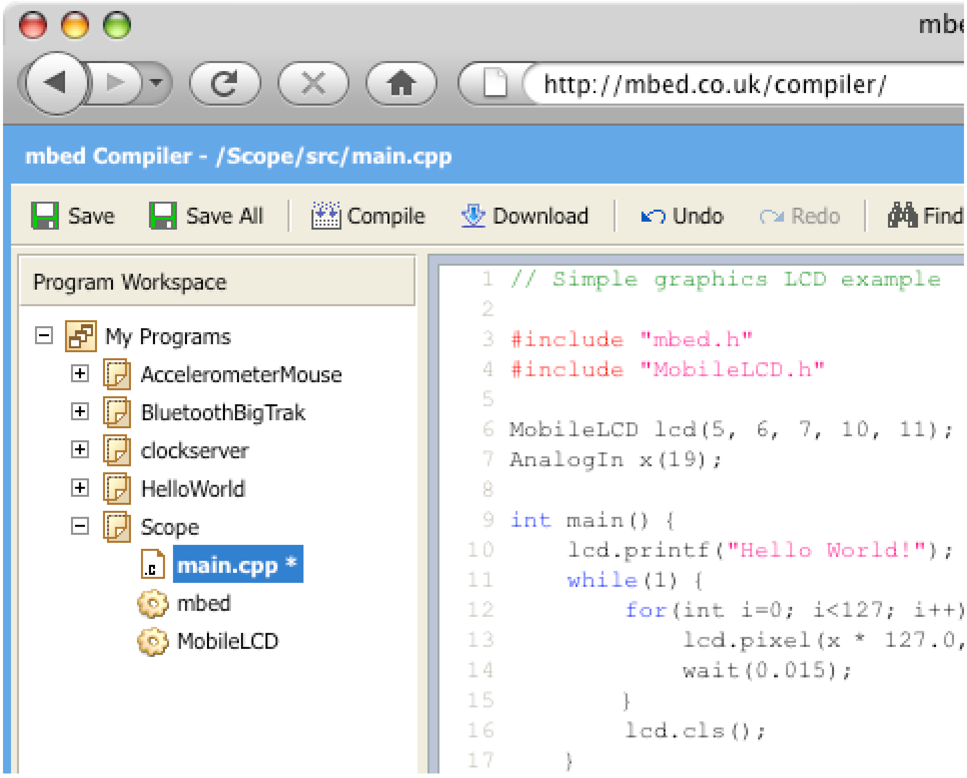

FIGURE 11. MBED compiler web page.

Current consumption in the microcontroller is 100 mA when drawing state is active. This amount of power is needed because I2C readings and writings are active in full speed and results have to be communicated to the labview program.

4.4 LabView

Labview is a graphical programming language made by National Instruments. It is designed to make programming as easy as possible. It uses two different windows. In Labview there is a one window for front panel and the other one for programming.

LabVIEW is different from most other general-purpose programming languages in two major ways. First, G programming is performed by wiring together graphical icons on a diagram, which is then compiled directly to machine code so the computer processors can execute it. While represented graphically instead of with text, G contains the same programming concepts found in most traditional languages. For example, G includes all the standard constructs, such as data types, loops, event handling, variables, recursion, and object-oriented programming - -.(3.)

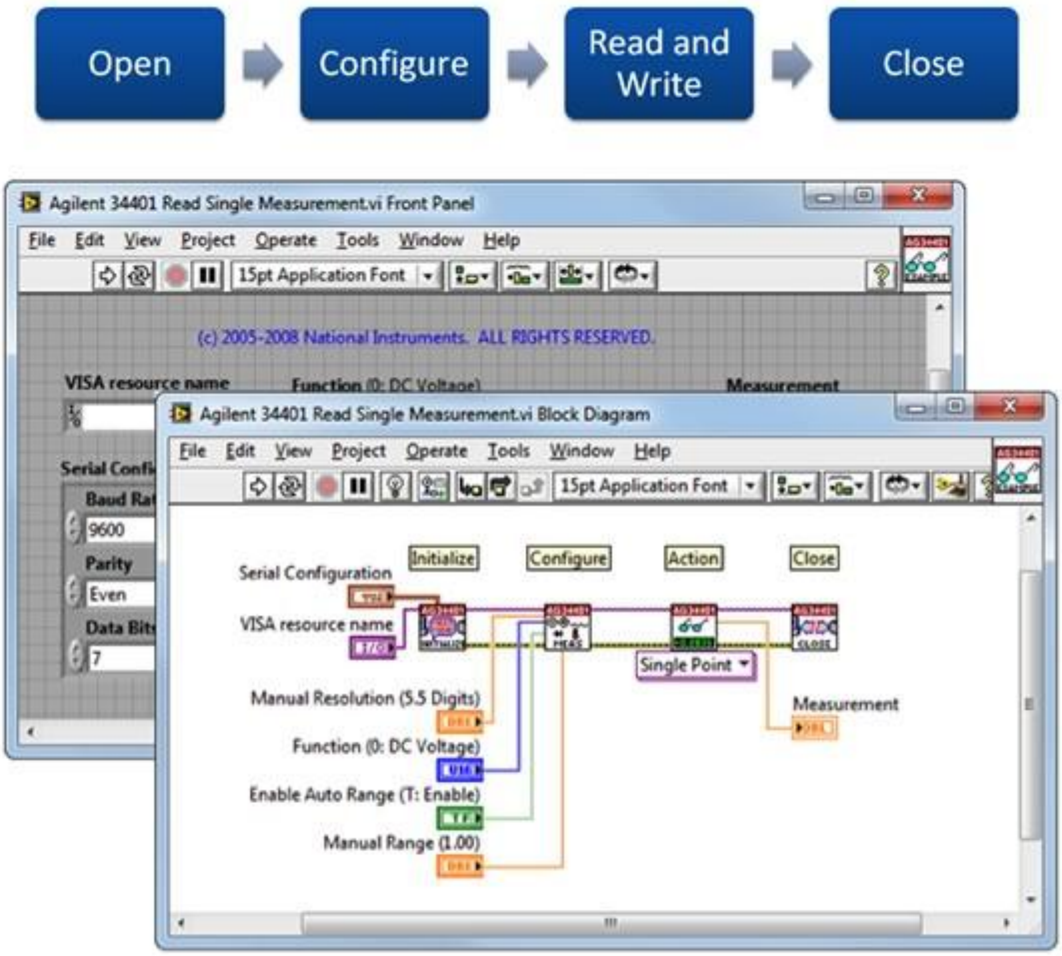

FIGURE 12. A While Loop in G is intuitively represented by a graphical loop, which executes until a stop condition is met

In addition to the data acquisition hardware, NI also offers other special test, measurement and control hardware. The modular instruments synchronize measurements, signal generation, radio frequency (RF) and switching components for automated test systems. The NI programmable automation controllers combine the ruggedness of a PLC and the performance of a PC for industrial measurement and control applications. The vision devices also offer unique capabilities not found in many traditional sensors, such as verifying component positioning, counting physical elements, and reading bar codes. Each hardware type includes its own driver software for easy integration into LabVIEW. The examples include the following:

Digital Multimeters	Switches
High-Speed Digitizers (Oscilloscopes)	Programmable Power Supplies
RF Signal Analyzers	Reconfigurable FPGA I/O
RF Signal Generators	Motion Controllers
Signal Generators	Vision Systems
High-Speed Digital I/O	

The drivers for all of these products were designed with LabVIEW in mind and feature convenient access to all of the available functionality of the hardware. The driver installs directly into LabVIEW and adds new functions to the Functions Palette so no time is wasted locating and including support for the hardware. NI device drivers generally implement advanced features such as device name aliases and hardware simulation, and therefore one can develop software without tying oneself to a particular device. As long as device supports the same functionality, the driver can adapt to the new device, even if the underlying technology changed dramatically, such as when moving from a PCI-based data acquisition device to a wireless device.

When transferring the Labview program to the customer for evaluation purposes it is not good idea to send the actual code to them. In these cases NI has developed a different environment which can easily be transferred to customers. There is a runtime environment driver which can download from NI web pages free of charge. From the Labview developing program it is possible to make a runtime.exe program which can then be delivered. When making runtime.exe it also possible to select from options if the runtime environment is taken into the package. This option increase the size of the package quite a much and to avoid too large a package size it is wise to remove the runtime environment a way and give a web address from which it can be downloaded.

5 DEMO BOARD SOFTWARE

All software is done in The Labview environment. When the software is ready and no more debugging features are needed, it is transformed into a run-time-executable. Then it is easy to transfer to customer.

5.1 Labview drivers for MBED

The Demo board uses NI's VISA (5) drivers to communicate with the MBED microcontroller. When MBED drives are installed the VISA drivers can see the MBED as a normal COM port. Number of the COM port varies depending of the environment and what other devices are used. There has to be a controller in the front panel to allow the user to change it to the right value. All information between PC and MBED is going thru the USB port in the character form. The first VISA driver has to know the right COM port. In this case it is the VISA resource name. The baud rate must be the same in both ends. The normal communication settings are number of bits, stop bit and parity bit. To minimize the traffic between devices, only important information is transferred. For example iw:aa:00:81 means I2C writing to address AAh and data is 0081h. As a mark for stop command, the line feed id was added. Only 12 characters are moved in this case. Every character is 8 bits + 1 stop + 1 parity = 10 bits. 12 characters multiplied by 10 = 120 bits. According to the example, the baud rate is 9600 which means 9600 bit/second and takes 12.5 ms to transfer the needed bits. In the demo board the actual baud rate is 460800 bit/sec. In that case it takes only 260 us to transfer that. Error handling is built in feature in LabVIEW and according errors, if any, it will be take into count and correcting actions will done. In FIGURE **13**. Visa connect to MBED is an example of the communication between PC and MBED is done.

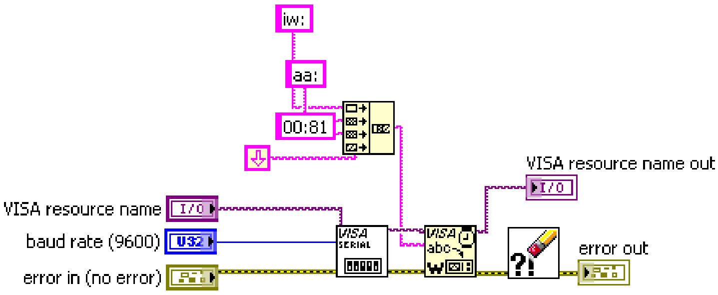

FIGURE 13. Visa connect to MBED

5.2 MBED software and files

The software inside the MBED is entered on the mbed.org web site. After successful compilation it is saved to the MBED which is connected to a USB port with a cable. In the computer's file manager it looks like a normal disk drive. After saving, it needs to reset to put the new saved version in use. Only single software can be installed at one time to avoid problems. MBED uses *.bin file for software. Other files that are not using the bin format can be installed to MBED. These files can be like a help file or instructions how to use the demo board and software. The actual LabVIEW software is too big to fit inside a MBED disk drive.

An example of how the main part is done in the C-code.

```
i2c.frequency(1200000);          //set frequency to 1200 KHz
spi.format(16,2);                // 16 bit, rising edge clocking
spi.frequency(1000000);          // spi frequency 1000 kHz
pc.baud(460800);                 // same as in LabVIEW
while (1) {
    if (pc.readable()) {
      serialBuffer[serialCounter] = pc.getc();
      if (serialBuffer[serialCounter]==0x0D || serialBuffer[serialCounter]==0x0A) {
            serialBuffer[serialCounter] = '\0';
            handleData(); // this will start data loop handle
            serialCounter=0;
       } else
       serialCounter++;
       led3 = !led3;
     }
}
```

5.3 Waveform generator software

The SPI protocol is used to the control function generator. In the Labview software control panel there are controllers for all the most important features. The Visa interface can see the MBED as a COM port and the baud rate is selected according to the software inside the MBED microcontroller. The Frequency controller is defining the signal frequency and the waveform controller is used to select the output waveform. FIGURE **14**. Waveform generator front panel.

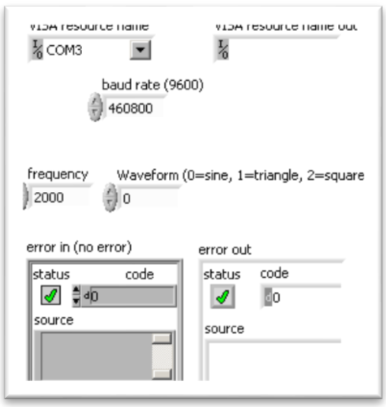

FIGURE 14. Waveform generator front panel

Each Labview software consists of a front panel and a block diagram. In FIGURE 15. Labview software from code side., there is a picture showing waveform generator code. It receives the needed values from the front panel controllers, and according to them it calculates the needed parameters and sends them to the generator circuit via the MBED controller.

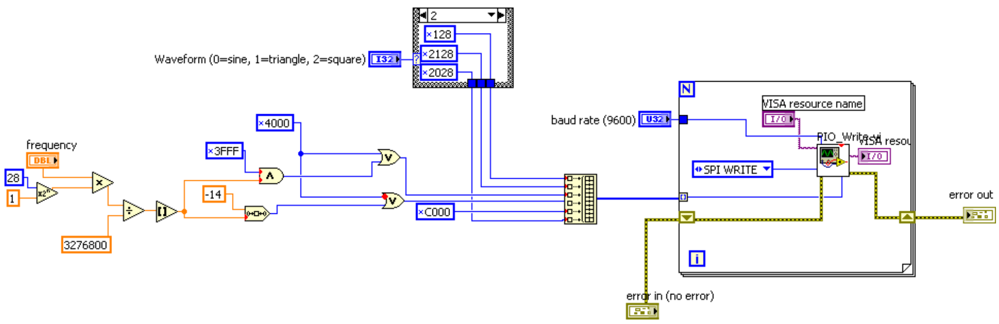

FIGURE 15. Labview software from code side.

After the waveform generator was ready, it was the right time to study what the output of the circuit was. FIGURE **16**. Example of the sinus signal from wave-form generator output in the time base. From the Y axis it is possible to see that the output is reaching the output positive peak over 650 mV value and the low-est value is 50 mV.

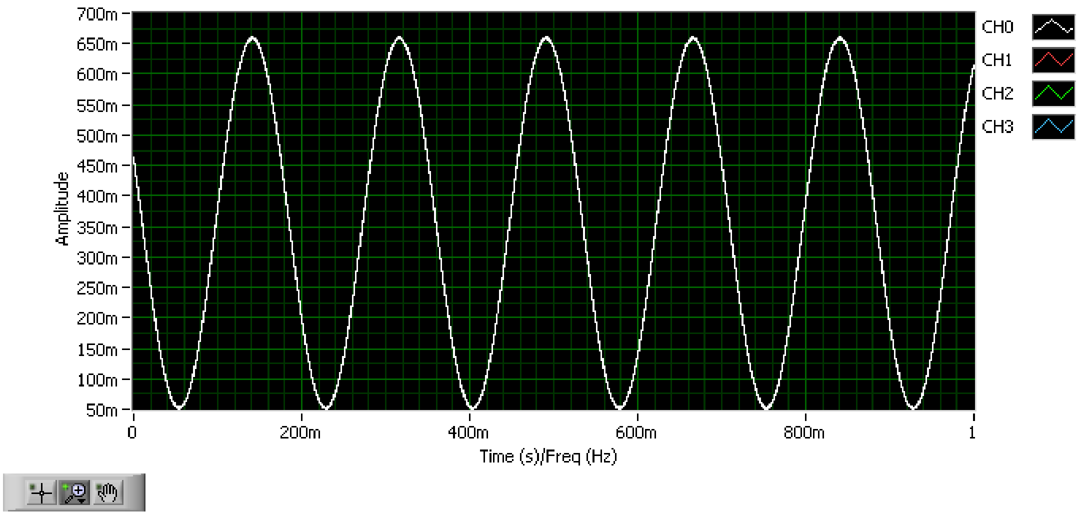

FIGURE 16. Example of the sinus signal from waveform generator output

When changing the settings to a triangle wave form it is possible to see that the waveform shape selector is working well and does what is expected. In FIGURE 17. Example of the triangle signal from waveform generator output in the time base.

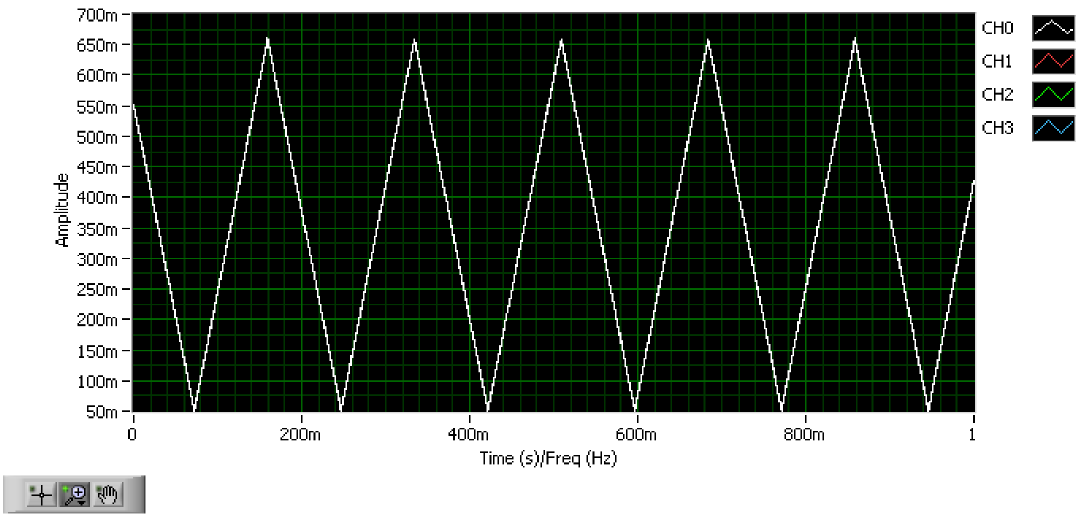

FIGURE 17. Example of the triangle signal from waveform generator output

After the time base investigation, it was time to check the signal quality in frequency base. FIGURE 18. Example of the signal spectrum from the waveform generator output. From the picture it is possible to see that the signal peak is about 200 Hz and all harmonics are quite low.

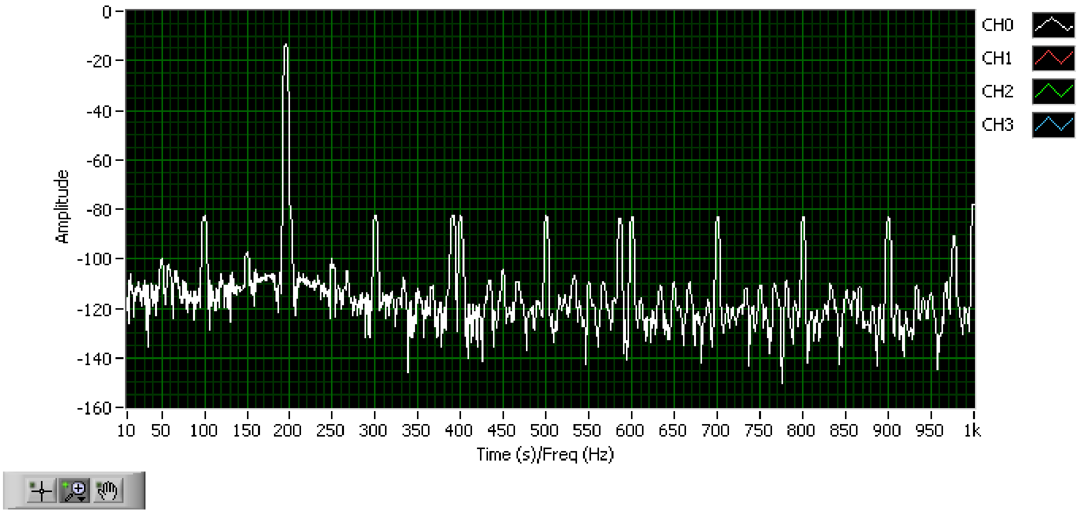

FIGURE 18. Example of the signal spectrum from the waveform generator output

As a conclusion it is easy to see that the quality of the waveform generator is enough to fulfill the requirements. According to the manufactures datasheet (6) the output maximum voltage level is 650 mV quite the same as what was measured from the demo board. FIGURE 19. Picture of harmonics from manufactures datasheet (6), and in that picture it is possible to see that the harmonic signals are about -60 dB and base noise is about -85 dB if it is compared to the main signal level. In the demo board, the harmonic signal levels are quite similar.

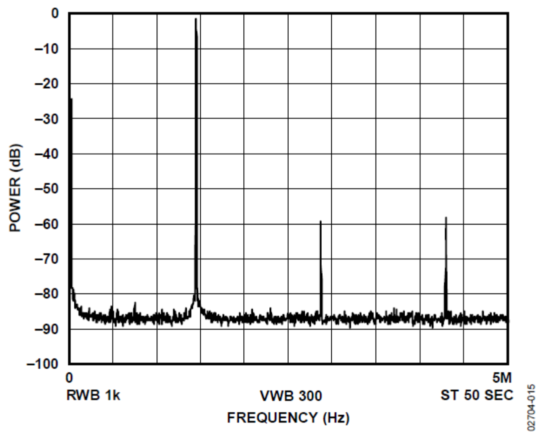

FIGURE 19. Picture of harmonics from manufactures datasheet (6)

5.4 Gesture recognition

The gesture recognition was also added to the software requirements to show how it can easily be added to the software and also to add value to the work from the customer’s perspective. When starting to think how gestures are implemented and what the differences between the gesture and letter recognition are, there are two different kinds of techniques. For this project, gestures were selected. Normally only a few gestures are used. Those are like C for Copy and U for Unselect. The minimum size of the gesture was defined to avoid mistaken touches on the panel. Then by using normalization, it was re-sized to 3x3 areas. After that it was easy to find the areas the gesture was using and in what order. When a user draws a C gesture, it is easy to see that it uses areas 3 2 1 4 7 8 9. Then, by converting that to the string form, it gives the string 3214789 which means copy in software. FIGURE **20**. Gesture normalizationis an example of how the normalization is done for gestures.

FIGURE 20. Gesture normalization

5.5 Oscilloscope

This feature was made purely with software in the MBED. It use a simple built-in ADC routine to make as many measurements as required. In table 1, there is an example of how the oscilloscope software use ADC to get 1000 samples in a short period of time. During the measurement, all other activities were canceled. After all samples were read, they were stored in the MBED's memory in the result[count] variable. Then the samples were sent to the LabVIEW program for a further action. In the MBED, pins 15 to 20 can be used as oscilloscope.

TABLE 2.

```
 // AD conversion routine
for(count = 0; count < 1000; count++){       // 1000 samples required

adc.start();                                 //Start ADC conversion

while(!adc.done(p20));                       //Wait for it to complete ADC in pin 20
result[count] = adc.read(p20);               //store ADC result
```

In FIGURE **21**. Oscilloscope interfaceis the interface as the user it sees it. It looks like a normal scope in order to make it easier to use if the user has earlier experience with those.

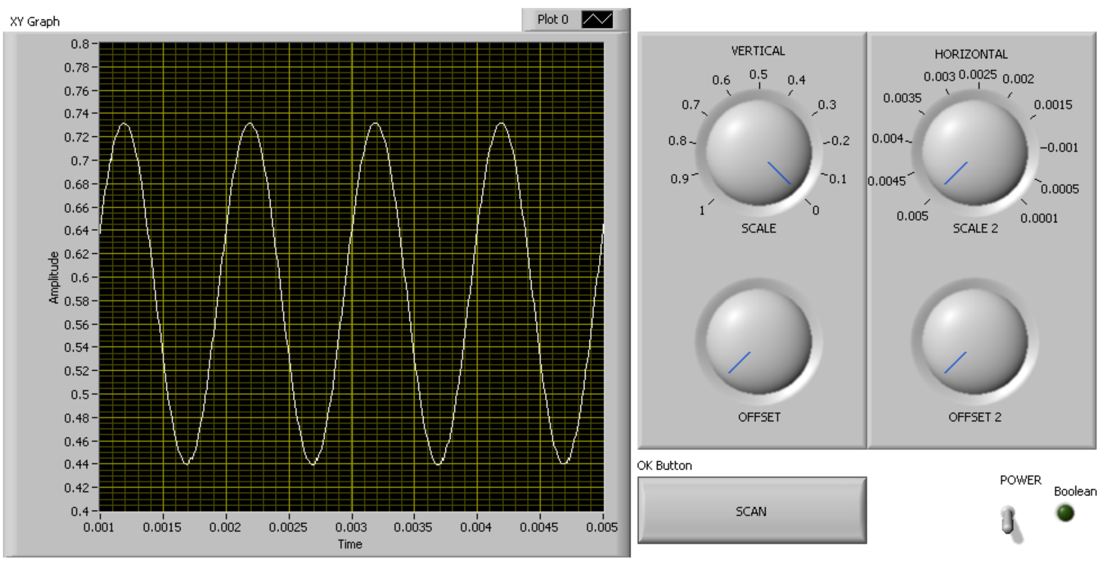

FIGURE 21. Oscilloscope interface

If the user requires it, the time scale plot can also be turned to the amplitude spectrum to study the results in the frequency scale using LabVIEW software features. FIGURE **21**. Oscilloscope interfaceshows a captured signal in time base and FIGURE **22**. Captured signal in frequency scale after FFT (Fast Fourier Transform).

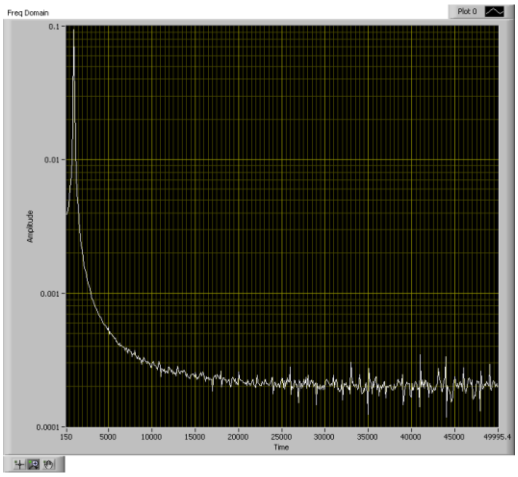

FIGURE 22. Captured signal in frequency scale after FFT

5.6 I2C

Because the MBED was using only 3.3V output voltage lines and the touch screen microcontroller was 1.8V, level shifting was needed. To fulfill this purpose, PCA9306 made by Texas Instruments (4) was used. It is a bidirectional I2C level shifter containing both SCL and SDA lines. I2C lines are always equipped with pull-up resistors. Both sides of the I2C lines require their own resistors. The EN signal is for enabling lines when the EN is high. In this project, there is no reason to disable the level shifter. The MBED is a master device and the touch screen controller is a slave device. The schematic is shown in FIGURE **23**. I2C level shifterbelow.

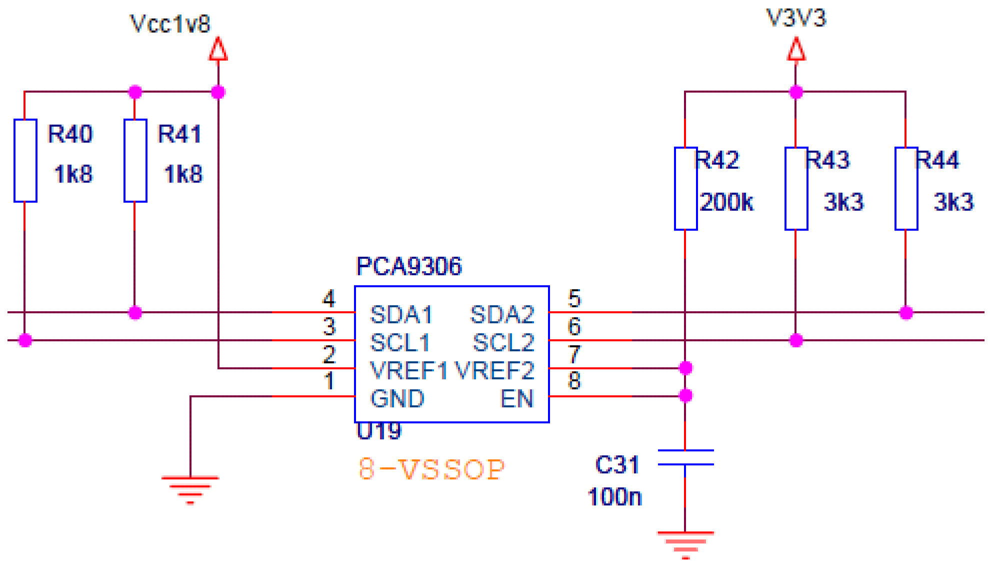

FIGURE 23. I2C level shifter

6 TEST BOARD PWB

When planning a printed wire board (= PWB) for a demo board, the size and clearness was critical. All the blocks were placed in a way that it is easy to use. There is only one wire connected between the computer and the demo board and it is located in the way that it does not disturb the user. In figure 24 there is a diagram showing how components are placed. In the middle upper area is the touch screen controller on the daughter board. The largest green PWB (Printed Wire Board) area represents the motherboard. In this thesis work, only the motherboard is documented. The rest of the pin headers are reserved to modify the mother board features such as which block is disturbed with noise. The MBED's oscilloscope interface is located on one pin header which allows the user to connect it where needed.

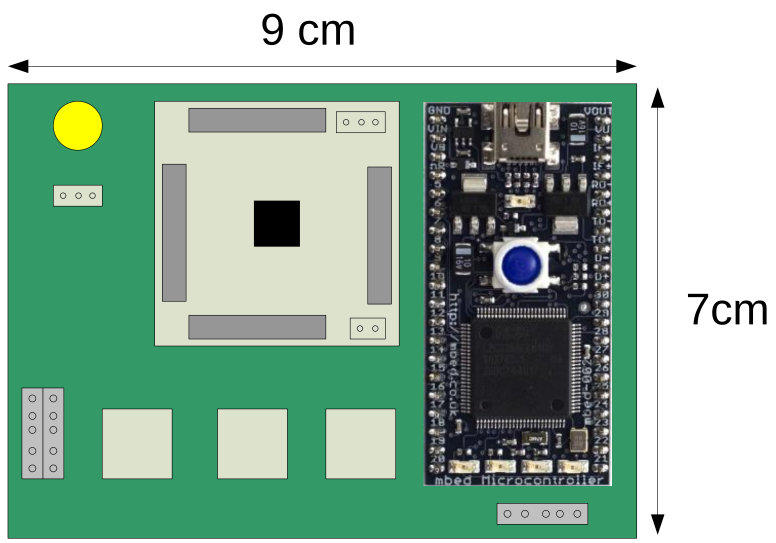

FIGURE 24. Demo board component placement

To allow the connecting of a resistive panel near the demo board, a support area for the panel was also needed. Two different versions were made to suit different situations.

Option A supports the different sizes which have been pre-selected earlier. The places for the panes are manufactured from a block of nylon. Option B supports all panel sizes. Adjustment can easily be made by loosening the screws and moving them as needed.

7 CONCLUSIONS

When this project was starting, it was not known how big a project this was going to be. In the beginning, there were only a few requirements but there was an agreement that the list would grow during the project. The biggest drawback was working with the pre-selected FTDI microcontroller. Three months' work was wasted due to bad selections and bad luck. The manufacturer did not want to co-operate, and after the problems with their ready-made drivers, which they did not want to fix, it became known that a new microcontroller was needed. With a better study of the microcontroller, this situation could have been avoided. After three months' hard work, the microcontroller was still unstable and only 50% of the commands were going through I2C lines with full responses. In receiving direction only 10% of I2C traffic was acceptable. After the first SPI command, the controller locked up and could not be used without rebooting. If the first write was done through SPI, it worked correctly but as soon as it performed an I2C write, the lock situation arose again.

With the MBED I2C, writing and reading were working after three hours work and the SPI started to work after one hour's study. The speed of the I2C traffic and to PC via USB was the only issue that was worrying. After a slight overclocking, it was not a problem anymore.

All blocks were tested with a "VERO" board to avoid problems. The software is also tested with them. Currently all the software is in separate pieces. It should be integrated into one main program which has its own pages.

Currently this project is on hold and is waiting for a better time to finish it. All software blocks are ready and the schematic is also ready. The components have been selected and a LOM (List Of Materials) has been completed. The schematic is also ready to be sent for layout and the instructions have also been documented and completed.

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