Embedded Software and User Interface Project for Breast Cancer Imaging

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Motivation

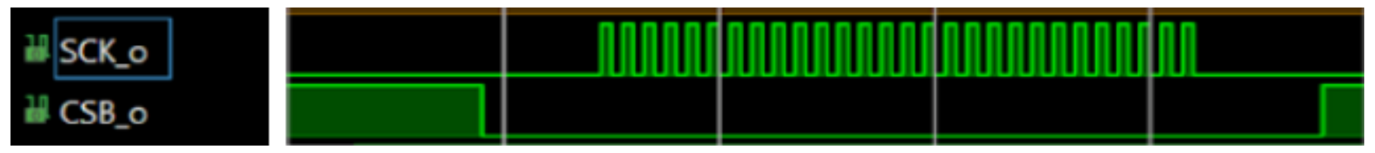
Breast cancer is one of the most common malignant tumors in women. Thus, there is urgent clinical need for early detection of breast cancer using microwave technology. Creating a low-cost, effective and mobile system is imperative to further the research and development for breast cancer detection.

Problem

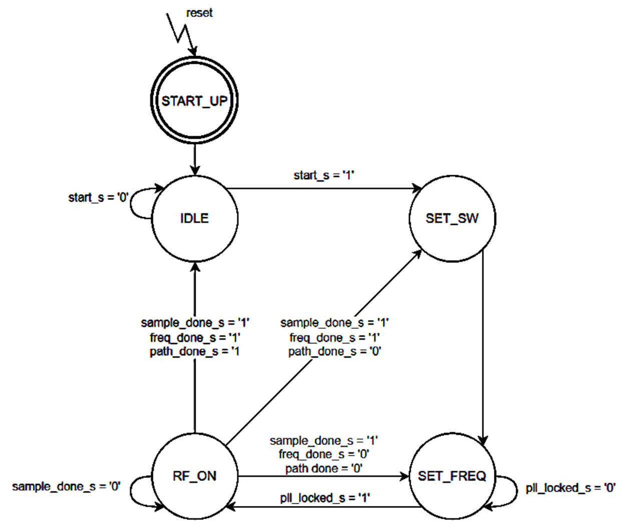
Wave View Imaging is moving towards a system on a chip (SoC) platform with a CPU and FPGA while currently using the Xilinx Zynq7000 series. The user interface (RFSense and all other software modules) need a Windows operating system, but this needs to be moved onto a more compact and embedded system instead. Furthermore, the current FPGA code running the measurement routine will also require improvements and the implementation of various components (distance sensor, Rx and Tx switches) all wrapped in a finite state machine for proper functionality.

Distance Sensor and Finite State Machine Logic

Separation Distance Measurement Controller: This controller measures the distance between the "plates" where the breast is placed. The implemented solution uses an absolute magnetic linear encoder system to find the distance from one plate to another.



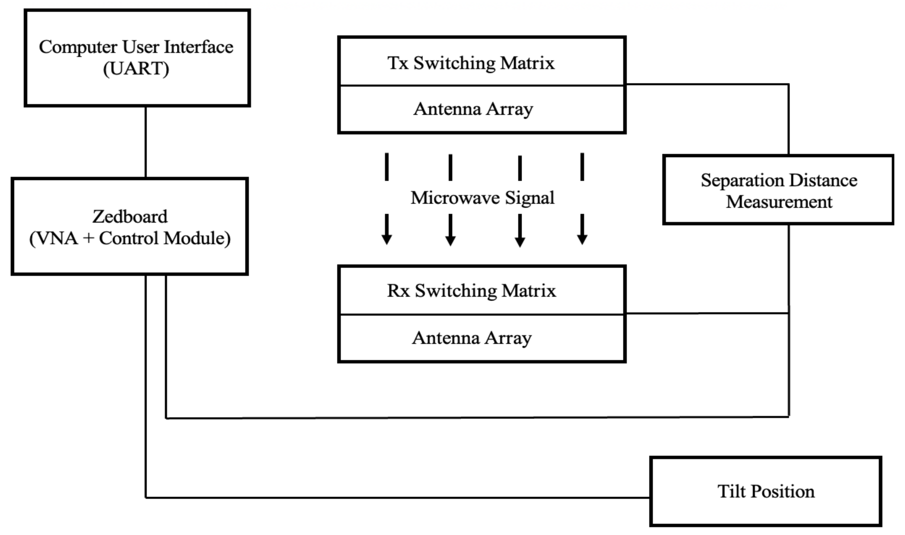
Finite State Machine: Using a finite state machine, we can send in multiple frequencies and switch configurations at once so that it automatically runs through all measurements.



Tilt Sensor and Tx and Rx Switches

Tilt Position Controller: The machine has three different tilt positions it can be in. The implemented controller states which position the machine is in or if there is an error occurring.

Rx and Tx Switches Controller: The goal of the device is to measure the frequency response between the receiving and emitting antennas which contain two different arrays (a path). This measurement routine consists of configuring different switches so that certain pairs of antennas can be selected and the path between them can be measured.



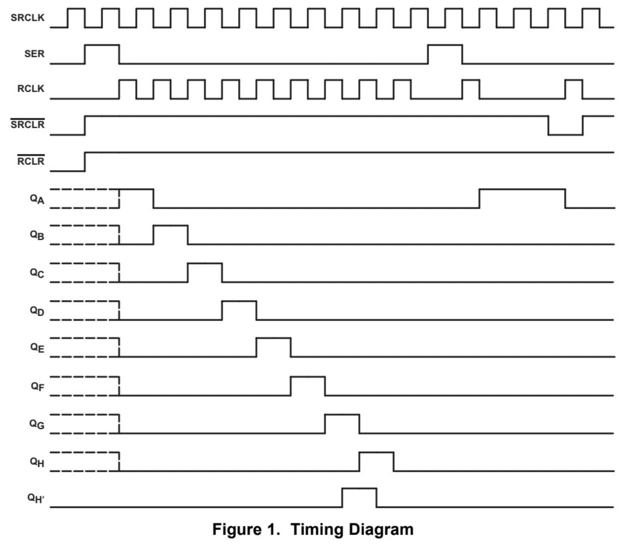


Figure 1. Timing Diagram

User Interface Solution

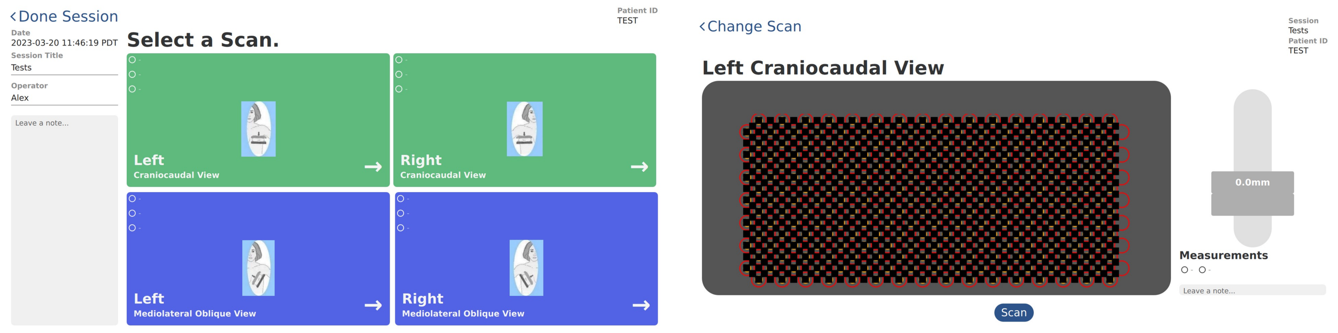
Feasibility verification on ZedBoard PetaLinux ARM v7:
The cross-compilation method is chosen for application migration. However, the cross-compilation toolchain of ARM v7 Linux lacks Qt6 (which RFSense depends on). Therefore, there are two methods to improve this technical route. Solution one: change RFSense to use Qt5. Solution two: independently compile the cross-compilation toolchain for Qt6 for ARM v7 Linux.

Feasibility verification on Raspberry Pi Debian ARM v8 Linux:
Enabled RFSense to support the Raspberry Pi environment by changing the CMake file. Replaced NI-VISA, which is required for the S4VNA software to communicate with the S4VNA hardware with PyVISA because it does not support ARM architecture. But PyVNA on ARM-based Linux systems, like the Raspberry Pi, does not officially support the S4VNA hardware. The simultaneous work of the hardware team has enabled the self-developed VNA module to replace the S4VNA hardware.

Feasibility verification on Ubuntu x86:
This technical route uses VMWare's Ubuntu x86 virtual machine for program migration. After refactoring the code, the migration was successful.

Software Results

The software team got the feasibility analysis of migrating RFSense to the ZedBoard, Raspberry Pi and x86 MCU. Finally, the application was migrated on the Ubuntu virtual machine. The following is the running screenshot.



Hardware Results

Implemented UART command **GTP (Get Tilt Position)** to detect tilt position

Implemented SPI protocol to obtain separation distance measurement with the use of UART commands **SSD (Set Separation Distance)** and **GSD (Get Separation Distance)**

Tested the viability of configuring switches with shift registers via SPI protocol and UART command **S (Set)**

Successfully looped through **various switches and frequencies** per measurement routine

Changed storage of files (dist.txt, tx.csv and rx.csv) from EEPROM to the **Fat File System on the SD card** of the ZedBoard

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