# USB Gain/Phase Analyzer
# Project Requirements Specification

**Watson Capstone Project WCP52**
**Sponsor: Professor Kyle Temkin**

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# 1 Scope

## 1.1 Identification

## 1.2 System Overview

A Gain/Phase Analyzer is an instrument used to plot the frequency response of a network or amplifier. The project proposal in Appendix A specifies a small, computer-controlled gain/phase analyzer for use by students and individuals. It can stimulate and then measure filters, amplifiers and control systems, allowing their behavior to be plotted and analyzed. The device is to be developed as an open-source project, so that students may study its inner workings.

## 1.3 Document Overview

This specification provides the essential project requirements in Section 3, Requirements, and the qualification method for each requirement in Section 4, Qualification Provisions.

In this specification, a requirement is identified by "shall", a good practice by "should", permission by "may" or "can", expected outcome or action by "will", and descriptive material by "is" or "are" (or another verb form of "to be".

# 2 Applicable Documents

The following documents of the exact issue shown form a part of this specification to the extent specified herein. In the event of conflict between the documents referenced herein and the contents of this specification, the contents of this specification shall be considered a superseding requirement.

# 3 Requirements

## 3.1 Required States and Modes

This system requires the following modes:

3.1.1 Idle: The signal source and detection subsystems are inactive, and the system is waiting for commands.

3.1.2 Analysis: The system is performing a gain/phase analysis.

## 3.2 System Capability Requirements

3.2.1 The analyzer shall be able to display a plot on the operator's PC in the form of a Bode plot.

3.2.2 The analyzer shall be capable of sourcing test signals between 1 kHz and 150 MHz. (Not applicable: state WCP52-3.1.1 — idle)
3.2.3 The analyzer shall be capable of output amplitudes up to 1.25 V RMS at frequencies up to 100 MHz. (Not applicable: state WCP52-3.1.1 — idle)
3.2.4 The analyzer shall be able to detect signals down to at least 40 dB below the output amplitude. (Not applicable: state WCP52-3.1.1 — idle)
3.2.5 The analyzer should be able to detect signals down to at least 60 dB below the output amplitude. (Not applicable: state WCP52-3.1.1 — idle)
3.2.6 Amplitude accuracy shall be within 3 dB, and phase accuracy within 5 degrees.
3.2.7 Amplitude accuracy should be within 1 dB, and phase accuracy within 1 degree, for frequencies less than 20 MHz.
3.2.8 The hardware shall not be able to be damaged by its remote interface, unless an “unlock” command has been issued.

## 3.3 System External Interface Requirements

3.3.1 The analyzer shall interface with a PC.
3.3.2 The analyzer should use a text-driven protocol.
3.3.3 The analyzer should use a common, standard communication protocol, for example, USB-CDC.
3.3.4 The analyzer shall use either SMA or BNC connectors to interface to the device under test (DUT).
3.3.5 The analyzer shall provide power via a front-panel connection for use with external DUT adapters. The voltage should be at least +/- 10V, and up to 1W should be available when not powered by USB.

## 3.4 System Internal Interface Requirements

3.4.1 All internal interfaces are left to the system designer.

## 3.5 System Internal Data Requirements

3.5.1 All decisions about internal data are left to the system designers.

## 3.6 Other System Requirements

3.6.1 The system should include a simple operator's manual, which should include a brief Theory of Operation explaining its design, instructions for using each function, and example test setups for characterization of filters and control loops.

3.6.2 The system shall include a protocol guide, showing how to communicate with it.

3.6.3 The PCB shall be produced using surface-mount technology as much as is reasonable, without no-lead packages unless absolutely required.

3.6.4 The interface should expose direct control of the hardware functions, allowing additional features to be implemented.

3.6.5 The system shall have no voltages greater than 30 V peak-to-peak accessible externally.

## 3.7 Precedence and Criticality of Requirements

3.7.1 All requirements have equal weight.

# 4 Qualification Provisions

The following classic qualification methods are to be used:

- Demonstration (D): The operation of the system, or a part of the system, that relies on observable functional operation not requiring the use of instrumentation, special test equipment, or subsequent analysis.
- Test (T): The operation of the system, or a part of the system, using instrumentation or other special test equipment to collect data for later analysis.
- Analysis (A): The processing of accumulated data obtained from other qualification methods. Examples are reduction, interpolation, or extrapolation of test results.
- Inspection (I): The visual examination of system components, documentation, etc.
- Special qualification methods (S). Any special qualification methods for the system, such as special tools, techniques, procedures, facilities, acceptance limits, use of standard samples, preproduction or periodic production samples, pilot models, or pilot lots.

| Method | Requirement | Description |
|---|---|---|
| D | WCP52-3.2.1 | Bode plot output |
| T | WCP52-3.2.2 | Signals sourced from 1 kHz to 150 MHz |
| T | WCP52-3.2.3 | Signals up to 1.25 V RMS under 100 MHz |
| D | WCP52-3.2.4 | Signals detected as low as 40dB below output amplitude |
| A | WCP52-3.2.6 | Accuracy within 3dB, 5 degrees |
| D | WCP52-3.3.1 | PC interface |
| D | WCP52-3.3.2 | Text-driven protocol |
| D | WCP52-3.3.3 | Standard communication protocol |
| D | WCP52-3.3.4 | DUT connectors are either SMA or BNC |
| A | WCP52-3.3.6 | Auxiliary power at least +/- 10 V, sources at least 1 W |
| D | WCP52-3.6.2 | Protocol guide is present |
| T | WCP52-3.6.5 | External voltages below 30V p-p |

*Table 1: Qualification Provisions*

# 5 Requirements Traceability

This section is not applicable because this is a system-level specification.

# 6 Notes

## 6.1 Acronyms and Abbreviations

PRS Project Requirements Specification
WCP Watson Capstone Projects
DUT Device Under Test

## 6.2 Bibliography

# Appendices

# 7 Appendix A: Project Proposal

**Watson Capstone Projects**
**Project Proposal Form**

Computer, Electrical, and Mechanical Engineering
Thomas J. Watson School of Engineering and Applied Science
Binghamton University

# 1. Project Title

**USB Gain/Phase Analyzer**

# 2. Organization Name and Address

Binghamton University
Department of Electrical and Computer Engineering
4400 Vestal Pkwy E
Binghamton, N.Y. 13902-6000

# 3. Contact Names, Phone, Email Address

a. **Sponsor Management Representative:**

Prof. Kyle Temkin

b. **Sponsor Technical Representative:**

Prof. Kyle Temkin

## 4. Project Description

A Gain/Phase Analyzer is an instrument used to plot the frequency response of a network or amplifier. These instruments are generally considered to be expensive, specialized pieces of equipment, with units from major manufacturers costing tens of thousands of dollars. However, these instruments could be very useful in a less expensive, more compact form, and particularly valuable in the educational sector.

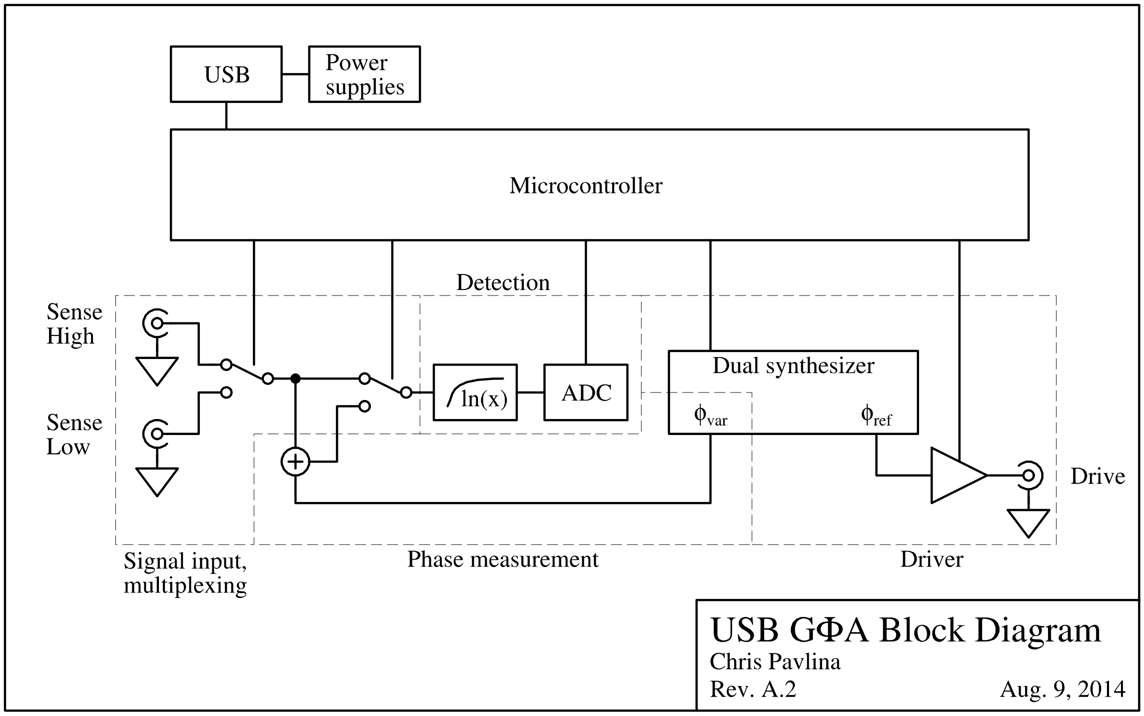
I propose a small, USB-driven gain/phase analyzer for low-frequency to mid-VHF bands (from around 1 kHz to 100+ MHz). The gain-phase analyzer shall be a low-cost instrument targeted at education, and should be open-source to allow students to see how it works. It shall be able to produce accurate and precise Bode plots of filters, amplifiers, control systems, and so on, for experimentation, circuit design, and circuit analysis.

## 5. Project Requirements

- The analyzer shall be able to display data to the operator in the form of a standard Bode plot, using a PC interface.
- The analyzer shall be capable of sourcing test signals between 1 kHz and 100 MHz, and able to detect them down to at least 50 dB below the output amplitude.
- The analyzer should be able to detect signals down to at least 80 dB below the output amplitude.
- Amplitude accuracy shall be within 2.5 dB, and phase accuracy within 5 degrees.
- Amplitude accuracy should be within 1 dB, and phase accuracy within 1 degree, for frequencies less than 20 MHz.
- The analyzer shall be capable of performing most analysis functions directly, allowing the PC software to be simple.
- The analyzer should use an easily-scripted, text-driven interface, for example, USB-CDC.
- The interface should expose direct control of the hardware functions, allowing additional features to be implemented.
- The user shall not be able to damage the hardware by its remote interface, unless an “unlock” command has been issued.
- The PCB shall be compact, and the enclosure should be no larger than what is required to contain this.
- The PCB shall be produced using surface-mount technology as much as is reasonable.

- The analyzer shall use standard connectors, either SMA or BNC, to allow the use of existing test equipment in a larger setup.

## 6. Project Graphic




## 7. Budget

**Major components:**

| **Item** | **Proposed part number** | **Total cost** |
|---|---|---|
| High-frequency synthesizer | AD9958 | $35.48 |
| PCB, 4-layer, two revisions | N/A | $120.00 |

The project will operate with a fixed budget of $500.

## 8. Deliverables and Meetings

**Deliverables:**

- Schematics and PCB artwork
- Enclosure drawings
- On-board firmware
- One working gain/phase analyzer
- Open-source PC companion software (command line-only is acceptable)

- Operator's manual including:
  - Theory of Operation explaining the function of the system.
  - Instructions explaining the use of each function.
  - Example test setup for filter characterization.
  - Example test setup for control loop characterization; for example, stability analysis of a voltage regulator.

**Meetings:**

We will meet weekly to discuss project plans and work which is to be completed.

## 9. Recommended Team Composition

| Mechanical Engr: | Electrical Engr: | Computer Engr: |
|---|---|---|
| 0 | 2 | 2 |

## 10. Citizenship Requirements

None.

## 11. Team Members

Christopher Pavlina (EE)