February 9th, 2021

Dr. Craig Scratchley
Dr. Shervin Jannesar
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, BC, V5A 1S6

Re: ENSC 405W Requirement Specification for ValueGraph

Dear Dr. Scratchley and Dr. Jannesar,

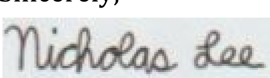
The following document outlines the requirement specifications for the ValueGraph graphing calculator. Our goal is to design an affordable graphing calculator that has a lifecycle after high school mathematics. We will create a graphing calculator model that can perform competitively in the current graphing calculator market at a reduced cost and have the functionality for teachers and professors to turn off various calculator features for exams.

The information regarding our project's requirements specifications will include the following details. Both the hardware and software requirements of our graphing calculator and radio frequency (RF) remote control for the three stages of development, as well as the necessary engineering standards, sustainability and safety requirements. Lastly, we will cover our Acceptance Test Plan for each stage of development of the ValueGraph graphing calculator.

Company 17's BC Instrument consists of six capable SFU engineering students. These talented team members are Dante Barr, Russell Ho, Chris Keilbart, Evan Lee, Nicholas Lee and Donald Tim Mustard. Each member is bringing their diverse experiences from the industry and education to create an exceptional graphing calculator for students.

The team at BC Instrument would like to thank you for reviewing our requirement specifications document. If you have any questions related to our document, please contact us through comments on our GitLab or contact our Chief Communications Officer, Nicholas Lee, at nicholas_lee_3@sfu.ca.

Sincerely,



Nicholas Lee
Chief Communications Officer
BC Instrument

Requirements Specification
For *ValueGraph* Graphing Calculator

Version 1.0

BC Instrument
Company 17

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Date Created: February 9th, 2021

Abstract

This document serves as an overview of the required requirements of the ValueGraph graphing calculator. The project will be separated into two physical units, the ValueGraph graphing calculator and the RF remote control that can disable specific functionality on all nearby calculators for a specific duration. Both the graphing calculator and RF remote control's hardware and software requirements will be covered, as well as the engineering standards and sustainability and safety requirements our project will adhere to. Lastly, a detailed Acceptance Test Plan will cover our project's testing requirements for the proof-of-concept prototype.

ValueGraph will be targeted to students in high school and university, as well as high school administrations for the purpose of supplying class sets. It will still be available for the rest of the general public, but marketing will focus on the previously stated groups. The remote control unit will be sold exclusively to high school and university administrators and instructors, to prevent students from having control over their own and classmates' graphing calculators in a test environment.

Table of Contents

Abstract **3**
List of Figures **5**
List of Tables **5**
Revision History **5**
1.1 Purpose 6
1.2 Product Scope 7
1.3 Requirements Classification 7
2. Overall Description **7**
2.1 Product Perspective 7
2.2 Design and Implementation Constraints 8
2.3 Assumptions and Dependencies 9
3. System Features **10**
4. Hardware Requirements **11**
4.1 Tactile Button Interface 11
4.2 RF Interface 11
4.3 LCD Screen 11
4.4 Microcontroller 12
4.5 Power 12
4.6 Casing 12
5. Software Requirements **13**
5.1 Input Functions 13
5.2 Mathematical Functions 13
5.3 Screen Output Functions 17
6. Nonfunctional Requirements **17**
6.1 Performance Requirements 17
6.2 Safety Requirements 18
6.3 Sustainability Requirements 18
6.4 Engineering Standards 19
6.5 Security Requirements 19
6.6 Documentation Requirements 20
7. Acceptance Test Plan **20**
7.1 Test Plan Requirements 20
7.2 Proof of Concept Prototype Test Plan Requirements 21
7.3 Engineering Prototype differences 21
8. Conclusion **21**
9. References **22**
Appendix A: Abbreviations **23**

List of Figures

Figure 1.1: Price Survey Results for high school and university students 6
Figure 3.0: Test Mode Invocation Sequence Diagram 10
Figure 5.2: Requested Features According to Group Survey 14

List of Tables

Table 1.3: Symbol classifications for the three stages of development 7
Table 4.1: Button Interface Requirements 11
Table 4.2: RF Interface Requirements 11
Table 4.3: LCD Screen Interface Requirements 12
Table 4.4: Microcontroller Requirements 12
Table 4.5: Power Requirements 12
Table 4.6: Casing Requirements 13
Table 5.1: Input Function Requirements 13
Table 5.2: Computational Function Requirements 14
Table 5.3: Screen Output Function Requirements 17
Table 6.1: Performance Requirements 17
Table 6.2: Safety Requirements 18
Table 6.3: Sustainability Requirements 18
Table 6.4: Engineering Standard Requirements 19
Table 6.5: Calculator Security Requirements 19
Table 6.6: Documentation Requirements 20

Revision History

Name	Date	Reason For Changes	Version
First release	2021/02/19	Genesis	1.0

1. Introduction

1.1 Purpose

Graphing calculators have become a staple in the high school mathematics curriculum since their invention in 1985 [1]. They became mandatory for the AP calculus exams in 1995, and are now a requirement in present-day senior high school mathematics courses [2]. Graphing calculators today have an advanced feature set in comparison to their scientific calculator counterparts. These more advanced calculators have features such as integration, root finding, and plotting various mathematical functions [3]. Therefore, graphing calculators have the ability to replace scientific calculators and be useful in higher level math courses. However, this is not the case as graphing calculators have limited use in university after high school due to being banned from various university courses' exams.

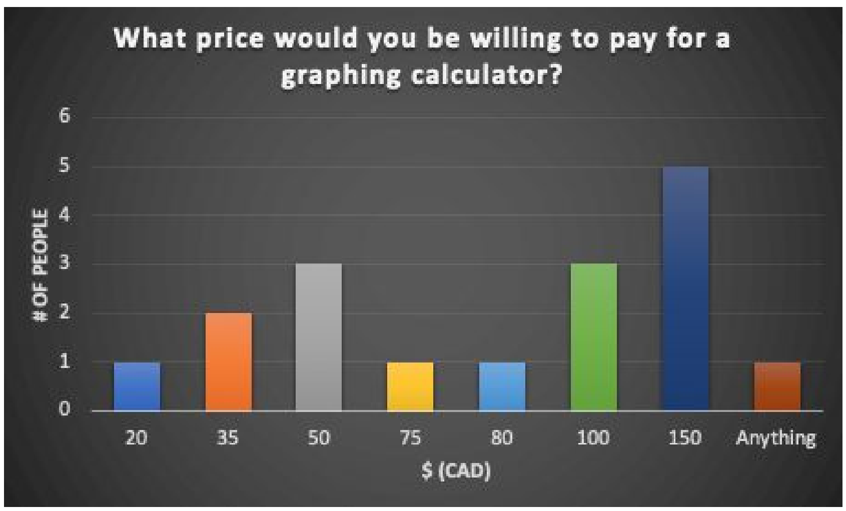

Figure 1.1: Price Survey Results for high school and university students

The market is currently dominated by Texas Instruments who had an estimated 80% market share of the international graphing calculator market in 2019 [4]. Texas Instrument's cheapest graphing calculator is the TI-83+ which retails for $146 (these, and all other prices in this document will be in CAD), and other models, such as the TI-Nspire CX II CAS retail for a higher price of $200 [5]. From an ongoing survey being taken by local high school and university students, shown above in **Figure 1.1**. The majority of respondents would pay a maximum of $100 for a graphing calculator. Current Texas Instrument graphing calculators on the market are anywhere from 46% to 100% more expensive. Therefore, our goal is to develop (in accordance to the necessary engineering standards, sustainability and safety requirements) an affordable graphing calculator for students that can be used at both the high school and university mathematics level. We will achieve our goal by designing a graphing calculator with a radio frequency remote control that can restrict certain functionality specified by the instructor during exams.

1.2 Product Scope

The purpose of this document is to outline the requirements specifications of the ValueGraph graphing calculator and the accompanying controlling remote. These specifications will describe in detail the necessary requirements that our graphing calculator must satisfy for the end user, as well as distinguish the specification requirements for the three phases of the project: alpha phase (including proof-of-concept), beta phase (including engineering prototype), and production phase (including final product). The major components of our project are: the graphing calculator, the controlling remote, and the communication between the two.

1.3 Requirements Classification

The requirements will be classified according to the following format:

Req. (Section Number).(Subsection Number).(Requirement Number)-(Stage of Development)

The three stages of development for our project are as follows:

Symbol Classification	Stage of Development
A	Alpha Phase (Proof-of-Concept)
B	Beta Phase (Engineering Prototype)
P	Production Phase (Final Product)

Table 1.3 Symbol classifications for the three stages of development

The alpha phase will include our proof-of-concept and the requirements implemented for the completion of ENSC 405W. The beta phase will include our engineering prototype and the requirements implemented for the completion of ENSC 440. Lastly, the production phase will include the requirements our final product must satisfy for mass production and be market ready for product sales.

2. Overall Description

2.1 Product Perspective

The idea for an improved graphing calculator started with Chris, a member of our group. His brother was working on a project with the same old TI-84 graphing calculator model that he had been forced to use in his high school classes 5 years previously. Every single emotion he could dredge up about this calculator was negative, ranging from confusion (trying to learn the required features) to disgust (at the extreme cost). From there, he decided the market was ready for a new competitor, one that was made this decade. This product is a replacement for the current market contingents, designed to be a much more versatile product for standardized testing.

This product will be available for the general public, for the use of any student in high school and university for standardized testing. The remote control function for teachers means that a more targeted approach marketing to school board administrations will also be used. The intent is to sell the remote control to the school boards, and have them require that their students purchase our calculator for their courses.

2.2 Design and Implementation Constraints

The most obvious constraint to both the design and implementation of this project is time. Capstone runs for eight months and the proof of concept prototype is delivered after four months. This puts a limit on the number of different mathematical operations we can implement, as each new feature has to be properly implemented and verified. This timing constraint also results in a procurement constraint - we cannot use parts that take a long time for shipping and delivery.

Graphing calculators are embedded systems, which means they have a lot of the constraints commonly associated with such systems: power, performance and memory. A calculator that runs out of power every week is not one that will sell well, nor is one that takes ten seconds to solve a definite integral. A calculator that uses more memory than it has available will not work at all, and is useless. We will need to carefully balance these factors when choosing a processor and implementing the software.

The specific system-on-chip or microcontroller we choose to use in our graphing calculator will definitely constrain the design. There will only be one processor, and there likely won't be an operating system in use as we move past the proof-of-concept phase. This slightly limits the implementation, as calculations cannot be parallelized, and we will need to make sure that the screen and input remain responsive under load.

One constraint that needs to be carefully considered during design is the cost of the final product. We aim to be an affordable option for students and educators, so it is important that our costs for components and their assembly remains low. The constraint of cost must be balanced with the requirements of the software (memory and performance) and hardware (power).

One final constraint that we need to consider is security. We need to design a reliable method to disable features remotely that cannot be easily avoided. It may not be possible to design a system that cannot be circumvented, given enough time and resources. If deactivating our method to remotely disable calculator functionality takes more effort than simply studying for a test, then few people would try to crack our calculator. This security requirement means we need to carefully design our remote access method such that it cannot be easily hijacked by anyone listening to and broadcasting on our frequencies. It also means that we must design our device in a way that the disabled features are not accessible before the test completes. For example, the features must remain disabled if the user powers off the device or removes the batteries. Security considerations also impact our implementation, as it means we probably should not use any Raspberry Pi or Arduino devices because the community has access to a lot of resources for interfacing and modifying such systems.

2.3 Assumptions and Dependencies

We plan on using one comprehensive library for performing the more heavy-duty mathematical operations of the calculator, such as root finding, matrix operations, and numeric integration. We also plan on using a graphing library. In choosing to pursue external libraries for these areas of our project we are making some assumptions about their suitability for our hardware. The first assumption that we are making is that there are suitable libraries out there (that will compile to our architecture and have permissive licenses).

The second assumption we are making is about the performance of these external libraries. In an embedded context like a graphing calculator it is important that the processor is able to quickly execute the mathematical functions required by the user. If the libraries we use are not performant enough, we may need to customize the library or build our own routines.

Another challenge with working in embedded systems is the memory limitation, both for executed code and variable storage. By using external libraries, we are implicitly assuming that these libraries are compact enough both to fit in our program ROM and are sufficiently memory efficient so that we do not exhaust our limited RAM. If these assumptions do not hold true we may be forced to modify the library sources to remove unused functionality or to come up with our own routines that use less memory.

If any of the above assumptions do not hold true then we may have to come up with our own mathematical routines for the calculator. This would likely negatively impact our requirements, as we may not be able to deliver some of the more advanced but optional functionality due to the constrained development time. In addition, performance requirements could also be negatively affected if we had to develop our own mathematical functions.

We are forced to make some assumptions about the components we will use in our product. As one of our aims with this project is affordability, we are assuming that we will be able to procure these components at reasonable prices and delivery times. Problems that arise from these assumptions not holding are not easily mitigated, as we cannot control the price and delivery dates of our suppliers.

At this early stage we are also making some assumptions to the feasibility of using RF to remotely broadcast a signal that causes receiving graphing calculators to disable specific functions. We have done research and we believe that it should be feasible, but until we actually get a prototype calculator and remote we don't know how well it will work in practice. Will a large lecture hall have too much reflection and interference, such that the calculators at the back will not see the signal? We cannot know this for sure until we develop our first prototypes.

3. System Features

As we have identified high school students as well as post-secondary students as our target market, we have identified common graphing calculator-related gripes for people from this demographic. From the poll mentioned earlier,, we observed that a common topic of concern is the price of the calculator. The results suggested that at least 67% of the participants would pay no more than $100 for a graphing calculator which is $46 cheaper than the TI-83+ and $100 cheaper than the TI-Nspire CX II CAS [5]. In addition to the price concerns identified by the participants, students have also voiced dissatisfaction with the quantity of buttons and menus in their calculators. To address these concerns regarding ease of use, we are aiming to produce a graphing calculator with a concise feature set accessed with an intuitive menu and button layout.

Lastly, it should be noted that in many examination environments, graphing calculators are not permitted because the functionality that they provide is far too powerful and limits assessment of their problem solving skills . Our solution to address this shortcoming is to provide test invigilators with more control over the students' calculators. High school or university instructors will be able to obtain a remote that is capable of one-way communication with their students' calculators over RF. When an examination period is about to begin, the instructor can select a set of features that they wish to disable for the duration of the test and send a broadcast to their students' calculators which will place their devices under test mode, with the specified features disabled. The general sequence for an instructor invoking test mode is described in the following diagram (**Figure 3.0**).

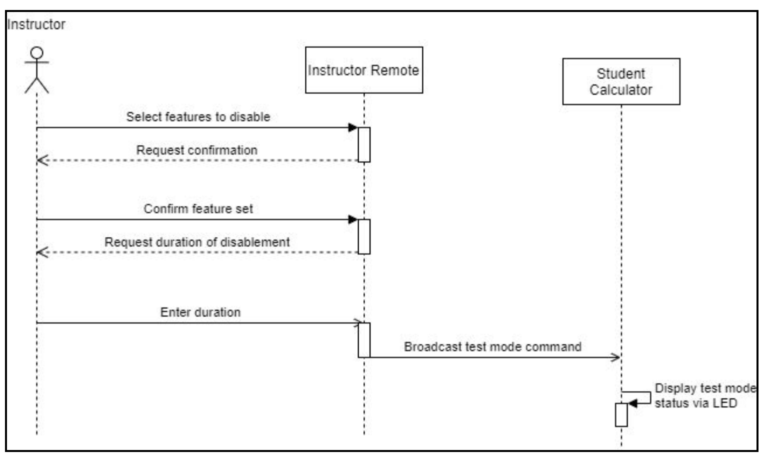

Figure 3.0: Test Mode Invocation Sequence Diagram

By providing instructors with the opportunity to quickly and wirelessly set exactly which features are permitted during exams, we can ensure that examinations operate in a more controlled manner. As an additional benefit, we eliminate the need for students to purchase calculators specifically for testing purposes.

4. Hardware Requirements

4.1 Tactile Button Interface

The primary way a user will interface with the system is by use of the tactile buttons for input. The tactile button interface requirement is contained in the table below.

Req. 4.1.1-A	The buttons shall be recognized as input by the system

Table 4.1 Button Interface Requirements

4.2 RF Interface

The calculators will be able to receive wireless communications through an RF receiver. These wireless communications will be sent from a separate remote control device that contains an RF transmitter. In order to verify signals have been received and the desired features are disabled, the device will use an LED for confirmation. To ensure that the calculators can be disabled in a large lecture hall, the communication range must be sufficiently large. Antenna for the devices will be stored in the unit to mitigate risk of them being damaged. Below is a table of requirements for our RF interface.

Req. 4.2.1-A	The remote and calculator shall send and receive signals over RF
Req. 4.2.2-B	The remote and calculator shall be able to communicate up to at least 30 metres
Req. 4.2.3-P	The remote and calculator shall look sufficiently different from each other
Req. 4.2.4-B	The calculator shall have an LED light to indicate that it has successfully received signals
Req. 4.2.5-P	Antenna shall be contained internally in the unit

Table 4.2 RF Interface Requirements

4.3 LCD Screen

The system has an LCD screen for data output and display. This LCD screen will be the only way it can display output to the user. The size and resolution of the screen must be competitive in the market [3]. The LED screen requirements can be seen in **Table 4.3**.

Req. 4.3.1-A	The display shall be capable of displaying 16 characters on a line
Req. 4.3.2-A	The display shall have a resolution of at least 96x64 pixels

Table 4.3 LCD Screen Interface Requirements

4.4 Microcontroller

The hardware will consist of a microcontroller capable of interfacing with all other inputs and outputs. This microcontroller needs to be flexible enough to interface with several IO devices. It also needs to be powerful enough to compete with other graphing calculators on the market. These requirements are seen below.

Req. 4.4.1-A	The microcontroller shall have sufficient memory for our software libraries and programs
Req. 4.4.2-A	The microcontroller shall have sufficient computational power to satisfy the performance requirements
Req. 4.4.3-A	The microcontroller shall have IO capabilities to interact with required interfaces(LEDs, LCD Screen, buttons, RF transmitter/receiver, battery)

Table 4.4 Microcontroller Requirements

4.5 Power

To power the unit we will have a battery integrated with the system. This battery should be able to be removed and replaced when necessary. To implement time-related features there must be a consistently powered RTC. All power requirements are contained in **Table 4.5**.

Req. 4.5.1-B	The system shall be powered by removable batteries
Req. 4.5.2-P	The system shall have a secondary battery charged by the main power supply to power an RTC

Table 4.5 Power Requirements

4.6 Casing

The casing requirements, seen below in **Table 4.6**, exist in order to promote longevity of the system by demanding that the casing is both durable, and form-fit to the hardware it will contain. To facilitate the manufacturing process, the interior casing should be accessible. The casing must also have sufficient air flow to maintain safe operational temperatures. To allow quick recovery from a dead battery during a crucial exam, the batteries must be easily swappable.

Req. 4.6.1-P	The system shall be durable enough to survive being dropped
Req. 4.6.2-P	The casing shall maintain a safe operating temperature for the system
Req. 4.6.3-B	The system shall be of an appropriate size for a calculator
Req. 4.6.4-B	The interior of the casing shall be accessible
Req. 4.6.5-B	The casing shall have an easily accessible battery compartment

Table 4.6 Casing Requirements

5. Software Requirements

5.1 Input Functions

To conform with standard operating expectations, our graphing calculator will operate according to button input. In addition, there is also a remote that sends RF signals to the calculator that must be read and decoded from the software side. All input function requirements are contained below in **Table 5.1**.

Req. 5.1.1-A	The system shall have functions to take in button input and use them to select software functions
Req. 5.1.2-A	The system shall interpret input from RF signals

Table 5.1 Input Function Requirements

5.2 Mathematical Functions

The mathematical functions we support were chosen to be competitive and comparable with devices currently on the market, and also to meet the wants and needs of consumers. The features desired by potential consumers can be found in **Table 5.2**, below **Figure 5.2**.

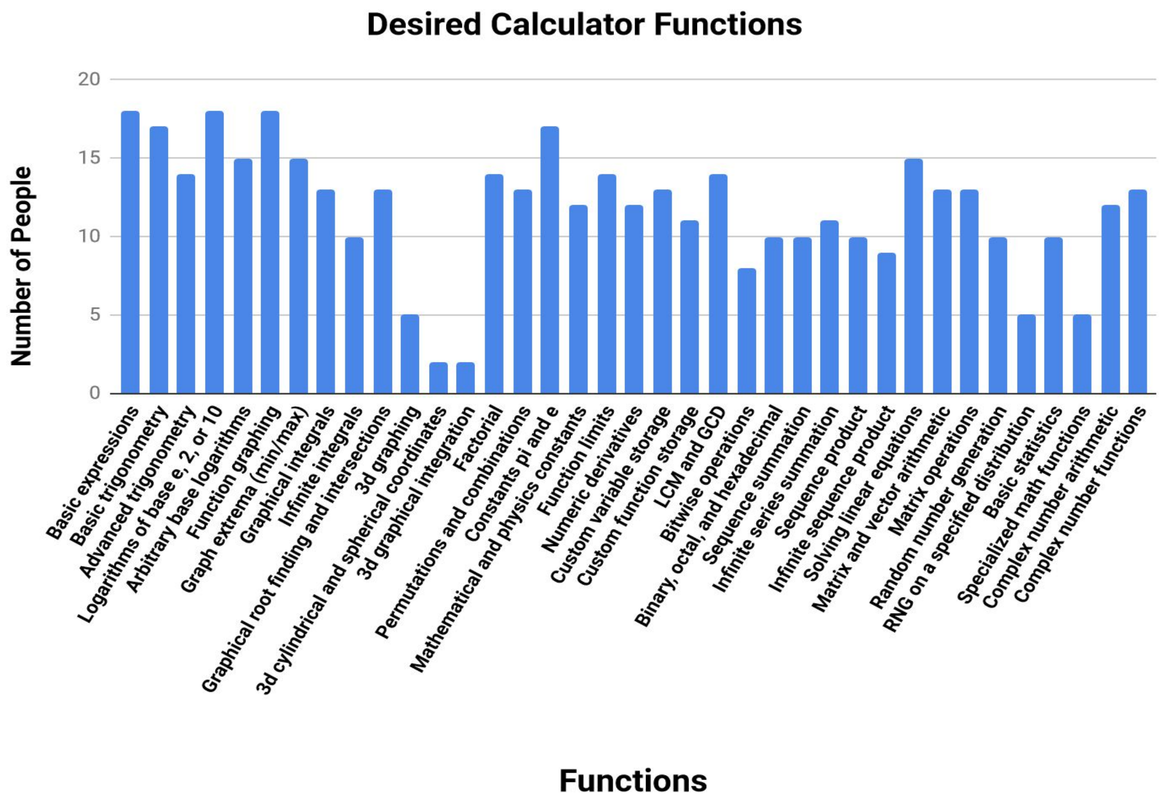

Figure 5.2: Requested Features According to Group Survey

Req. 5.2.1-A	The system shall be able to compute basic operations (addition, subtraction, multiplication, division, exponents, modulus)
Req. 5.2.2-A	The system shall be able to compute basic trigonometric operations (sine, cosine, tangent, with their inverse and hyperbolic variants)
Req. 5.2.3-A	The system shall be able to compute advanced trigonometric operations (cosecant, secant, cotangent, with their inverse and hyperbolic variants)
Req. 5.2.4-A	The system shall be able to compute the lowest common multiple and greatest common denominator
Req. 5.2.5-A	The system shall be able to compute logarithms of base 2, e, 10, and an arbitrary user specified base
Req. 5.2.6-B	The system shall be able to graph multiple arbitrary 2D functions specified in cartesian coordinates
Req. 5.2.7-P	The system may be able to graph multiple arbitrary 2D functions specified in polar coordinates

Req. 5.2.8-B	The system shall be able to compute and display the maximum and minimum of functions over a range
Req. 5.2.9-B	The system shall be able to generate and display a table of values for a given function over a specified range
Req. 5.2.10-B	The system shall be able to compute and display definite integrals with finite or infinite bounds
Req. 5.2.11-B	The system shall be able to compute and display the roots of an input function
Req. 5.2.12-B	The system shall be able to compute and display the intersections between two functions
Req. 5.2.13-A	The system shall be able to compute factorials
Req. 5.2.14-A	The system shall be able to compute permutations and combinations (nPr, nCr)
Req. 5.2.15-A	The system shall make accessible the constants pi and e
Req. 5.2.16-P	The system may make accessible accurate representations of additional scientific constants (such as the speed of light, the mass of an electron, Avogadro's number…)
Req. 5.2.17-P	The system may be able to compute and display mathematical limits
Req. 5.2.18-P	The system may be able to compute numeric derivatives
Req. 5.2.19-A	The system shall be able to store values in variables
Req. 5.2.20-P	The system may be able to store user inputted functions
Req. 5.2.21-A	The system shall be able to compute bitwise operations (and, or, xor, not, logical shifting)
Req. 5.2.22-A	The system shall be able to output in decimal, binary, octal or hexadecimal
Req. 5.2.23-A	The system shall be able to function in radian or degrees mode
Req. 5.2.24-P	The system may be able to function in gradian mode

Req. 5.2.25-A	The system shall be able to compute a finite sequence summation
Req. 5.2.26-P	The system may be able to compute an infinite series summation
Req. 5.2.27-A	The system may be able to compute a finite sequence product
Req. 5.2.28-P	The system may be able to compute an infinite series product
Req. 5.2.29-A	The system shall be able to solve systems of linear equations
Req. 5.2.30-A	The system shall be able to compute matrix and vector arithmetic (element-wise addition, subtraction, multiplication, powers)
Req. 5.2.31-A	The system shall be able to compute and display matrix operations (multiplication, determinants, cross product, dot product, transpose, inversion, row reduction)
Req. 5.2.32-A	The system shall be able to generate random numbers
Req. 5.2.33-P	The system may be able to generate random numbers according to a specified statistical distribution
Req. 5.2.34-P	The system may be able to compute and display basic statistics according to a given set of input data (mean, median, mode, variance, standard deviation, quartiles)
Req. 5.2.35-P	The system may be able to compute the normalized cumulative distribution function
Req. 5.2.36-P	The system may be able to compute the error function
Req. 5.2.37-A	The system shall be able to handle and compute with complex numbers (addition, subtraction, multiplication, division, powers, magnitude, phase, conjugates, trigonometry, logarithms)
Req. 5.2.38-P	The system may be able to input, generate and store spreadsheets

Table 5.2 Computational Function Requirements

5.3 Screen Output Functions

Located in **Table 5.3**, below is the functionality for outputting necessary information to the screen. This output can range from simple numbers to legible graphs.

Req. 5.3.1-A	The system is capable of outputting multiple lines of numbers and characters to the screen
Req. 5.3.2-B	The system is capable of creating complex visual images to display on the screen such as graphs of multiple functions

Table 5.3 Screen Output Function Requirements

6. Nonfunctional Requirements

6.1 Performance Requirements

Our graphing calculator must meet certain performance requirements to ensure an optimal user experience. In terms of computations, it is important that results are fast, reliable, and dependable. Physical durability is also important, as calculators are often passed down in families and rarely get replaced. Battery life is another important factor, for obvious reasons. The performance requirements are listed in **Table 6.1**.

Req. 6.1.1-B	The calculator shall be able to graph an arbitrary function over an arbitrary range in less than two seconds
Req. 6.1.2-A	The calculator shall be able to solve a 4x4 system of linear equations in less than two seconds
Req. 6.1.3-A	The calculator shall represent numbers in double precision
Req. 6.1.4-A	The calculator shall provide deterministic answers
Req. 6.1.5-B	The batteries should last for at least 24 continuous hours of periodic computations
Req. 6.1.6-P	The calculator should withstand drops from a height of 2 meters
Req. 6.1.7-P	The buttons should withstand 10,000 clicks

Table 6.1 Performance Requirements

6.2 Safety Requirements

The calculator must be compliant with safety standards to prevent harm and injury to users. There should not be any catastrophic failures caused by an electrical failure or operating the calculator under reasonable temperatures. Also, calculators are frequently located on desks, so falling is inevitable. The calculator should not be damaged (or cause damage) when that happens. The safety standards are listed in **Table 6.2.**

Req. 6.2.1-P	The calculator shall be compliant with CSA standards
Req. 6.2.2-A	The internal components of the calculator shall be enclosed with a protective casing
Req. 6.2.3-P	The calculator shall be composed of non-toxic materials and shall not pose any health risks to the user through electromagnetic radiation
Req. 6.2.4-P	The case shall be made from non-conductive material
Req. 6.2.5-B	The case shall have no sharp edges that could wound an individual
Req. 6.2.6-P	The calculator shall be safe to operate within -20°C to 50°C
Req. 6.2.7-P	The surface temperature of the calculator shall not exceed 30°C under stress at room temperature
Req. 6.2.8-P	The buttons should stay secure and attached to the case

Table 6.2 Safety Requirements

6.3 Sustainability Requirements

BC Instrument aims to incorporate environmental sustainability into our product as much as possible. Therefore, we aim for sustainability for the full lifecycle of the product: from manufacturing, to disposal. These aims are elaborated in the following table, **Table 6.3.**

Req. 6.3.1-P	The material used in 3D printing for the case must be made from recyclable material
Req. 6.3.2-P	The calculator must be sold in recyclable packaging
Req. 6.3.3-P	The internal components must be recyclable

Table 6.3 Sustainability Requirements

6.4 Engineering Standards

Throughout the development of our system, the relevant hardware, software, and environmental engineering standards must be considered. The referenced engineering standards are listed in **Table 6.4.**

Req. 6.4.1-P	The system will adhere to guidelines set out in ICES-003, outlining the limits and methods of measurement to information technology equipment [6]
Req. 6.4.2-P	The system will adhere to guidelines set out in CAN/CSA-C22.2 No. 0-19 (R2018), outlining the canadian electrical code [7]
Req. 6.4.3-P	The system will adhere to guidelines set out in CAN/CSA-ISO/IEC 9126-1:02 (R2007), outlining systems and software quality requirements and evaluation [8]
Req. 6.4.4-P	The system will adhere to guidelines set out in IEC GUIDE 114:2005, outlining the basics of environmentally conscious design [9]
Req. 6.4.5-P	The system will adhere to guidelines set out in IEC 61566:1997, outlining safe radio transmission frequencies [10]
Req. 6.4.6-P	The system will adhere to guidelines set out in IEC 62209-2:2010, outlining human exposure to radio frequency fields from hand-held wireless communication devices [11]
Req. 6.4.7-P	The system will adhere to guidelines set out in IEC 62031:2018, outlining safety specifications for LED modules [12]
Req. 6.4.8-P	The system will adhere to guidelines set out in RoHS (Directive 2002/95/EC), outlining the restriction of hazardous materials [13]

Table 6.4 Engineering Standard Requirements

6.5 Security Requirements

Table 6.5 below outlines the security requirements to protect the integrity of exams.

Req. 6.5.1-A	The calculator shall be in test mode for the amount of time specified by the instructor and shall not be easily circumventible by students
Req. 6.5.2-A	The features disabled by the remote shall not be usable for the specified duration
Req. 6.5.3-B	The calculator shall not allow arbitrary code execution

Table 6.5 Calculator Security Requirements

6.6 Documentation Requirements

The typical format of documentation for graphing calculators is a paper manual inside the box of the calculator, with an online copy available also for convenient reference at any time. Usually these manuals are quite long, making it unduly challenging to understand which features the calculator has to offer and how they may be accessed (the Ti-84 Plus English online manual is 400 pages long! [14]). We aim to deliver a concise but comprehensive freely available online manual for our users, and **Table 6.6** outlines these documentation requirements.

Req. 6.6.1-B	There should be an online manual or website available to describe the usage and functionality of the graphing calculator
Req. 6.6.2-B	The manual should cover all of the functionality supported by the graphing calculator
Req. 6.6.3-B	There should be a separate online manual or website for the master remote that explains how it can be used

Table 6.6 Documentation Requirements

7. Acceptance Test Plan

7.1 Test Plan Requirements

The test plan for the Proof-of-Concept Prototype is intended to prove that the system is able to address our 3 main requirements:

1) Basic mathematical calculations
2) The RF connectivity between the remote held by a test administrator, and the calculators held by the students/test takers
3) The disabling of certain features via the established RF connection

In the process of proving these 3 critical components of the product's design, security concerns arising from the second requirement will be addressed by the test as well. Other concerns, such as cost concerns and battery concerns can be reported based on data, and will not be part of the test plan.

7.2 Proof of Concept Prototype Test Plan Requirements

The test plan will consist of two phases. First, a prototype calculator will be handed out to two or three of the ENSC 405 administrators. They will be given a chance to use the calculator normally, so they can see the comfort and ease with which the calculator can perform the required mathematical functions seen in section 5.2. Users will get an idea of the speed and simplicity of the prototype over the process of the test.

In the second phase, a remote controller will be used. The LED on the calculators will come on to acknowledge the connection to the remote, and certain calculation features explored previously will be disabled. The testers will then be encouraged to attempt to use these functions, to show they have been properly disabled. The security protocols in place will then be mentioned to give an idea of the difficulty required to hack a calculator model.

7.3 Engineering Prototype differences

The main difference between the proof of concept prototype and the engineering prototype is simply the number of calculators that can be connected to a single remote, and the appearance of the product. In the 2 months remaining in ENSC 405, it is unlikely that a full set of 6-10 prototypes will be available, as it is likely a few revisions will be built and scrapped before the product is ready. It is also likely that the prototypes that are ready for testing will not have the proper finish and polish associated with an engineering prototype. As mentioned in section 7.1, the proof of concept prototype will deliver all essential functions, but there is also the possibility that more calculation features will be added on in a later software revision as well.

8. Conclusion

This document serves as a reference for the product design of BC Instrument's ValueGraph Graphing Calculator. The ValueGraph product is composed of two main subsystems, the graphing calculator itself, and the remote control system that can enable and disable the features of a nearby ValueGraph calculator according to a test administrator's preferences.

The remote control unit will use RF to enable/disable calculation features for the graphing calculator. The RF communications must be secure, and it must be easy to tell if a graphing calculator has had features disabled. If a graphing calculator has had features disabled, this mode is referred to as "test mode". The control unit will only be available to teachers/teachers administrations for security purposes.

The graphing calculator itself must meet the requirements of a normal graphing calculator, while simplifying the layout for convenience. It must also have a competitive price margin to compete in the current market, which is currently monopolized by TI. Further security measures will be implemented to restrict the hackability of the product, and an LED will also be used to allow differentiation between "test mode" and standard working conditions. The product must be portable, durable, lightweight and comfortable for the convenience of the user.

Test plans for the various development stages have been outlined, and the acceptance test procedures have been described in section 7 for the proof of concept device. Finally, the device safety and sustainability concerns were discussed. The product will be designed to adhere to applicable safety standards, and the product's sustainability and environmental impact will be taken into account while completing the calculator and its remote. The final product will have to abide by these standards.

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Appendix A: Abbreviations

Abbreviation	**Meaning**
AP	Advanced Placement
CAN	Canada
CSA	Canadian Standards Association
ICES	Interference-Causing Equipment Standard
IEC	International Electrotechnical Commission
IO	Input/Output
LCD	Liquid Crystal Display
LED	Light Emitting Diode
RAM	Random Access Memory
RoHS	Restriction of Hazardous Substances
ROM	Read-Only Memory
RF	Radio Frequency
RTC	Real Time Clock
TI	Texas Instruments