University of Southern Queensland

Faculty of Health, Engineering & Sciences

Remote Access Intravenous Pump Emulator Training System

A dissertation submitted by

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Abstract

Remote Access Laboratory (RAL) based learning is fairly uncommon outside of engineering faculties. Although, due to an increasing number of online higher education alternatives dominating traditional on-campus education options, and the sheer number of nurses spread across Australia, nursing and midwifery disciplines present an additional candidate for remote access learning applications.

The project aim is to develop a remotely accessible IV pump emulator (IVPE) training system for nursing and midwifery students based on a web server enabled Human to Machine Interface (HMI) operator panel and a Programmable Logic Controller (PLC). This project extends from an IVPE designed in 2012 for a Baxter IV Pump. Since its development, the Baxter IVPE has been used in teaching and research; however, the Baxter IV pump is now no longer commonly used in Australian health facilities and teaching practices. This projects IVPE will be based on the CareFusion Alaris™ system that USQ's School of Nursing and Midwifery is currently using for teaching IV administrations IVPE incorporates educational materials, a learning mode (guided) and an assessment mode (unguided) for user to learn easily and the test their skills on setting up the virtual pump and correctly programming the medication administration.

IVPE was developed using CLICK PLC ladder logic and C-more HMI graphical software design. Main navigation tools, the resources page, the majority of learning and assessment modes have been completed, while technical problems occurred with the webserver configuration, thus remote access is so far unsuccessful. Overall, the system is still in development but shows significant potential for further work by myself or future research students.

University of Southern Queensland

Faculty of Engineering, Health and Sciences

ENG4111 Engineering Research Project Part 1 &

ENG4112 Engineering Research Project Part 2

Limitations of Use

Certification of Dissertation

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

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Signature

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Date

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Nomenclature

AHCPRA	Australian Health Care Practitioner Regulation Agency
Alaris	CareFusion Alaris™
CRT	Cathode Ray Tube
EXT	External/Online studying mode (see also ONL)
EN	Enrolled Nurse
F/W	Firmware
H/W	Hardware
HCP	Health Care Professional
HMI	Human Machine Interface
I/O	Input/Output
ICT	Information and Communications Technologies (see also IT)
IP	Internet Protocol
IT	Information Technologies
IV	Intravenous
IVPE	Intravenous Pump Emulator
LCD	Liquid Crystal Display
LED	Light Emitting Diode
NC	Normally Closed contact
NMBA	Nursing and Midwifery Board of Australia
NO	Normally Open contact
ONC	On-Campus studying mode
ONL	External/Online studying mode (see also EXT)
PC	Personal Computer

PLC	Programmable Logic Controller
PSTN	Public Switched Telephone Network
USQ	University of Southern Queensland
RAL	Remote Access Laboratory
RDC	Remote Desktop Connection
RDP	Remote Desktop Protocol
RN	Registered Nurse
S/W	Software
SCADA	Supervisory Control And Data Acquisition
SGD	Sun Global Desktop
VPN	Virtual Private Network

1. Introduction

The nursing and midwifery profession is a likely partner for remote access learning applications due to Australia's growing number of online higher education alternatives that are dominating traditional on campus education options. This growth combined with the sheer number of nurses spread across Australia, particularly those in isolated rural areas, it is surprising that little innovation has been done in the way of remote access tools to enhance learning experiences in this educational niche.

1.1. Aim

The project aim is to develop a flexible remotely accessible IV pump emulator (IVPE) for nursing and midwifery students based on a web server enabled Human to Machine Interface (HMI) operator panel and a Programmable Logic Controller (PLC).

Previous work completed in 2012 developed an individual access Baxter IV pump emulator based on a Siemens S71200 PLC and WinCC operator interface accessible through Remote Desktop Protocol (RDP) with authentication and external verification through a booking system and Sun Global Desktop (SGD).

The use of SGD and the booking system has proven inconvenient and a web server presents more agile and versatile options. New industrial HMI panels are now available with built-in web server capabilities, meaning that they can be used for both local and remote control for individual and group work constructs.

In addition, a second brand of IV pump is now in use across Australia which requires the development of a new emulator and clinical training device to suit the new hardware. The IVPE will be based on the CareFusion Alaris™ IV Pump.

With the use of industrial automations technology and realistic, user-friendly design, this project aims to produce an enhanced training tool for IV pump training and assessment purposes.

1.2. Objectives

The below listed project objectives are adapted from the project specification (see Appendix A – Project Specification)

- Develop an accurate and user-friendly PLC and HMI emulation of the CareFusion Alaris™ IV pump system.
- Incorporate learning resources and, training and assessment modes.
- Incorporate the capability of a short survey on the final page of the HMI before exiting to gain valuable feedback.
- Explore HMI panel web server technology and configure for remote access.
- Evaluate outcomes, functionality and operation from feedback provided by nursing staff and/or student survey feedback.

Additional objectives that will be undertaken if time and resources permit:

- Additional learning aids, for example, voice hints to be added to text prompts.

IV Pump to be emulated is the CareFusion Alaris™ PC Unit with two Alaris™ Pump Modules (see Figure 1).

Figure 1: CareFusion Alaris™ PC Unit with two pump modules (CareFusion 2016)

The above objectives are quite broad and are in regards to the project as a whole. The below objectives are specifically research related objectives of the project. Through other research projects, the existing Baxter IV pump emulator system was proved significantly beneficial when combined with the real pump training.

This project will attempt to address new research areas, such as:

- Can an emulator be developed for this IV system?
- Does the IVPE emulate the IV system accurately?
- Is the new hardware and software combination applicable and more user friendly?
- Is the webserver technology suitable for this application?

1.3. Motivation

Most hospitals, private wards and medical facilities have upgraded to the CareFusion Alaris™ IV pump, hence, there is significant demand for a new training IVPE. Along with the new pump model, more advanced technology is available to improve ease of access to the IVPE and decrease costs (when compared to existing

IVPEs system expenses). The below statistic is singularly motivation enough to desire improvement of such high rates of IV medication administration errors.

> "Of 568 IV administrations, 69.7% had at least one clinical error and 25.5% of these were serious. Wrong rate was the most frequent error type and accounted for 95 of 101 serious errors. Error rates and severity decreased with clinical experience." (Australian Commission on Safety and Quality in Health Care, 2013).

1.4. Dissertation Overview

This remaining sections of dissertation are organised as follows:

Chapter 2 *covers related background topics.*

Chapter 3 *explores literature and existing technologies related to this project.*

Chapter 4 *details methodology, task analysis and design procedures.*

Chapter 5 *briefly details IVPE page structure, navigation and content design.*

Chapter 6 *covers PLC/HMI software development in detailed phases.*

Chapter 7 *examines and discusses project challenges and outcomes.*

Chapter 8 *concludes the dissertation and suggests further work.*

2. Background

This chapter briefly addresses some relevant background areas to this research project; including the IV system used for this project, Australia's nursing demographic, technology's impact on nursing education over time and a brief history of both programmable logic controllers and human to machine interfacing.

2.1. CareFusion Alaris™ System

CareFusion is a relatively new medical company that combined forces with *Becton, Dickinson and Company* in 2015, their combined vision of IT and medical solutions has brought forward the industry-leading Alaris™ range of infusion. Commonly referred to as the 'brain' of the system, the Alaris™ PC unit is the foundation to the Alaris™ modular platform that allows for customisable infusion delivery. The PC unit can wirelessly transmit key drug and IV therapy data using Guardrails™ software, centralising access to infusion and monitoring data (CareFusion 2016). The PC unit's software, Guardrails Suite MX, is what gives the Alaris™ system the term 'smart pump'. Guardrails provides safety parameters to medication administration programming by double-checking dose, duration and delivery rate as well as protecting critical infusions, such as chemotherapy (CareFusion 2016).

Module types available to use with the PC unit:

- Alaris™ Auto-ID Module - barcode ID scanning unit, supports pump module programming, reducing the likelihood of programming errors
- Alaris™ Syringe Module - syringe pump that helps continuously and intermittently deliver fluid, medication, blood and blood product infusions

- Alaris™ Pump Module - large volume infusion pump that helps continuously or intermittently deliver fluids, medications, blood and blood products to adult, paediatric or neonatal patients
- Alaris™ SpO_2 Module - continuously and noninvasively monitors blood oxygen levels and pulse rates in adult, paediatric and neonatal patients.
- Alaris™ $EtCO_2$ Module - enables continuous respiratory system monitoring, end-tidal (EtCO2) functionality pauses a PCA infusion if the patient's respiratory status falls below hospital-defined limits
- Alaris™ PCA Module - integrates a syringe-based patient-controlled analgesia (PCA) device with large volume pump, syringe, $EtCO_2$ and SpO_2 modules on a single hardware platform

(CareFusion 2016)

CareFusion indicates that a maximum of four modules in total can be used in conjunction with the PC unit; however, this does not include the Auto-ID Module. Figure 2 shows 5 of 6 modules (SpO_2 module not shown) types compatible with the Alaris™ PC Unit.

Figure 2: PC & five modules, left to right: Syringe, Pump, Auto-ID, PC, PCA (CareFusion 2016)

2.2. Registered Nurse and Midwives Statistics

The Nursing and Midwifery Board of Australia (NWBA) has recently released data on Australia's nursing and midwifery registrants in September 2015. To assist in the understanding of the Australian nursing demographic, relevant registrant statistics are listed below:

- Approximately 350,000 registered nurses
- Approximately 30,000 registered midwives
- Approximately 89.5% of registrants are female, 10.5% are male
- Average percentage of registrants in each age bracket is approximately 7.7% of the total number of registrants
- Approximately equal distribution of registrants across ages brackets within the 25 - 59 years range. 55-59 years bracket has the largest number of registrants at 12.9%

(See Figure 3) (NWBA 2016)

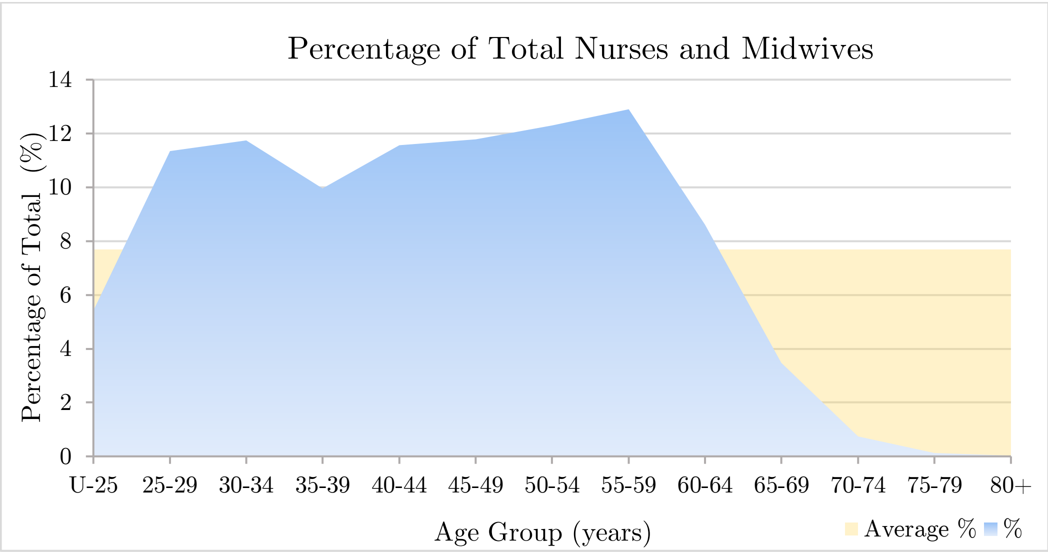


Figure 3: General registration by age group adapted from (NWBA 2016) (U-25 = under 25)

2.3. Technology, education and nursing

Within the last 15 years technology has had a proliferation of advancement. This boom in history has seen the current school students and young adults being raised on technology and many using the internet from a young age. Technological innovation has not only impacted social change but has been the primary driver of educational transformation (Sinclair et al. 2016). This young generation of 'digital natives' has forced traditional learning environments to integrate and support technology in order to enhance traditional face-to-face education (Sinclair et al. 2016).

Before the internet existed, non-school individuals wishing to gain education relocated to metropolitan areas to attend a place of learning, for example a university; however, today's public can access a wide range of higher education, learning resources and learning platforms throughout the internet (Purdue University 2016). Online learning is not uncommon, university students can choose to study online (externally) from wherever they wish. A prime example is USQ, where approximately 70% of the student body studies externally (online) (University of Southern Queensland 2016). Thanks to technology, there is an unprecedented scope for those eager to learn with access to this online world.

An earlier boom in technological advances has also affected education significantly, specifically the education of Australian nursing students from the 1980s onwards. Prior to 1980, nursing education was public hospital based with an apprenticeship style system – a model that produced nurses with exceptional practical clinical knowledge and abilities but with limited theoretical knowledge (Harwood 2011) (Australian Government 2013). Regulatory bodies for nursing were established in each state and territory, providing minimum standards for both the theory and clinical components of nurse education. Subsequently, by 1980, many regional nursing schools began to close as stringent educational requirements were too difficult to fulfil (Australian Government 2013). Also in 1980, was a rapid technological increase in the health sector resulted in regulatory bodies pushing for health care professionals to expand their knowledge base as quick as possible. Student nurses required additional training. Their hours increased from 1000hrs (over 3 years) to 1500hrs (over 3 years), which ultimately made the training system no longer viable outside of the larger metropolitan centres (Australian Government 2013).

In 1984 the decision to move nursing education from the hospitals into the tertiary sector was finalised. The last state to complete the transition was Queensland in 1994, since then all Australian registered nurses have been educated to the undergraduate bachelor degree level (Harwood 2011). Although the transition was successful overall, many professionals have noted how graduate nurses struggle with the transition from a 'thinking orientated' academic environment to a 'practice orientated' clinical environment of the workforce (Harwood 2011). Consequently, Universities are attempting to include as much practical learning as possible with simulated ward environments, real medical equipment and actual placements for work experience. Factors such as; funding for equipment, class size, students to equipment proportions, group dynamics, learning speeds and abilities, and available resources, can significantly affect how successfully a student will learn and then, ultimately, how they will function and perform in the workplace.

Most, if not all, highly skilled science and technology professionals must be continuously learning to stay 'with the times' and develop further knowledge. Health care professionals are expected to complete a number of hours of 'professional development', especially those in remote areas. Due to geographical isolation and/or not being enrolled in a formal course or programme of study, it can be difficult for rural professionals to access learning opportunities for equipment training and face-to-face sessions with professionals (Sinclair et al. 2016). However, as mentioned earlier, our technological era can provide numerous online resources and the possibility of remotely accessible laboratories (RALs).

USQs engineering faculty has many Remote Access Labs across most (if not all) of their engineering discipline areas (University of Southern Queensland 2015). RALs are not common outside of engineering domains; however, they are sparking interest as an education tool in the health sector because of its wide distribution and isolated services across rural Australia and to enhance learning of current university students.

2.4. Brief History of Industrial Automation

Beginning in the 1700's across the UK's majority, the Industrial Revolution was triggered by significant technological, socioeconomic, and cultural changes (Encyclopædia Britannica n.d.). Major technological advances originated mainly from newfound materials; such as Iron and Steel, and energy sources (i.e. fuel, electricity, steam engine, coal, internal combustion engine). From these came the invention of new machines (i.e. power loom, spinning jenny) and new transportation and communication technologies (Encyclopædia Britannica n.d.). As these developments gained momentum small-scaled economies and labour forces were thrust into large-scale specialised industrial processing and manufacturing (Dowling, Carew & Hadgraft 2010). By the mid 1800's the foundation for modern technologies was firmly established.

Semi-automated process lines were incorporated into a wide variety of industries, possibly the most famous example is the first mass produced automobile, T Model Ford, which was manufactured in the early 20th century and designed by Henry Ford (Dowling, Carew & Hadgraft 2010).

A combination of technology advances subsiding and a spike in use of existing technologies placed major strain on telecommunications systems – especially the PSTN where manual, human-assisted switching gave way to automated, electro-mechanical switches; although automated their power consumption was hefty and unsustainable (Weldon 2016). This plateau prompted the research for more efficient electronics and subsequently, the invention of the transistor in 1926 (Computer History Museum 2016).

Before the introduction of the transistor most manufacturing automation was achieved through pneumatics and logic networks of interconnected devices, such as; electro-mechanical switches, relays, timers and counters (Hayden, Assante & Conway 2014). Fully automated systems could be achieved this way; however, system efficiency needed vital improvements with on/off switching being controlled by power relays. With numerous relays required for machinery, relays were stored in bulk in large electrical cabinets that would become a complicated mess of wiring over time; maintenance, troubleshooting and replacing components became practically impossible (Automation Direct 2015). This challenge pushed for the development of technology to control switching and simulate relay control – the basis of modern Programmable Logic Controller (PLC) technology.

2.4.1. Introduction of Programmable Logic Controllers

Major American car manufacturer, General Motors, was struggling with the complicated relay control situation along with many other large manufacturing companies. Engineers from General Motors fed up with the current methods saw an opportunity for change. In 1968, a set of requirements for the development of a 'standard machine controller' were publically released:

- A solid-state system that was flexible like a computer but priced competitively with a like kind relay logic system
- Easily maintained and programmed in line with the already accepted relay ladder logic way of doing things
- It had to work in an industrial environment with all its dirt, moisture, electromagnetism and vibration
- It had to be modular in form to allow for easy exchange of components and expandability

(Automation Direct 2015) (Young 2005)

One of the above design requirements was that the controller had to be *"programmed in line with the already accepted relay ladder logic way of doing things"*, this would ensure all of the existing workers, electricians and plant engineers would have no trouble understanding the new system. The ladder style preserved the physical order of components - the control power hot wire would be the left rail, with the control power neutral as the right rail. Various components such as relay contacts, pushbuttons, selector switches, limit switches, relay coils, motor starter coils, solenoid valves, etc., could be shown in their logical order - these would form the ladder's rungs (Automation Direct 2015).

The above design criterion resulted in the invention of the PLC which has since revolutionised the automation industry (Automation Direct 2015). Multiple companies responded to the design challenge but only one company won the contract with General Motors. The successful competitor was Bedford Associates, run by Richard Morley, who swiftly redirected the company focus to control technology and renamed it Modicon - standing for Modular Digital Control (Young 2005). By mid-1969, the first viable programmable controller was on the market, Modicon's "084". Although a remarkable achievement, sales were low until 1973 when an improved replacement model "184" became available, consequently skyrocketing sales (Automation Direct 2015). While Modicon was an early leader in programmable controller technology, several companies weren't far behind; they were so close behind there's reason to believe that the companies Allen-Bradley, and Siemens, were also producers of the first PLCs (Hayden, Assante & Conway 2014). The development boom over a few years clouds the timeline; however, it remains clear that Modicon is most acknowledged as the first creator.

With development underway and, programming device and communications technology constantly improving, over time PLCs became increasingly more powerful due to the improved computing power and memory size capabilities (Hayden, Assante & Conway 2014). The first dedicated programming devices were impractical and large, with time they were replaced by handheld devices which have now been surpassed by PCs. Currently PLCs are programmed via proprietary programming software running on a computer. PC to PLC communications provides the ability to program and easily test and troubleshoot. In addition, PLCs can be networked with other PLCs, additional I/O modules, motor drives, and human to machine interfaces (Automation Direct 2015).

PLCs are robust industrial electronic systems typically used for controlling a wide variety of mechanical systems and applications, a few applications include traffic signals, elevators, car washes, automatic doors, conveyer belts and even roller coasters (George Brown College 2015). Thanks to human to machine interfacing, PLC technology is so seamlessly and invisibly integrated into our daily lives today's younger generations wouldn't be able to imagine our current society without it (George Brown College 2015).

2.4.2. Development of Human to Machine Interfacing

'Human to machine' interfacing systems are known as HMI systems - simply standing for Human Machine Interface. Traditionally HMI systems are focused predominately on industrial manufacturing and process control, where the HMI communicates with a controller and is used to monitor and control, or exclusively monitor a real world process (Rohee, Riera & Carré-Ménétrier 2007). However, the term HMI can now cover a broad range of systems and devices, and is often even referred to as 'visualization' instead of HMI (Katzel 2012). HMIs can be smart phones and tablets, industrial computers, household appliances, or even office equipment, it is simply a graphical interface that allows human users and the machine to communicate with ease (Tan 2014) (see Figure 4).

Figure 4: A range of smart HMI devices (Katzel 2012)

Initially industrial systems were hardwired and extremely inflexible, HMI was in the form of physical push buttons, lights, gauges, and indicators. After some time, cathode ray tube (CRT) monochrome screens and rudimentary text-based displays were integrated with the existing systems. These systems weren't user friendly and any level visualization had to be programmed into the text-based environment (Katzel 2012).

Following the invention of the PC, and evolving screen and communications technology, the HMI industry changed completely, shifting its focus from hardware to software and from CRT to LCD displays and touchscreens. Industrially hardened control panels and aluminium or steel panel PCs are combined with HMI software graphics to create dynamic operator interfaces (Katzel 2012).

HMI systems provide a visual representation of a control system, real time data acquisition and a user-friendly centralised control centre while allowing the user to build almost any application and maintain it easily through a variety of flexible software (Anaheim Automation 2016).

Figure 5: Example HMI screen of a plant process (Katzel 2012)

Figure 5 shows an image of an example HMI design for a plant process that allows the viewer to read continuous data (i.e. tank and pressure levels), discrete data (i.e. pump on/off status), and allows real world changes to be made to the plant (i.e. turning pumps on/off) (Rohee, Riera & Carré-Ménétrier 2007)

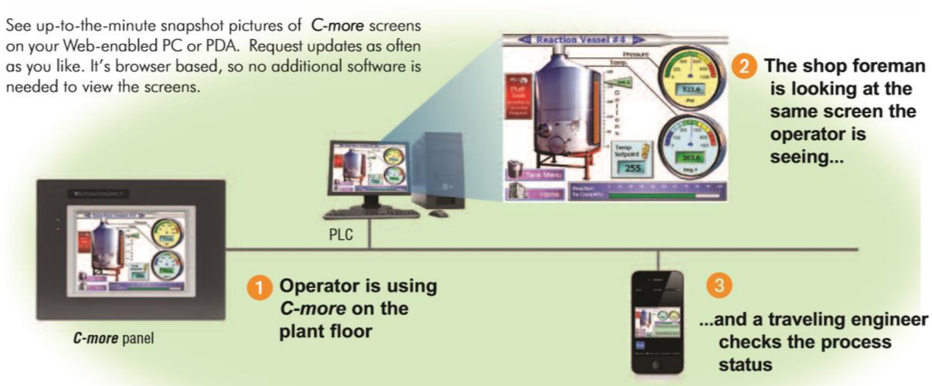


Figure 6: An example of a HMI Remote Access System (Automation Direct 2016)

Figure 6 shows possible uses of the remote access web server capabilities, allowing authorised personnel access to the current HMI panel screen and real time data or screen captures of the panel. This kind of human to machine interfacing is the most commonly used in the industry today; however, this project HMI system won't be controlling a real IV Pump, the HMI/PLC combination together emulates the Alaris™ IV Pump and will be accessed through the webserver feature.

3. Literature Review

This chapter explores existing literature in relation to nursing education frameworks, previous work in this project area, educational tool design techniques, and other existing remote access tools used for educational purposes.

3.1. Current Framework of Nursing Education

As nursing becomes increasingly advanced, technologically and scientifically, expectations of graduate's knowledge and skills are also increasing. Graduates are required to have the capability to make independent clinical decisions to ensure patient safety from the beginning of their career (Harwood 2011).

To ensure all graduates are clinically capable and meet the necessary professional requirements, the nursing's educational framework revolves around the national standard of competency provided by the Nursing and Midwifery Board of Australia (NMBA). Registered nurses (RN) are required to meet these standards before joining the workforce and continue to adhere to throughout their careers (Mater Education 2016).

NMBA's 2016 RN standards for practice consist of the following seven standards, a competent RN:

1. Thinks critically and analyses nursing practice.
2. Engages in therapeutic and professional relationships.
3. Maintains the capability for practice.
4. Comprehensively conducts assessments.

5. Develops a plan for nursing practice.
6. Provides safe, appropriate and responsive quality nursing practice.
7. Evaluates outcomes to inform nursing practice.

(Nursing and Midwifery Board of Australia 2016)

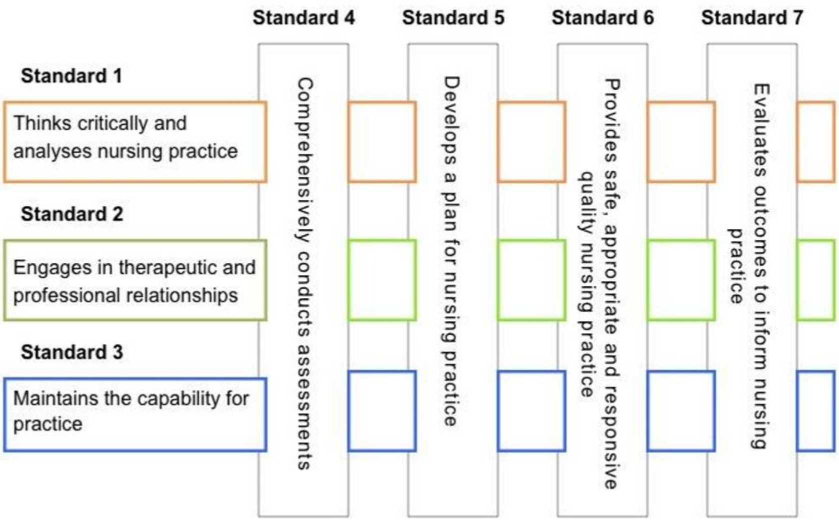


Figure 7: Registered Nurse Standards (Nursing and Midwifery Board of Australia 2016)

Standards 1 and 3 are most related to this research project due to its support for critical thinking, analysis of nursing practice and maintaining the capability for practice.

A basic framework tool is the *Nursing Process* which outlines five fundamental nursing steps: assessment, diagnosing, planning, implementing, and evaluating (Singh 2013).

3.1.1. Pedagogical Aspects of Clinical Training

A recurring characteristic amongst higher-education based clinical disciplines is the dominance debate between theory and practice. Currently there are a variety of learning options, most are face-to-face environments or a blend of face-to-face and online learning. Exclusively online learning for clinical disciplines is not ideal as exposure to practical environments is necessary. Based on the standards above, an equal balance of both theoretical content and practical use of the content seems to be the preferred option.

Figure 8 illustrates a typical (modern) combination of higher-education pedagogical tools for nursing. Student learning occurs via traditional lectures and tutorials, problem based learning, clinical placements, ward simulations, and online learning. Bridging to the health care setting is mostly attributed to simulation and clinical practice.

Figure 8: Model of educational delivery and transition from learner to patient centred (Mater Education 2016)

Even with increased amounts of untraditional learning materials (i.e. online learning), educators are still heavily encouraged to make content relevant, meaningful and engaging. A study, Crookes (2015), explored the views, techniques and definitions of 'meaningful' and 'engaging' teaching in nursing education. Crookes (2015) interviewed a large number of nurse educators on this topic, overall the results were as follows:

- Educators who preferred 'meaningful' methods attempted to make their content meaningful and more relevant through a variety of strategies, including clinical simulation, and by being clinically credible.

- Educators who preferred 'engaging' methods attempted to make their content interesting to capture student's attention via a variety of strategies, including the use of interactive games, engaging with students, as well as keeping a well-managed classroom environment.

A common and effective pedagogical approach for nurse education today is through simulated teaching and learning. Simulated in the sense of roleplay scenarios, not in an engineering sense (i.e. of an online or 'virtual' simulation). Undergraduate students often train in 'mock', simulated wards with manikin patients; however, the equipment (e.g. IV pumps) is all real. Effective simulations offer a method to integrate theoretical and practical learning without endangering real life patients. The large majority of research conducted on simulated clinical settings is extremely positive and overall state that these environments allow students to develop competence and confidence in a safe environment through meaningful and engaging scenarios (Berragan 2011) (Murray, Grant & Howarth 2008).

3.1.2. Current IV Training Methods

At USQ, IV medication administration training is across a few weeks of practical training one - two times a year. Training is completed in simulated ward environments where students work in groups completing activities together (case studies) providing infusions for manikin patients. Group work can be detrimental to some learners who need extra time to independently learn and complete the tasks.

3.2. Medication Errors

Medication errors can have a serious negative impact, not only directly to the affected patient, but also indirectly to the professional reputation, personal wellbeing and integrity to the personnel at fault (Anderson & Townsend 2010).

The *Oxford English Dictionary* defines an error as something done incorrectly through ignorance or carelessness; a mistake, for example in, calculation, judgement or action. Many other definitions exist, although, possibly a more relevant definition can be 'a failure to complete a planned action as intended, or the use of an incorrect plan of action to achieve a given aim' (Aronson 2009). More specifically, a medication error can be described as 'a failure in the treatment process that leads to, or has the potential to lead to, harm to the patient', where the treatment process refers to all medications (Aronson 2009).

The National Coordinating Council for Medication Error Reporting and Prevention (NCCMERP) organisation states a medical error is:

> "Any preventable event that may cause or lead to inappropriate medication use or patient harm while the medication is in the control of the health care professional, patient, or consumer. Such events may be related to professional practice, health care products, procedures, and systems, including prescribing; order communication; product labelling, packing and nomenclature; compounding; dispensing; distribution; administration; education; monitoring; and use." (NCCMERP 2016)

Anderson & Townsend (2010), Aronson (2009) and Terry (2015) all agree that errors can occur within any step of the complex process that encompasses prescribing, transcribing, dispensing, and administering drugs and monitoring patient response.

For a range of medical steps, possible errors can occur when:

- deciding which medicine and dosage regimen to use
    - prescribing faults i.e. irrational, inappropriate and/or ineffective prescribing, under-prescribing, over-prescribing
- writing the prescription
    - prescription errors: i.e. incorrect spelling, unintelligible handwriting
- manufacturing the formulation
    - wrong strength, contaminants, wrong or misleading packaging
- dispensing the formulation
    - wrong drug, wrong formulation, wrong label
- administering or taking the medicine
    - wrong dose, wrong route, wrong frequency, wrong duration
- monitoring therapy
    - failing to alter therapy when required, erroneous alteration

(Aronson 2009)

Seen in Table 1, J.K Aronson (2009) also categorises medication errors into: Knowledge based, Rules based, Action based and Memory based errors.

Table 1: Error categories, adapted from J.K Aronson (2009)

Error Category	Brief explanation
Knowledge	Lack of knowledge e.g. unsure how to program IV pump correctly, prescribing drug incorrectly
Rules	Bad rule e.g. misapplying a good rule
Action	Accident e.g. selecting wrong drug
Technical	Writing illegibly, e.g. 'Panadol' is dispensed instead of 'Pridadel'
Memory	Lapses e.g. forgetting patient's allergies, forgetting to set a maximum daily dose for a 'take as required' drug

Other studies have categorised errors into *procedural* and *clinical* errors. Procedural errors where those similar to forgetting to check ID of patient, didn't check drug packaging for expiry date, failed to record administration data afterwards. Clinical errors where those similar to administering an incorrect amount or rate of IV fluids, administering drug 1 hour or more on either side of the prescribed administration time.

Nichols, et al. (2008) conducted a qualitative study at a Fremantle teaching hospital, in 2005, to study the clinical contexts contributing to harmful medication errors finding approximately 57% of the observed staff members contributed to a significant medication error. The study also stated "most errors were due to slips in attention that occurred during routine prescribing, dispensing or drug administration", these types of mistakes can be categorised as action based. Knowledge based errors were mostly caused by prescribers failing to acquire relevant information before prescribing unfamiliar drugs (Nichols et al. 2008).

International organisation, the Institute for Safe Medication Practices, has identified 10 key elements that can lead to medication errors:

- patient information
- drug information
- adequate communication
- drug packaging, labelling, and nomenclature
- medication storage, stock, standardization, and distribution
- drug device acquisition, use, and monitoring
- environmental factors
- staff education and competency
- patient education
- quality processes and risk management

Overall, the literature points to the majority of errors occur due to lapses in focus, communication and memory; where these lapses were often caused by fatigue and stress. Nichols et al. (2008) supports this by stating "errors were more likely to occur during tasks being carried out after hours by busy, distracted staff, often in relation to unfamiliar patients".

3.2.1. General Medication Error Statistics

Anderson & Townsend (2010) point out that most errors in the administration phase are executed by nursing - since administration is usually performed by nurses. Administration errors account for 26% - 32% of total general medication errors.

"Overall, 80% of medicine administrations were associated with either a procedural or clinical error, with 74% of medicine administrations associated with a procedural error and 25% associated with a clinical error." (Roughead, Semple & Rosenfeld 2013)

In 2013, Australian hospitals were reported by the Australian Commission on Safety and Quality in Health Care Review (ACSQHC) to have incorrectly administered medication to 5-10% of patients during the period 2011-2012. Nationally over that period, Australian hospitals would have approximately received 9 million admissions nationally, 5-10% of those admissions equates to approximately 450,000 to 900,000 patients subjected to an error either on admission or during their stay (Terry 2015).

3.2.2. IV Specific Medication Administration Error Statistics

IV fluid administration is a crucial component of clinical care. IV administration errors can be extremely detrimental to patients and thus can increase admission time and healthcare costs. Although IV administration errors are very serious, little is known about them. Most existing research and data was accumulated in the 1990's or outside of Australia. Two stand-out studies have been performed in Australia since 2000, Han, Coombes & Green (2005) and Westbrook et al. (2011), both of which indicate moedrate to high IV administration error rates and have been used as references in numerous other sources, including the Australian Commission on Safety and Quality in Health Care review in 2013. Table 2 below displays error rates from a range of studies illustrating the erractic results even within Australia i.e. 11.5% to 69.7%.

Table 2: IV administration error rates from international literature.

Origin of Study	Percentage of administrations where at least one error occurred	Literature
Germany	53%	(Taxis & Barber 2004)
UK	49%	(Taxis & Barber 2004)
Brazil	81%	(Hoefel et al. 2008)
Australia	11.5%	(Breeding et al. 2013)
Australia	18%	(Han, Coombes & Green 2005)
Australia	69.7%	(Westbrook et al. 2011)

The last study in the above table, Westbrook et al. (2011), observed 568 IV administrations, 69.7% had at least one clinical error and 25.5% of these were serious. The wrong rate was the most frequent error type and accounted for approximately 94% of the serious errors.

Table 3: Medication administration errors: Australian hospitals 1988-2007 (Roughead, Semple & Rosenfeld 2013)

	Total opportunities for error	Error rate (excluding minor timing errors)	Type of medication error				
			Timing error	Wrong dose	Omission	Wrong formul'n or route	Other
WARD STOCK-BASED SYSTEMS							
Stewart et al., 1991 [53]	2017	369 (18.3%)	75 (3.7%)	46 (2.3%)	82 (4.1%)	6 (0.3%)	160 (7.9%)
McNally et al., 1997 [54]	494	76 (15.4%)	22* (4.5%)	20 (4.0%)	13 (2.6%)	2 (0.4%)	19 (3.8%)
Lawler et al. 2004 [24]	4887	Omission only assessed			369 (7.6%)		
COMBINATION SYSTEMS							
Rippe and Hurley, 1988 [55]	312	52 (16.7%)	24 (7.7%)	6 (1.9%)	12 (3.8%)	3 (0.96%)	7 (2.2%)
Camac et al., 1996 [56]	370†	47 (12.7%)	25 (6.8%)	N/G‡	N/G‡	N/G‡	N/G‡
INDIVIDUAL PATIENT SUPPLY							
de Clifford et al., 1994 [57]	164	10 (6.1%)	1 (0.6%)	2 (1.2%)	5 (3.0%)	0	2 (1.2%)
McNally et al., 1997 [54]	502	24 (4.8%)	12* (2.4%)	2 (0.4%)	7 (1.4%)	0	3 (0.6%)
Thornton and Koller 1994 [58]	242	20 (8.3%)	2 (0.8%)	0	13 (5.4%)	0	5 (2.1%)
IV FLUID ADMINISTRATIONS							
Han et al., 2005 [25]	687	124 (18%)					

* Major timing errors included, minor timing errors excluded – a deviation of 2 or more hours from the ordered time. All other studies define a 'timing error' as a deviation of one or more hours from the ordered time.
† Total data using two different storage sites – ward bay medication drawer and patient's bedside locker.
‡ N/G – insufficient data given to calculate rate of individual error types

In Table 3 above, the highlighted data from Roughead, Semple & Rosenfeld (2013) originated from an IV fluid administration study, Han, Coombes & Green (2005), conducted across three surgical wards in the one Australian training hospital. This study observed a total number of 687 opportunities for error, with 124 of those opportunitites resulting in an error - equating to 18% of IV fluid administrations having at least one error.

Han, Coombes & Green (2005) and Westbrook et al. (2011) both state that an incorrect flow rate was the highest occuring error. Additionally, both works agree that IV administration errors are preventable and more frequent than other general medication administration errors.

3.2.3. Medication Administration Error Prevention

Across the board internationally there is a wide range of literature in relation to preventing general medication administration errors yet there is a limited number of sources addressing strategies for prevention of IV medication administration errors specifically. Most prevention strategy suggestions are aimed towards promoting safer practice amongst undergraduate nursing students whether in regards to general medication or IV treatment administration. A few sources suggest maintaining healthy work environments to minimise stress and fatigue levels in nurses; however, realistically, the nursing profession is very demanding mentally and physically - little can be done in this prevention area.

Suggested prevention strategies were predominantly focused on increasing practical training before placement, increasing knowledge of equipment use and calculating dosage rates, following checklists to minimise errors from carelessness and lapses in concentration - all aimed towards nurse training.

In regards to specifically IV administrations, Westbrook et al. (2011) saw a 10 - 18% decrease in error rates for each additional year of experience the administering nurse accumulated for the first 6 years of experience. Some sources discussed the use of 'smart pump' technology, which refers to the use of IV pump software that aids in error prevention by capturing the error before it reaches the patient (Nichols et al. 2008).

Many nursing education providers and studies suggest adhering to a procedural checklist for general medication administration, commonly referred to as the '6 Rights'.

'6 Rights'

Right patient? Right drug? Right dosage? Right time? Right route? Right to refuse.

Anderson (2010) suggests the following extras:

Right reason for the drug? Right documentation? Right evaluation and monitoring?

The '6 Rights' checklist helps to ensure the correct patient is being treated with the right drug, with the right amount through the right route and at the right time, followed by recording the administration in the medication records. The 'right to refuse' refers to the patient's right to refuse medication and also the clinician's right to withhold administration if they feel necessary to do so.

Overall, excluding the previous IVPE's documentation, there is a distinct lack of literature addressing specific educational technology tools and resources designed to prevent IV medication and infusion errors occurring.

3.3. Previous Work - Baxter IVPE

Firstly, the difference between simulation and emulation must first be defined before continuing with this section. Gaba (2001) defines a simulation as "a technique – not a technology – to replace or amplify real experiences with guided experiences that evoke or replicate substantial aspects of the real world in a fully interactive manner". While Webster (2008) defines emulation as, for example, "having a computer act exactly like [a piece of equipment]". Another way to describe the difference is that a simulator is an environment which models, but, an emulator is one that replicates the usage as on the original device or system.

This research project is building off previous work on an existing Baxter IV Pump Emulator. The existing IVPE was developed in 2012 for Mr. Daniel Osbourne's Engineering Research Project under the supervision and guidance of Dr Les Bowtell and in collaboration with USQ's Dr Victoria Terry for PhD Research from 2012-2015. Terry completed her PhD thesis, *Online versus face-to-face: development,* *refinement, implementation, and evaluation of an online intravenous pump emulator, including outcomes for clinical practice for nursing students*, in 2015, based on developing (with Osbourne and Bowtell) and evaluating the success of the Baxter IVPE. USQ's Nursing and Midwifery staff continue to use this tool for training first year nursing students in the Semester 2's practical sessions. Entry level students are the only level to be trained with the Baxter pump as it is a relatively simple pump although it is no longer commonly used in the Australian health workforce.

Osbourne (2012) trialled two emulation methods for the Baxter IVPE, the first method involved using appropriate IV pump hardware controlled by a PLC and HMI software on a dedicated PC. Whereas the second method involved no physical pump hardware, only PLC and HMI software on a dedicated PC. The second option proved most effective emulation method, as well as the easiest to implement and the most cost effective.

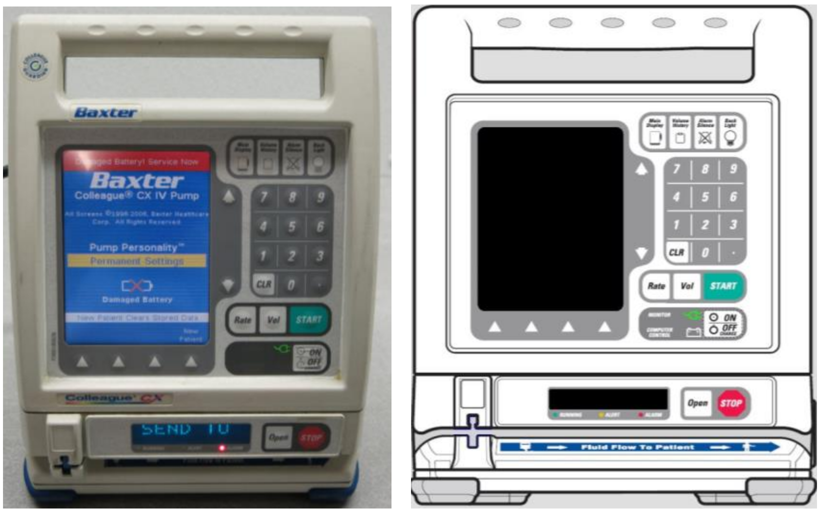


Figure 9: Existing System (Real IV Pump - Left, Emulated Pump - Right) (Osbourne 2012)

The Baxter IVPE is based on a Siemens S71200 PLC and WinCC operator interface (on a dedicated PC) accessible through Remote Desktop Protocol (RDP) with authentication and external verification through a booking system and Sun Global

Desktop (SGD). RDP is a proprietary protocol developed by Microsoft, allows a user to connect to a computer running Windows from another computer running Windows that's connected to the same network or to the Internet (assuming all settings and permissions are correct). The Baxter IVPE included three main sections: resources, a learning mode and an assessment mode (see Figure 10, Figure 11 & Figure 12).

Baxter IVPE second method resources are as follows:

PLC H/W: Siemens S71200 PLC

PLC S/W: Siemens TIA Portal v10.5

HMI S/W: Siemens WinCC Flexible 2008

HMI H/W: PC accessed through RDP

Figure 10: Baxter IPVE Welcome Screen (Osbourne 2012)

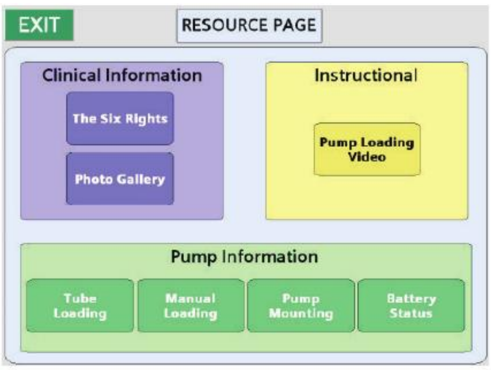


Figure 11: Baxter IVPE Resource Page (Osbourne 2012)

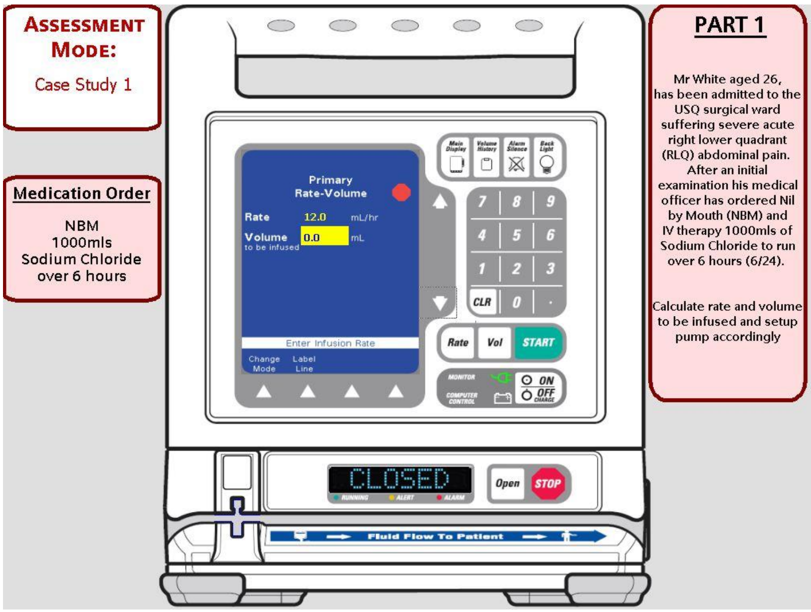


Figure 12: Screen capture of Baxter IVPE during Assessment Mode

After extensive testing, student assessment, surveys and trialling, it was found that face-to-face teaching with real pump was as effective as training with the IVPE on its own, however, results significantly improved when both methods of IV Pump training were used.

Testing of IVPE and USQ nursing students was conducted in three groups; one group of on-campus students with only real pump access, one group of external students with only IVPE access, and the last group was a combination of on campus and external students with access to both the IVPE and the real pump. The last group (Group 3) performed the best out of the 3, while Group 1 & 2 performed similarly.

Group 1: ONC – Real Pump ONLY
Group 2: EXT – IVPE ONLY
Group 3: ONC & EXT – Real Pump & IVPE
Results: Group 1 & 2 performed similarly, Group 3 performed above the others (Terry 2015) (Terry et al. 2016)

Additional data from Terry (2015) showed students mostly felt accessing and booking the IVPE through RDP and the booking system was not ideal and discouraged extra voluntary use. The booking system also limited access to only one individual at a time.

The above results from Terry (2015) and Terry et al. (2016) are extremely important to this project as they highlight the need for a new IVPE (with a more effective remote access solution) to enhance learning capabilities.

3.4. Learning with Information and Communications Technologies

For effective integration of ICT with existing learning frameworks, many studies are suggesting 'meaningful' and 'engaging' techniques. According to Ausubel (1963), meaningful learning occurs when new experiences are related to what a learner already knows. In contrast, rote learning is described by Ausubel as learning a sequence of words with little attention to the meaning - simple memorisation. Meaningful learning assumes the student already has some prior knowledge that is related to the new learning area and are motivated to explore the new material. Another pair of contrasting learning activities types are reception learning and discovery learning. Reception is where the learning areas and information are presented to the student directly as a whole - rather than 'discovering' what needs to be learnt, which is what discovery learning entails. Although Ausubel's work is not central to technology, it still remains a foundation for a large portion of educational frameworks today. Grabe & Grabe (2007) explores Ausubel's theories and presents an informative graphical representation of different learning activities and where they are approximately positioned as proposed by Ausubel (see Figure 13). Grabe & Grabe (2007) also suggests that the most effective learning outcomes occur when meaningful and discovery learning are combined (upper right quadrant of Figure 13).

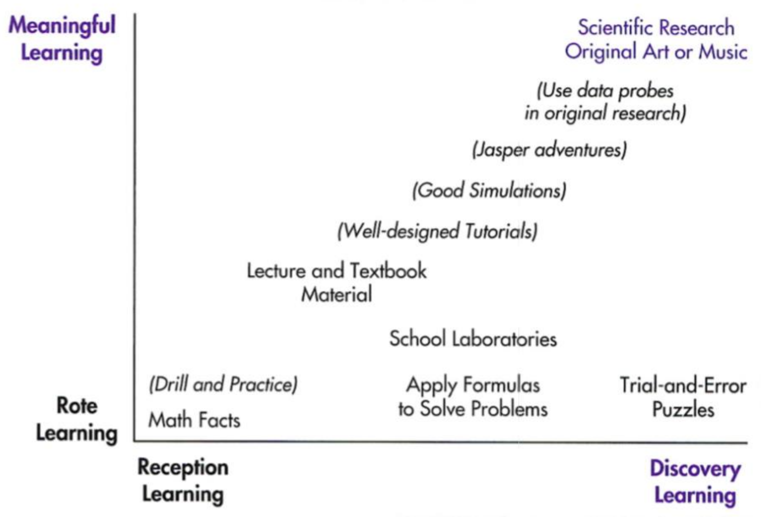


Figure 13: Learning activities categorised by two dimensions (Grabe & Grabe 2007)

Attempts to improve learning through ICT have been ongoing since its arrival, most have been influenced by several theories of learning, namely behavioural, cognitive and social learning theories (Barak 2006). Barak (2006) outlines four instructional principles for effective design and use of ICT supported learning: learning is contextual, learning is an active process, learning is a social process, and reflective practice plays a central role in learning.

3.4.1. Designing ICT tools for educational purposes

Effective ICT education tools incorporate both basic pedagogical and technical principles of interactive design to support the purpose and context of the learning environment. For best outcomes of designing educational ICT tools, stimulate critical thinking and problem solving (Grabe & Grabe 2007). Gillespie et al. (2007) states three key areas which need to be considered when designing a virtual learning environment: look and feel; tools and communication; reviewing design.

1.5.2. Remote Access Technologies in Education

Literature in relation to online learning/remote access learning/e-learning all agree that online technologies allow for students to participate in learning activities when time permits and this freedom has greatly increased the opportunities for many students to participate in formal programs (Oliver 2002).

Although online material can be considered ‘remote access’ outside of engineering and IT faculties, within them remote access is more technical; for example gaining access to a PC or camera feed in an engineering laboratory through the network or through the internet. University of Southern Queensland’s engineering faculty runs multiple remote access laboratories for research, experiments and teaching.

> “Our Remote Access Laboratory (RAL) system provides students, communities and industry with off-site access to practical and laboratory experiments - bridging the gap between real-life and virtual learning spaces... RAL allows students, regardless of location, to actively engage in contextual action-oriented learning and achieve course objectives with less emphasis on attending on-campus training sessions.”
> (University of Southern Queensland 2015)

Osbourne (2012), Bowtell et al. (2012), Bowtell et al. (2013), Terry (2015) and Terry et al. (2016) all support the notion of pairing remote access technology with nursing education. All of the above mentioned sources discuss that remote access tools are uncommon outside of engineering faculties, Bowtell et al. (2012) specifically mentions this might be due to “the intricacies of these practicals not being as straightforward and readily reproducible as typical physics or science experiments”. Osbourne (2012) believes the research conducted points to a niche opportunity for remote access learning tools in nursing and perhaps other academic faculties. There is a surplus of materials focused on simulators, distance learning, RAL and automation technology but few (to none) that offer a combined approach for emulation education tools.

4. Task Analysis & Project Methodology

This chapter outlines the project methodology including: planning, design and test procedures, resources required, project completion timeline, ethical components, and risk management associated with development and completion of the IVPE.

4.1. Project Planning

In the case of large projects, it is best to break down the requirements and goals of the whole project into manageable portions for effective productivity and transitional flow throughout the length of the project. Additionally, separating the project into tasks allows for easier goal and progress evaluation. Planning elements such as an ethics, risk and resources analysis are also necessary for a successful project.

4.2. Task Plan & Analysis

The project objectives specified in Appendix A – Project Specification are useful for breaking down the project into main tasks.

Initial Investigation & Background Research

An initial literature review was necessary to gain an understanding and appreciation of previous tasks that are similar in nature and any related topic area that could aid development. The information gained there was used to make justified design decisions regarding future project tasks.

Design Planning & Development

Design planning and development does not involve software development, only the development of learning and assessment mode purposes, learning resources content, structure of modes and pages within IVPE.

Software & Communications Development

This phase implements the previous phase's planned designs with hardware and software. Communications setup between PLC, HMI and PC is required before software development can be implemented. Within this phase a design and test procedure can be followed for specific, small software implementation tasks (see section 4.2.1). The remote access and webserver functions of the HMI panel with be investigated in this phase as well. (Chapter 6 IVPE Software Development will focus largely on this phase of the task plan).

Evaluation & Results

Results will be obtained through evaluating the level of completion attained by the final stages of the project, and the level to which the system meets design and project objectives. Additional evaluation will stem from my personal qualitative analysis of the system, peer and supervisor feedback, survey results obtained from IVPE, and responses to research questions.

4.2.1. Design & Test Procedure

Design and test procedures are a staple of software development. Following the below procedure will aid to minimise bugs and maintain objectives throughout each step.

Define Task/Problem

Determining what the task is and what it should achieve, it could be a small a task as creating a push button to close a text box. Keep the task as simple as possible. Consider the users action and the emulator's reaction.

Develop Idea

Consider ways to solve the problem/complete the task. Determine the best way to program/design the idea.

Create HMI

Create the task/graphic/button and its associated memory address and nickname (address and nickname together will be referred to as the 'tag' from here on). Check layering and visibility.

Import to PLC

HMI database of tags needs to be imported to PLC program before programming this task.

Write Logic

Once the PLC has the tasks tags in its system, the logic can be written to complete the task with the predefined tags.

Download to PLC & Run

Once the coded sequence seems sufficient, save, compile and download to the PLC. Ensure the program on the PLC is up-to-date.

Test & Debug

Once the program is running, test to locate any bugs in the code. Make any necessary changes or improvements. If changes are made return to *Download to PLC & Run* phase.

Final Check

A final check must be done to ensure task has been completed sufficiently, flows into the existing logic and HMI, and if the task is a pump function - that it is an accurate emulation. If any of these are unsatisfactory return to *Develop Idea* phase.

4.3. Resource Analysis

Required resources include physical hardware, software, PC, personal time, supervision time, nursing resources, and specifications documentation. Table 4 outlines required resources and their estimated time and/or price cost, the majority of the equipment has already been purchased by USQ. Nursing resources include access to Alaris™ IV pump and educational content - this will be discussed further in Chapter 5 . Dr Victoria Terry has recommended to have similar nursing material to the Baxter IVPE.

Table 4: Required Resources and Approximated Costs

Resource	Quantity	Cost ($AU)	Cost (hrs)	Comment
CareFusion Alaris™ IV Infusion Pump	1	-	-	Access available to pump at USQ
Koyo Click PLC (C0-02DD2-D)	1	240	-	Available from USQ
PLC 24V DC supply	1	50	-	Available from USQ
PLC USB to RS232 programming cable	1	40		Available from USQ
PLC CLICK software (C0-PGMSW)	1	0	-	Free download from automation direct
HMI C-more EA9-T6CL Touch Screen	1	700	-	Available from USQ
HMI C-more EA9-PGMSW program	1	180	-	Licence for PC available from USQ
Ethernet Cable	1	5	-	Available from USQ
USQ Staff Support	1	-	21	Allocated staff time per student
USQ Laboratory Access	1	-	120	Estimate
Total		$1,215	141 hours	

4.3.1. PLC Specifications & Resources

PLC resources include the PLC itself (see Figure 14) and the CLICK programming software (C0-PGMSW) that is available for free download. Other accessories to be used in conjunction with it are a 24V DC power supply, RS232 to USB programming cable, and a connection cable to HMI panel.

Figure 14: CLICK Koyo C0-02DD2-D PLC (Automation Direct 2016)

The CLICK Koyo C0-02DD2-D PLC is an analog model. Further hardware specifications can be seen in Table 5, Figure 15 and Appendix C – PLC Specifications. Data types and memory can be also seen in Appendix C.

Table 5: Comparison of PLC types (Automation Direct 2016)

PLC Types	Discrete I/O		Analog I/O		Communication Ports			Battery Backup	RUN time Edit
	Inputs	Outputs	Inputs	Outputs	Port 1	Port 2	Port 3		
Basic PLCs	8	6	N/A	N/A	RS-232	RS-232	N/A	N/A	N/A
Standard PLCs	8	6	N/A	N/A	RS-232	RS-232	RS-485	Yes	N/A
Analog PLCs	4	4	2	2	RS-232	RS-232	RS-485	Yes	N/A
Ethernet Basic PLCs	8	6	N/A	N/A	Ethernet	RS-232	N/A	Yes	Yes
Ethernet Standard PLCs	8	6	N/A	N/A	Ethernet	RS-232	RS-485	Yes	Yes

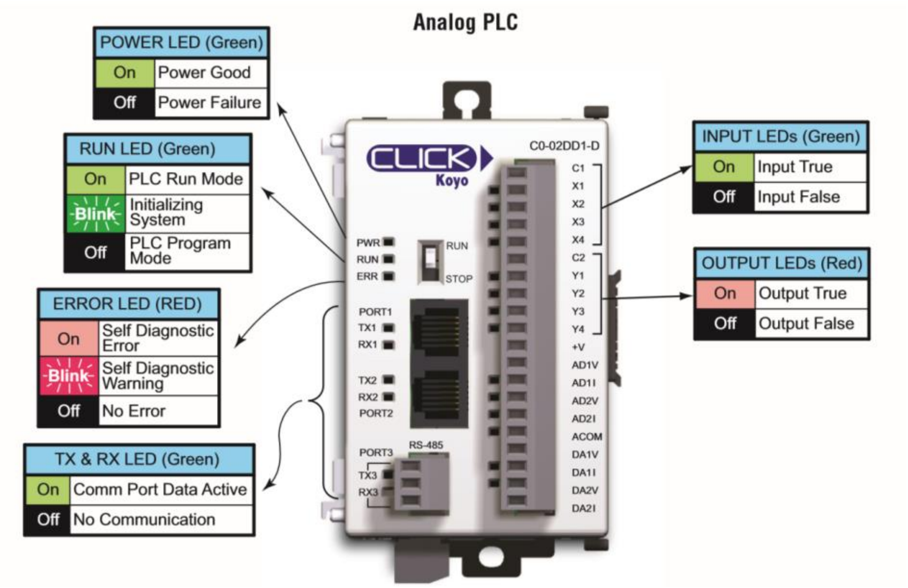


Figure 15: C0-02DD2-D/C0-02DD1-D I/O, ports and indicators (Automation Direct 2016)

Most important details to note from Figure 15, are communications ports 1-3, power/run/error indicators, and run/stop state switch. Additionally, from Table 5 above: Ports 1 and 2 are RS232, Port 3 is RS485.

4.3.2. HMI Specifications & Resources

HMI resources include the HMI panel itself (H/W) from the C-more EA9 touch screen interface panel series and the corresponding C-more HMI software. Other accessories to be used in conjunction with it is an Ethernet cable, and the possibility of a USB computer mouse and extra memory for data logging (i.e. USB or SD card). The EA9 series includes different sized screens with varying capabilities; however, for this project the EA9-T6CL 6 inch full feature model is used. The software C-more EA9-PGMSW is designed for all EA9 models. Figure 16 shows images of an EA9 panel.

Figure 16: HMI C-more Touch Panels (Automation Direct 2016)

Some additional feature specifics are: 6-inch colour TFT (5.7 inch viewable screen), 64k colours, 320 x 240 pixel QVGA screen resolution, 800 MHz CPU, 12-24VDC powered, IP65 (when mounted correctly; for indoor use only), non-replaceable LED backlight, three serial ports, USB 2.0 Type A and B ports, Ethernet port, and SD memory card slot. Further features and specifications can be seen in Appendix D – HMI Specifications.

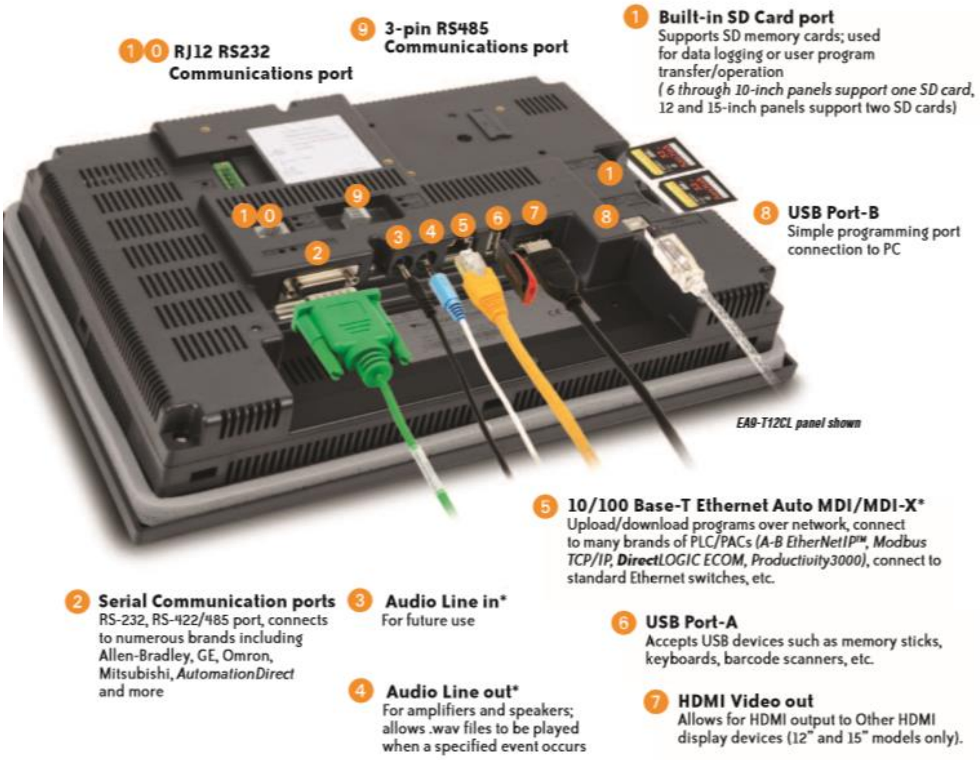


Figure 17: EA9-T6CL Features (Automation Direct 2016)

The C-more programming software environment can be seen in the below figure with Navigation, Object Layer List, Object List and Parts List panes pinned around the screen. In the Object List pane, several object types can be seen. Each object type has many design options for personalisation. This software has a wide range of buttons, indicators, dynamic/static graphics and text, numeric inputs and displays, animated graphics options, as well as basic screen change menu panels. A convenient function is the screen background options of a colour or to display another screen as a background (see Navigation pane - bottom left of Figure 18).

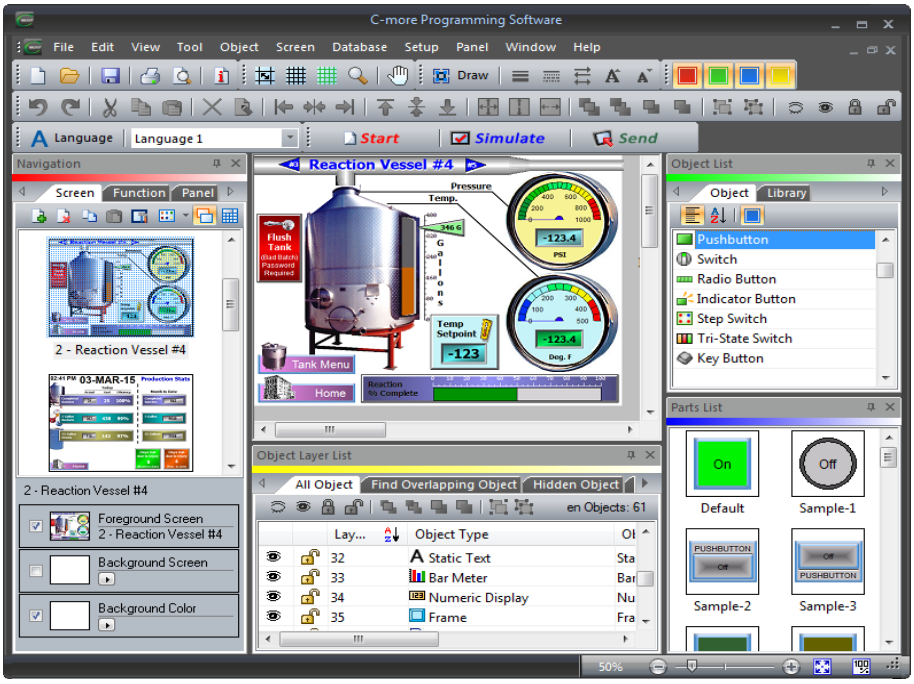


Figure 18: Example Picture of a HMI project being developed (Automation Direct 2016)

4.3.3. Hardware & Communications Configuration Setup

Before design planning and software development phases can commence, initial set up of hardware and communication links between the PLC, HMI panel and PC need to be briefly addressed.

Communications connections are necessary for uploading software to the PLC and to the HMI panel, and also for cross communication between the PLC and panel. The below tables cover the connections types and their respective protocol. Some cables have built-in adapters when converting from one protocol to another. Table 6 includes an analysis of the PLC and PC bi-directional communications. Table 7 analyses the bi-directional communications of PLC and HMI. Table 8 analyses the bi-directional communications of HMI panel and programming PC. Protocols used are serial Modbus (RS232 and RS485), Ethernet and USB.

Table 6: PLC to PC connection ports, cables and protocols

	PLC	↔	PC
Protocol	Modbus RS232	↔	USB
Connector Type	6-pin phone cable RJ12	↔	USB
Port	Port 1 or 2	↔	Any USB port

Table 7: PLC to HMI panel connection ports, cables and protocols

	PLC	↔	Panel
Protocol	Modbus RS485	↔	Modbus RS485
Connector Type	Direct wiring between 3-wire removable terminal blocks	↔	Direct wiring between 3-wire removable terminal blocks
Port	Port 3	↔	Port 2 (#9 in Figure 17)

Table 8: Panel to PC connection ports, cables and protocols

	Panel	↔	PC
Protocol	Ethernet	↔	Ethernet
Connector Type	8-pin Ethernet RJ45	↔	USB
Port	Ethernet Port (#5 in Figure 17)	↔	Ethernet Port

Figure 19: Programming Cable RS232/USB (Automation Direct 2016)

The C-more HMI EA9-T6CL panel can be powered by 12-24VDC or by an AC/DC power adapter (EA-AC) from a 100-240V, 50/60Hz power source. The former option will be used via the PLC's 24VDC power supply and wired to the DC connector at the rear of the panel.

4.4. Consequential Effects

Consequential Effects, Ethics, and Risk Analysis, Evaluation and Control have been relocated to Appendix E – Consequential Effects

4.5. Project Timeline

A Gantt chart was devised in the initial project planning stages as a progress guide, ideally, the timeline should be followed closely. See in Appendix B – Project Timeline.

5. IVPE Initial Design Planning

This chapter briefly outlines visual and structural design planning stages, discusses design objectives, screen layout, navigation and purposes, and educational nursing information to include.

5.1. Design Objectives

Design objectives were briefly touched on in the Introduction chapter. In order to achieve the same or higher learning levels than utilising an actual pump, design objectives for features and functions have been set out to produce the desired outcomes. Figure 20 outlines desired features, functions and outcomes of the IVPE.

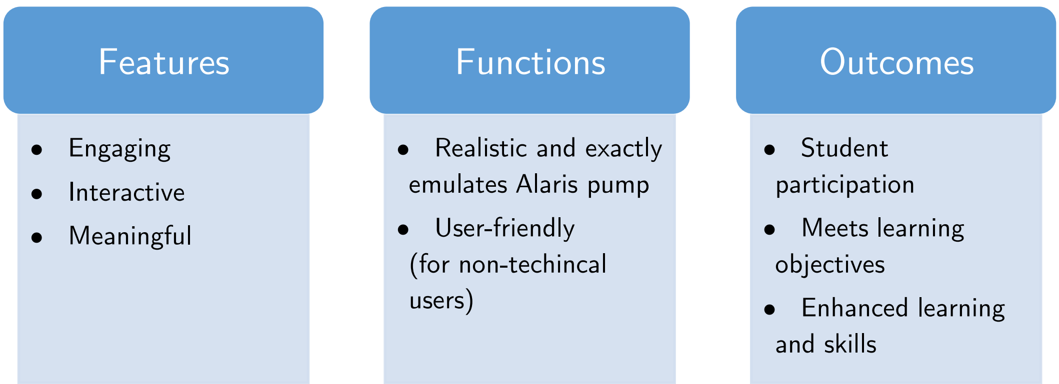


Figure 20: IVPE Design Objectives adapted from (Terry 2015) and (Osbourne 2012)

5.2. IVPE Page Structure & Navigation

A basic structure diagram can be seen in Figure 21, beginning with a welcome page (similar to a ‘limitations of use’ page), then continuing on to the main ‘home’ display with options of continuing to *Resources Page* or *Survey Page,* or entering *Learning Mode* or *Assessment Mode.*

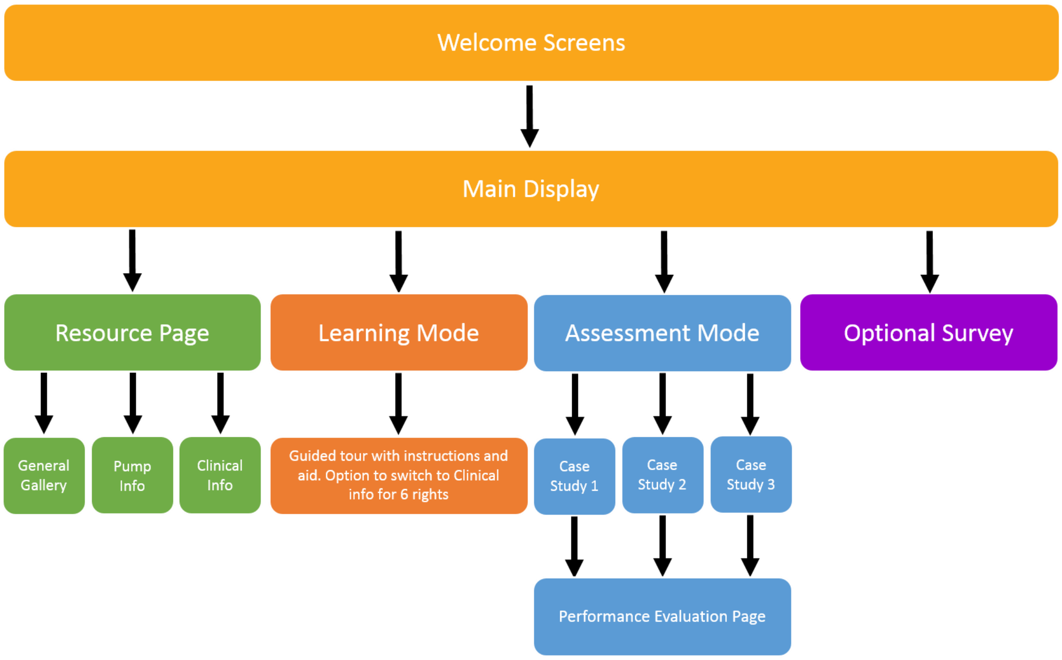


Figure 21: IVPE Page Structure

Each block of Figure 21 will be discussed further in the following section.

5.3. IVPE Mode Purposes & Content

Resource Page

Resources included are related to pump information, clinical skills, instruction and safety information. IVPE nursing content is located in the resources page where there is a general gallery, pump information gallery and medication administration gallery. A large part of the resources included are snippets of the Alaris™ manual and basic clinical safety training i.e. 'The 6 Rights' - is a procedural medication administration checklist for error prevention (see Literature Review section 3.2.3 and Appendix H – IVPE '6 Rights' Resources).

Learning Mode

The learning mode walks the user through how to operate the pump with pop up hints at each step of the process that should automatically close if the step is completed or it is closed before completing the step. The level of guidance will be simple instructions such as 'Press the [...] button', 'Pump A's alarm is on, check [...]'.

Assessment Mode

Assessment mode has no guidance and the pump must be set up according to the requirements of different case studies. The user's independent assessment attempts are assessed and results shown at the conclusion of assessment. Case studies to be included in the assessment mode have been reused from the Baxter IVPE as Dr Terry was satisfied with the activities to remain the same (see Appendix I – IVPE Assessment Case Studies).

Learning & Assessment Mode pump processes will be based on the below flow chart. It is assumed that connecting the medication bag to the administration set is done before priming the line since demonstrating how to do this step will be extremely difficult (unless shown through a series of images in the resources galleries). Assessment mode will utilise this sequence for evaluating user performance by comparing the order of the user's actions and if the case study steps can be completed in the required or most effective manner.

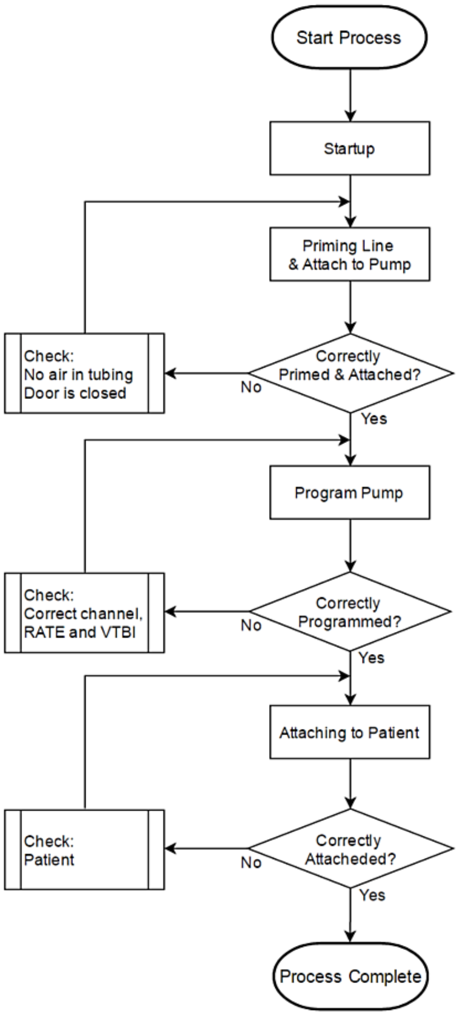


Figure 22: Clinical Experiment Process Flowchart adapted from (Bowtell et al. 2012)

Survey

After completing learning and assessment modes, a survey option will be available for the user to share invaluable feedback on their experience of the IVPE. The survey will target visual design, realism, ease of use, level of difficulty, comprehension, and overall rating of each learning and assessment modes.

6. IVPE Software Development

This chapter covers PLC/HMI software background followed by the software development in detailed phases. Not all PLC code with be shown throughout this chapter. Entire code listing can be seen in Appendix N – PLC Code Listing.

6.1. Software Development Phases

Initial stages of development focuses on aesthetics of the IVPE; an effective emulator duplicates functions and visuals exactly (or as best as possible). Once the visual foundation is ready, pump functions and content development can begin. The remaining sections of this chapter will be structured as follows:

Software Background

- HMI S/W design features (addressed in Chapter 4 - Section 4.3.2)
- PLC S/W information
- Data types & memory addressing
- System data flow overview

Phase 1: HMI foundations & Pump Aesthetics

- Document Alaris™ visuals
- Develop foundation styles
- Develop welcome pages and main menus
- Develop foundation pump visuals in HMI software

Phase 2: Develop Main Program & Resources Page

- Develop structure and programming of resources page
- Add content once programming is satisfactory

Phase 3: Foundation HMI/PLC development

- Learning and assessment modes have the same base of HMI and programming
- Simultaneous development of HMI/PLC as more pump functions/behaviours are added
- This phase completed in segments i.e. do HMI of one pump function, then do PLC programming for that one function, then go back to HMI design for next function

Phase 4: Separate development of learning, assessment and survey modes

- Foundation for learning and assessment modes are ready, break off into developing learning and assessment mode independently
- Further learning mode development includes hints, guidance
- Further assessment mode development includes assessment capabilities, PLC program tracking the user's answers/operation of pump in comparison to the required steps for each case study

Phase 5: Final stages and remote access/webserver setup

- Final stages of debugging and fixing
- Set up of remote access technology and built-in webserver capabilities

6.2. Software Background

Before beginning HMI design and logic programming an understanding is required of what HMI features exist, PLC memory types and ranges are available, and lastly, what/how will the components communicate to each other. Cables, wiring and hardware configuration was discussed in Chapter 4 - Section 4.3.3; however, the ports in question must also be configured internally.

Data Types, Ranges & Memory Databases

The PLC protocol/driver (Automation Direct CLICK Serial) is specified to the HMI S/W when creating a new project, this way the program automatically acquires the PLC data types and ranges. Data types can be seen in Appendix C – PLC Specifications. The main data types and their possible memory address ranges:

Discrete Control Relay (BIT): C1 - C2000

Short Integer (INT): DS1 - DS4500

Double Integer (INT2): DD1 - DD1000

Control bits are utilised for on/off switching (set, toggle or momentary). Double integers will not be common; however they may be needed for large math operations. Apart from static shapes, text and bitmaps, objects in the HMI S/W will require a memory address with a 'Tag Name'. The below Figure is a partial screen capture of HMI memory database - the PLC program also requires this data.

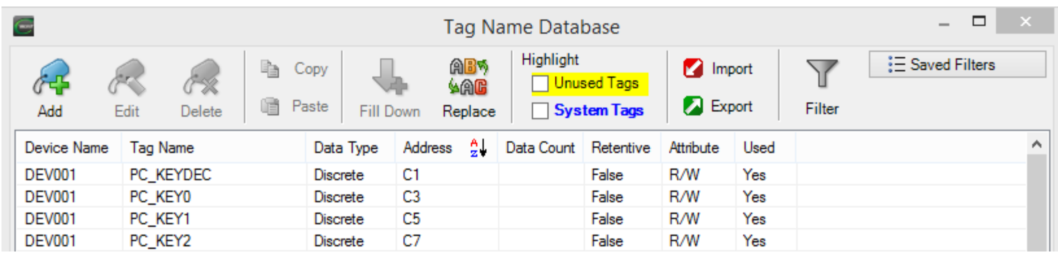


Figure 23: HMI Tag Database

C-more and CLICK are from the same parent company which allows for memory database compatibility. The HMI database can be exported to a .csv file to be then imported into the PLC database; however minor formatting needs to occur first before importing to PLC.

HMI .csv Data Format:

ProtocolID, DeviceName, TagName, DataType, DataCount, Retentive, Address, ArrayStart, ArrayEnd

	A	B	C	D	E	F	G	H	I
1	ProtocolID	DeviceName	TagName	DataType	DataCount	Retentive	Address	ArrayStart	ArrayEnd
2	107	DEV001	SCREEN_NUM	Unsigned_int_16	1	0	DS1	0	0
3	107	DEV001	RECT1	Discrete	1	0	C251	0	0
4	107	DEV001	RATE_VAL_5TH	Unsigned_int_16	1	0	DS45	0	0
5	107	DEV001	VTBI_VAL_4TH	Unsigned_int_16	1	0	DS54	0	0
6	107	DEV001	PC_KEY1	Discrete	1	0	C5	0	0
7	107	DEV001	PC_KEY3	Discrete	1	0	C9	0	0

Figure 24: HMI tag database export file format

PLC .csv Data Format:

Address, DataType, Nickname, Initial Value, Retentive, Address Comment

	A	B	C	D	E	F
1	Address	DataType	Nickname	Initial Value	Retentive	Address Comment
2	DS1	INT	SCREEN_NUM	0	No	
3	C251	BIT	RECT1	0	No	
4	DS45	INT	RATE_VAL_5TH	0	No	
5	DS54	INT	VTBI_VAL_4TH	0	No	
6	C5	BIT	PC_KEY1	0	No	
7	C9	BIT	PC_KEY3	0	No	

Figure 25: PLC tag database export file format

ProtocolID, DeviceName, DataCount, ArrayStart and ArrayEnd columns are all removed. DataType formatting changes: Discrete => BIT, Unsigned_int_16 => INT, Unsigned_int_32 => INT2. Other changes, Retentive: 0 => No, 1 => yes.

The CLICK software control logic language used is called Ladder Logic which consists of placing contacts, outputs and functions on ‘rungs’ of a ladder. The software executes from left to right, top to bottom. A well-structured program maximises readability, efficiency and ease of fault-finding. A typical view of the PLC workspace can be seen in Figure 26.

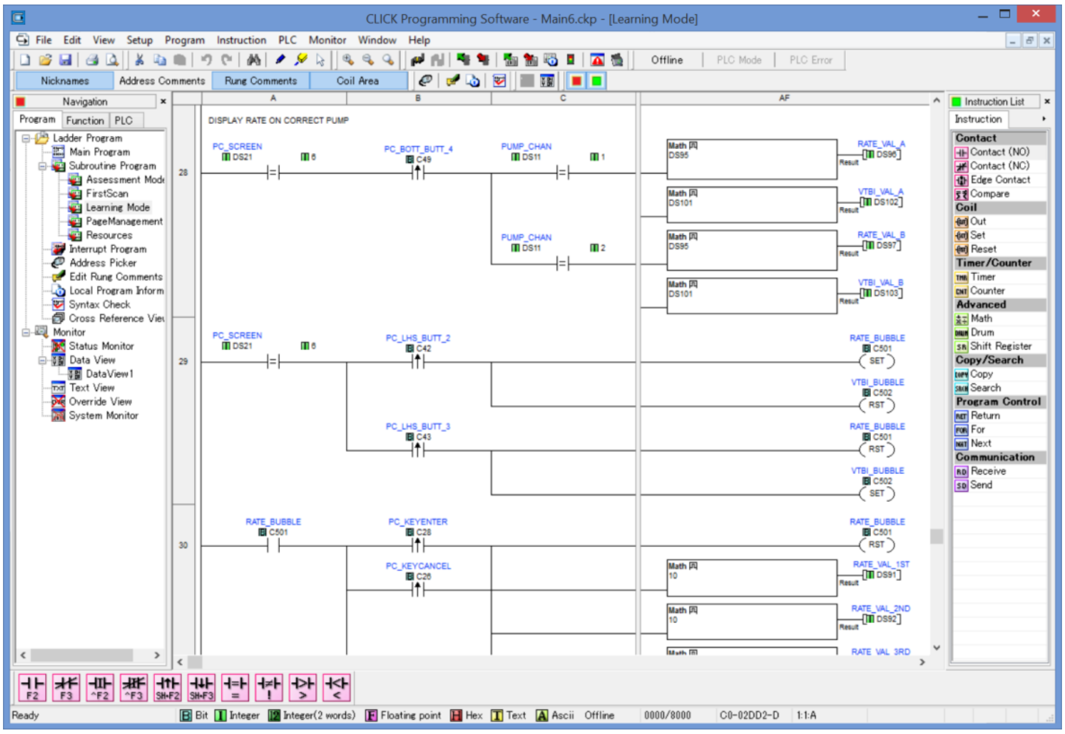


Figure 26: A typical view of CLICK software

See Appendix K – PLC Comm Ports setup

Data Flow

Lastly for software background, data flow and relationships between IVPE user, PLC and HMI is vital to the programming. PLC memory table is the database of tags, addresses and values. Figure 27 illustrates a rudimental data flow sequence that can be explained by: user does an action (i.e. clicks button), HMI reacts by setting necessary tags -> reaction seen by PLC -> PLC follows out actions for that change -> sends new data back to PLC. In the case of *independent* HMI actions, if an event triggers multiple actions where some are completed via PLC code and some are completed independently in the HMI software - there can be a short time delay between HMI code and HMI/PLC code.

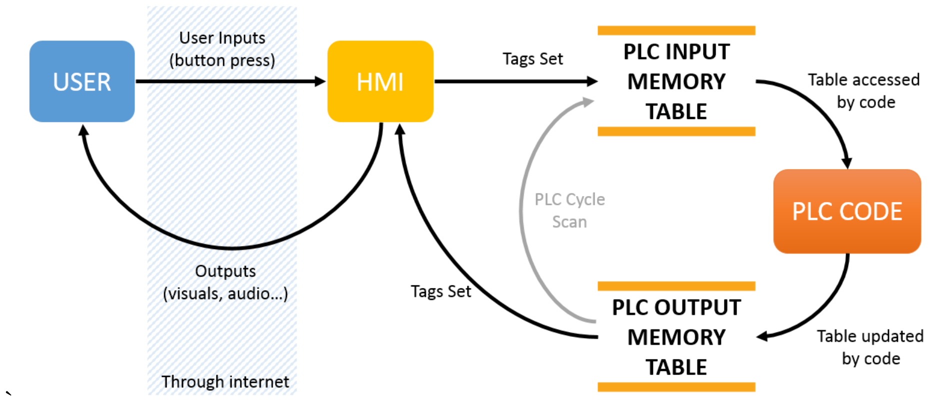


Figure 27: Basic System Data Flow Diagram adapted from (Osbourne 2012)

6.3. Phase 1: HMI Foundations & Aesthetics

In order to realistically and exactly emulate the IV systems functions, visuals and audio were recorded and documented through a collection of images and video prior to software development phases. Ideally, the IVPE should be as realistic as possible, by documenting the functions, visuals, text and audio they can be replicated as closely as possible. Visual cues were documented through a collection of images and videos of the pump and were then transferred into the HMI visuals design.

A high quality photo of a PC with two pump modules was provided by the retailer website. The original photo was the most viable image but still required editing. Photoshop and Paint were used to trim, stretch and tilt the modules until they were more front-on angled with no side views. See Appendix J – HMI PC & Pump Graphics Development for comparison between original and edited, and see Figure 28 for final version.

Figure 28: IVPE Alaris Background Graphics (with tubing)

To begin with 7 screens need to be created: 4 (one for each mode/page), plus 2 background screens and 1 welcome screen. Background screens have a main navigation bar that will always be visible once past the welcome message screen.

Figure 29: Background screen 1 (left) and Background screen 2 (right)

Home screen, learning, and assessment modes will have background screen 1 (with pump graphics) set as a background layer, where all other mode screens (i.e. resources and survey) will use the second for the top navigation bar.

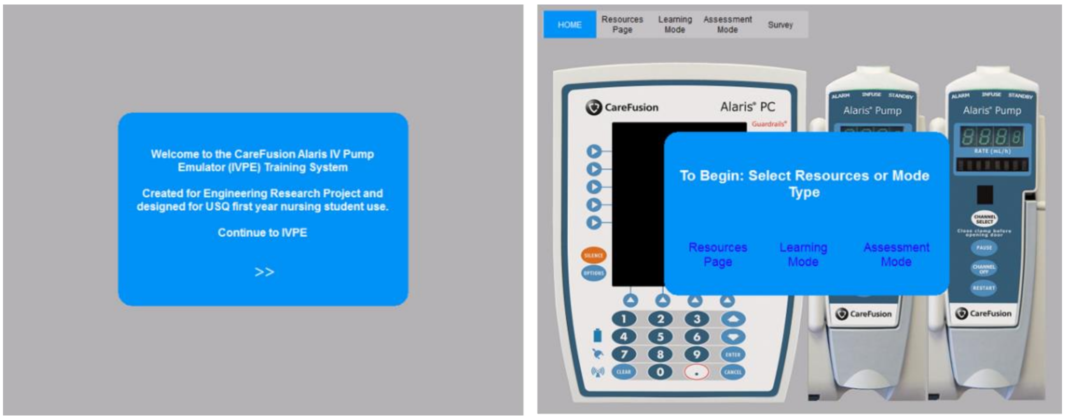


Figure 30: Welcome screen (left) and Home screen (right)

To achieve the above 4 screens, no PLC programming was completed as all actions are within the HMI. Blue round-cornered rectangular boxes are purely for system messages that will usually require a flashing continue button or a flashing option to be selected. In the Welcome screen “>>” a transparent screen change button takes the IVPE to the Home Screen. From there, other screens can be chosen via another system box with screen change buttons. The screen selector bar functions the same as the screen change buttons.

6.4. Phase 2: Main Program & Resource Page Development

6.4.1. Main program

Two main points to note before main program is written: subroutines cannot be nested with this PLC model, and secondly, the PLC can track current HMI screen number through integer DS1 - this was setup in the HMI *Panel to PLC* dialog box.

Subroutines:

- First scan call (SC2 internal system bit) to pre-set variables before use
- Page management is call each scan to reset variables when not in use throughout the entire program execution
- Resources subroutine is called when screen number is 15
- Learning mode subroutine is called when screen number is 25
- Assessment mode subroutine is called when screen number is 40
- Survey subroutine is called when screen number is 45

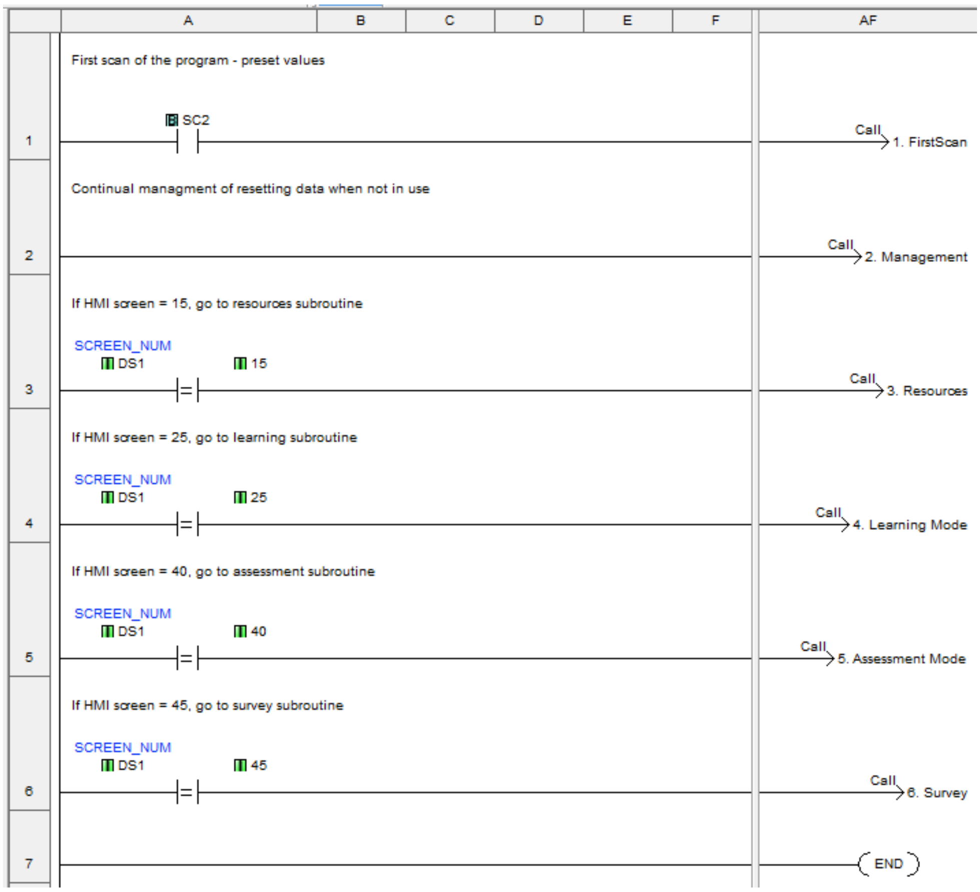


Figure 31: Main Program with subroutine calls

6.4.2. Resources Page

HMI

Resources page consists of 3 menu buttons for general gallery, pump information gallery and medication administration (‘6 Rights’) gallery that trigger ‘pop-up’ windows containing resource graphics. Each gallery has a rectangular button on the left of the screen, the colour is softer when it is unselected and more intense when it is selected. These gallery selection buttons trigger the pop up window with the gallery contents.

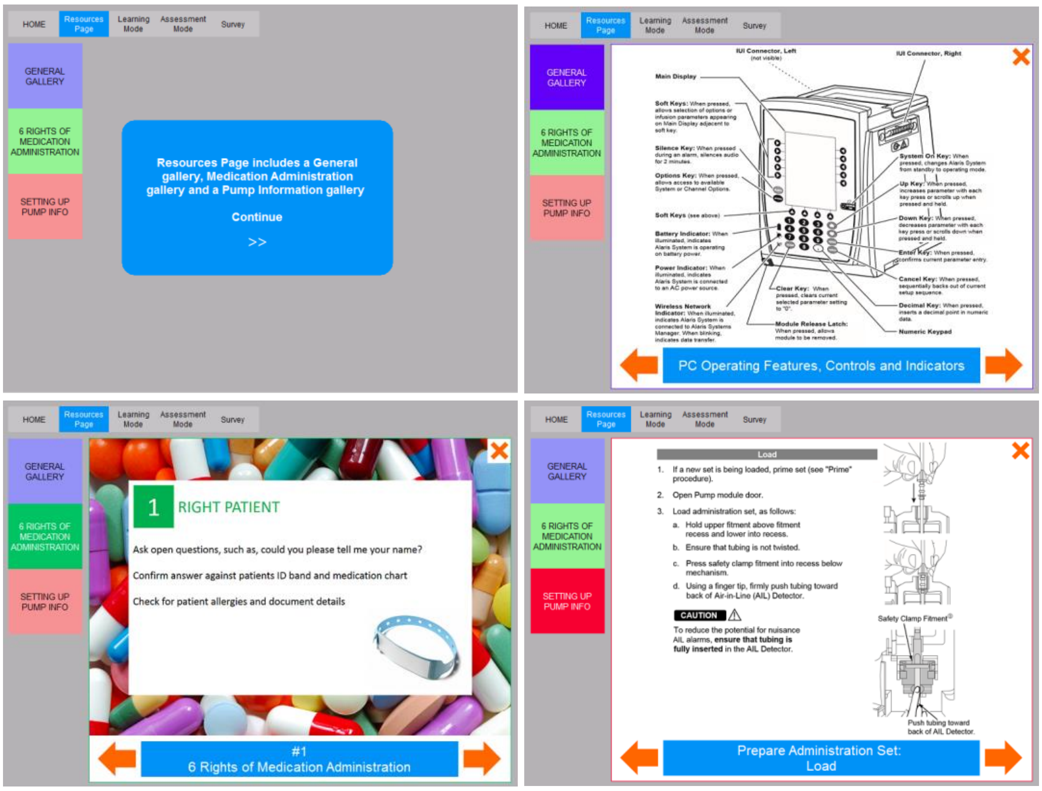


Figure 32: Resources Page - Nursing Content

Each pop up window has the same orange cross exit button - this ensures only one window is open at a time. The current gallery picture being shown is determined by the gallery picture value tag. Left and right arrows increment and decrement integer number respectively. Also loops back to start when at the end of the gallery and in the opposite direction - see code below.

PLC

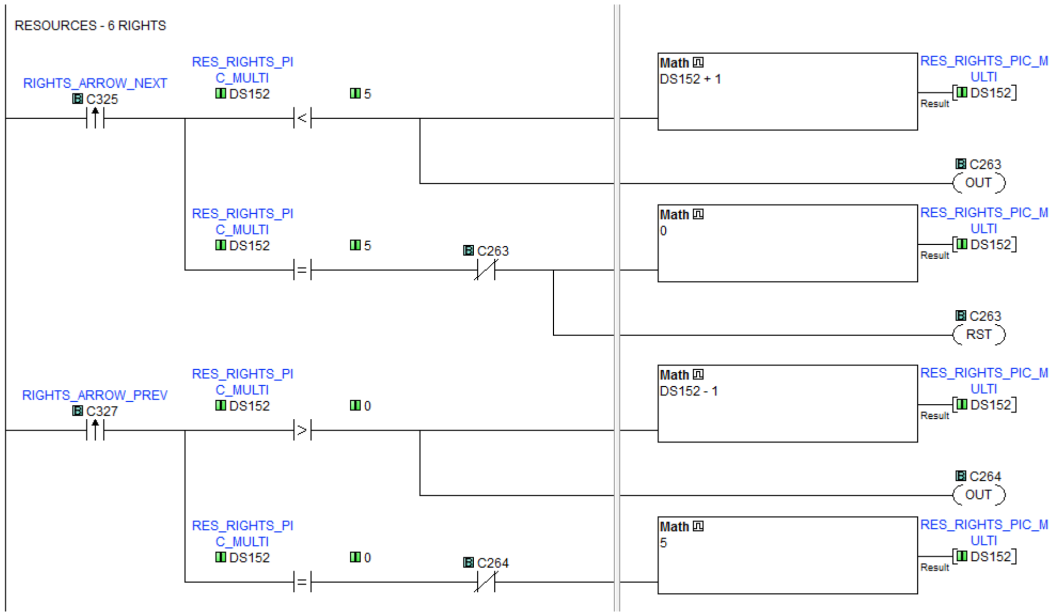


Figure 33: Incrementing with NEXT arrow and decrementing with PREV arrow

Above figure is the code for clicking through the '6 Rights' gallery which has 6 pictures within a *multistate bitmap*, therefore the pictures will correspond to integer values of 0 - 5.

The logic can be explained in simple terms:

- If the gallery isn't on the last picture & the next arrow is pressed -> go to next picture (increment)
- If the gallery is on the last picture & the next arrow is pressed -> go to first picture (pic 0)
- If the gallery isn't on the first picture & the previous arrow is pressed -> go to previous picture (decrement)
- If the gallery is on the first picture & the previous arrow is pressed -> go to last picture (in this case, pic 5)

Figure 34 below is simply resetting the gallery integers when they are not in use. Pressing the orange exit cross closes all pop-up windows which in turn resets the values.

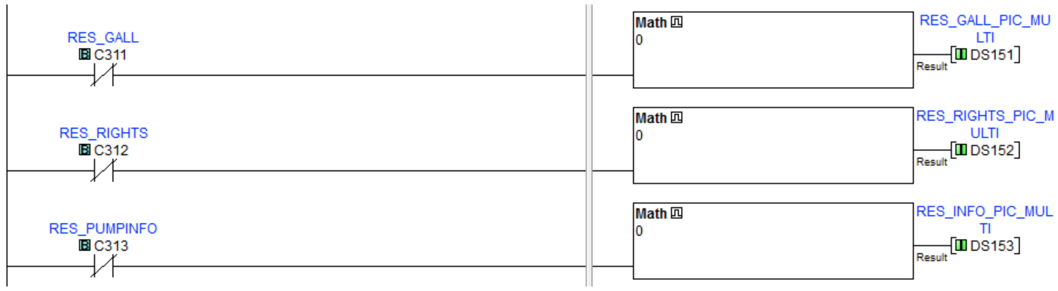


Figure 34: Resetting gallery integers if the gallery is closed

6.5. Phase 3: Foundation HMI/PLC development

Initially for this phase, learning and assessment modes were built off the same 'base model' of pump graphics, pump statuses (alarm, running, standby), internal PC screens, text on pump displays, invisible push buttons over each soft key on the PC and on the pumps. Once the 'base model' was sufficient, it was duplicated to form learning and assessment screens. The duplication meant there had to be a clear separation between mode/page memory locations. Duplicated data was moved to new locations so the two modes wouldn't interfere with each other. A segmented data plan was used to plan and track all the modes and they're respective tags (see Appendix L – Data Tags & Memory Plan). Some buttons that are only momentarily ON or OFF don't require to be duplicated.

Utilising the Design & Test Procedure covered in Chapter 4, a segment of HMI is created then the PLC code is developed for that segment/task. It became apparent that

A significant part of the visual emulation is recreating the PC screens. Two main backgrounds are used behind the text.

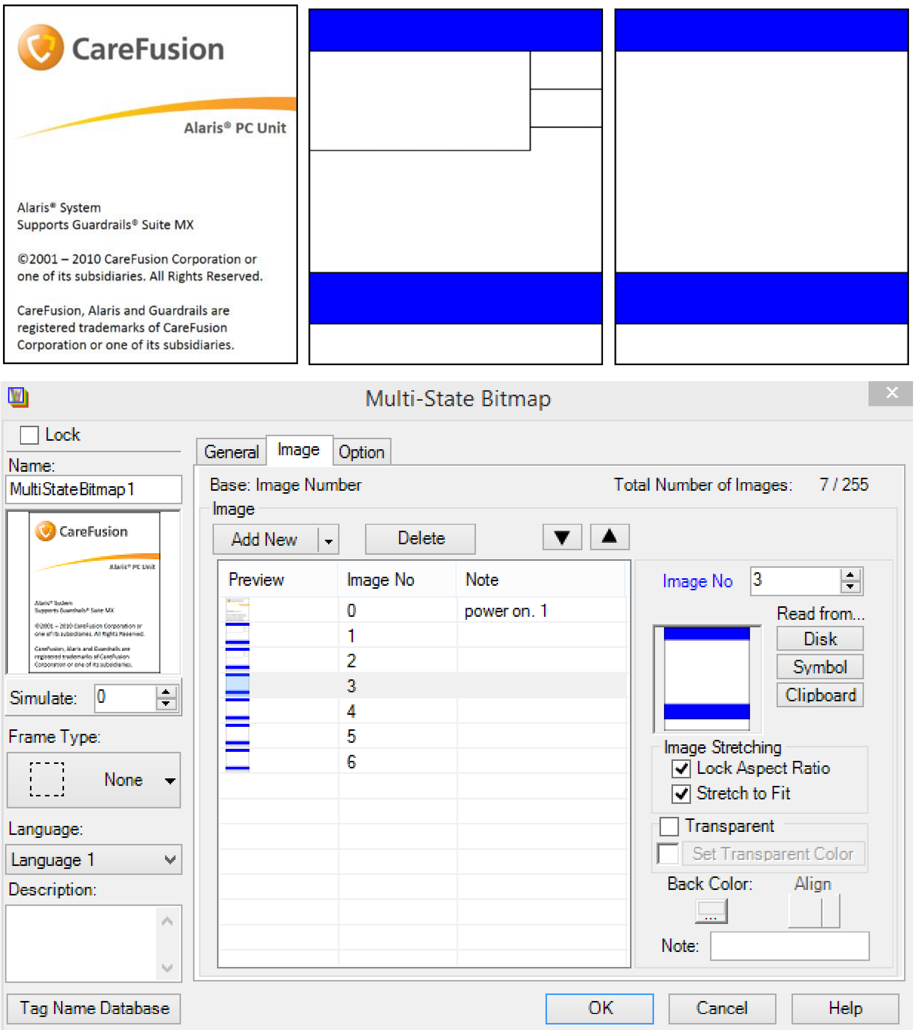


Figure 35: PC screen backgrounds in multistate bitmap

There are 7 screen configurations within the PC so far (0-6). In the HMI S/W groups of text layer over the multistate PC_SCREEN, text layers have visibility options set to a particular tag and value, i.e. text for screen 5 turns visible when PC_SCREEN = 5. The PC screen number is controlled by the PLC code, whereas the visibility is within the HMI.

Demonstrating how to insert the administration set (IV tubing line) is difficult to keep realistic. Utilised this cartoon IV tubing and lined it up with a real pump photo.

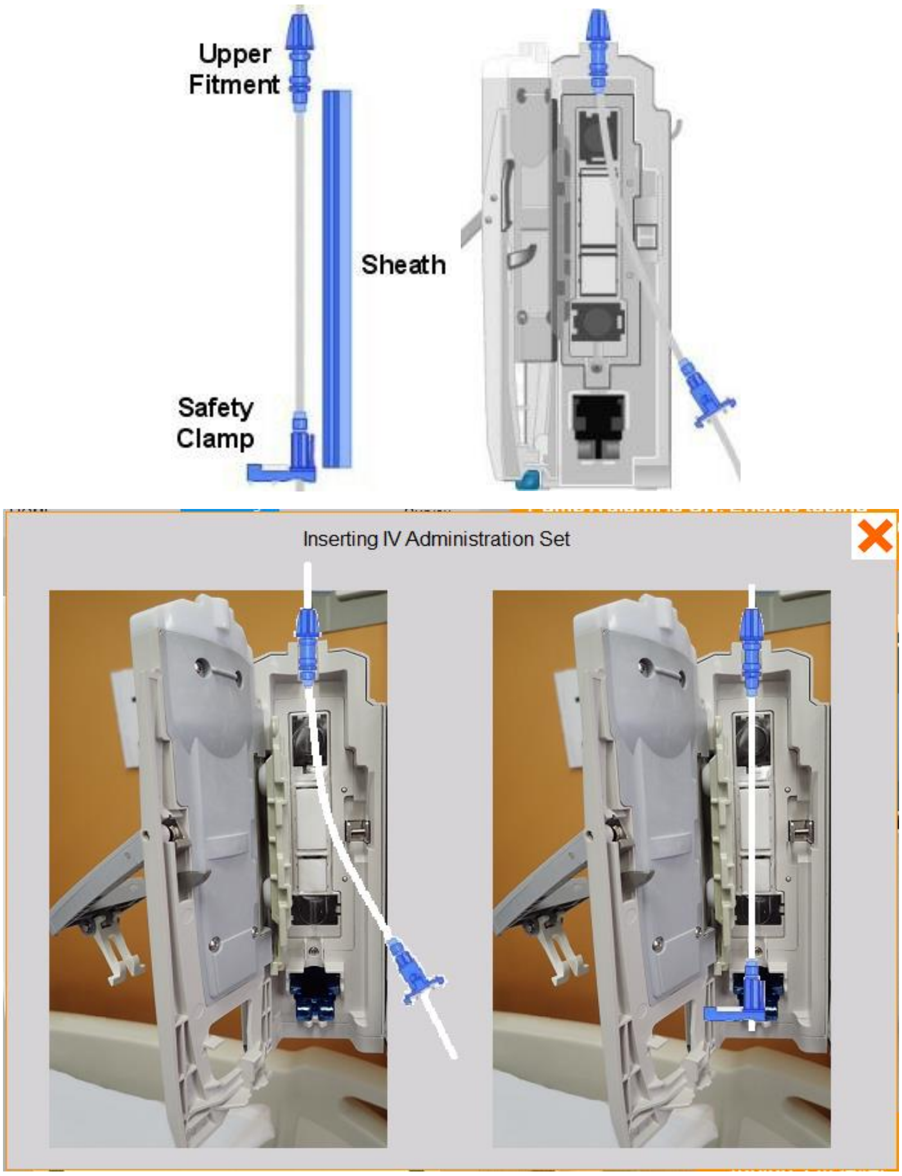


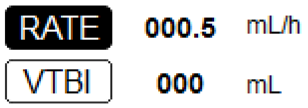
Figure 36: Inserting IV Set before programming channel

Channel A is now primed and inserted into pump, rate and volume of medication should be programmed.

Entering RATE and VTBI

1^{ST} PRESS = 5

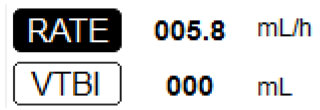
RATE_VAL = 5



2^{ND} PRESS = 8

RATE_VAL = RATE_VAL*10 + 8

= 58



3^{RD} PRESS = 2

RATE_VAL = RATE_VAL*10 + 2

= 582

Figure below shows a section of code from the learning mode subroutine, just before the 1^{st} numerical key is pressed to enter the rate.

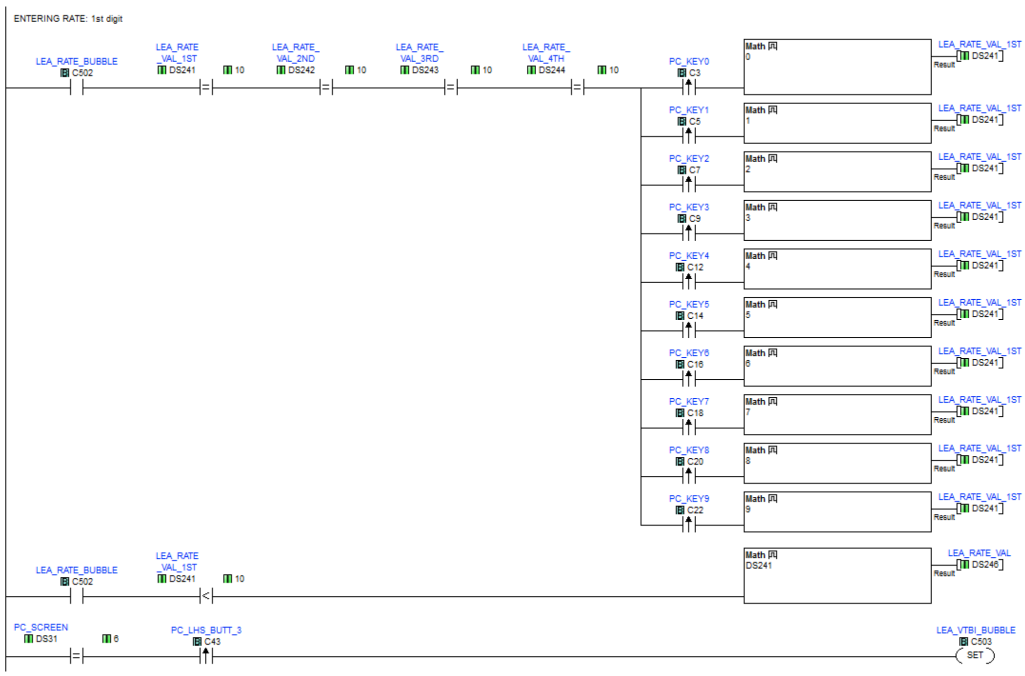


Figure 37: Control logic for 1st key press of RATE

Numerical entry via PC invisible buttons

Rate entry has 4 places, therefore can take up to 4 key presses to fill the entry. Tags used from learning mode rate:

LEA_RATE_VAL_1ST

LEA_RATE_VAL_2ND

LEA_RATE_VAL_3RD

LEA_RATE_VAL_4TH

If only 0 to 9 can be pressed, make the initial value of those data tags 10, thus if a value is smaller than 10 a button has been pushed. The same techniques are used for entering VTBI and assessment modes RATE/VTBI.

Top row of the below figure shows the three status lights: red - Alarm, green - Running (Infuse), yellow - Paused (Standby). When the alarm is triggered the indicator light flashes on and off, the other lights are solid when triggered.

Figure 38: Recreating pump status indicator lights

When the Alarm status is triggered an elongated beeping tone begins and won't stop until the problem is solved or the SILENCE soft key is pressed on the PC. In the HMI S/W there is an event manager database that allows combinations of tags to trigger an event which can sound an alarm. It also has the option of looping the sound file a specified number of times or indefinitely. Indefinitely is what is needed for this alarm type; however, if the trigger conditions are changed the alarm does not stop. A similar problem is the *idle* beep which begins after 30 seconds after the last key press and can be silenced. Without the alarm or idle noise, the quality of emulation will decrease. Short noises that only require one loop work well e.g. soft key button press (standard one beep), illegal button press noise (short double beep), and start-up beep (pulsed beep).

6.6. Phase 4: Separated Development of Learning, Assessment & Survey Screens

6.6.1. Learning Mode

Before beginning the learning mode the user is prompted by the warning bubble in the next figure. *Yes* closes the warning bubble while *No* takes the user to the 6 Rights resources page.

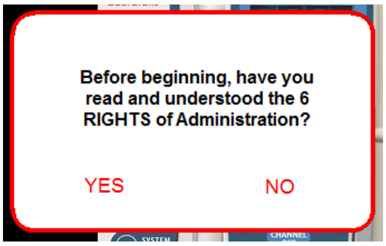


Figure 39: Warning Bubble

Developing hint bubbles for guided learning mode was fairly simply process, for each PC screen there was a new hint. Hint bubbles display a short instruction on what step to take next, to close the bubble either complete the instruction or click the flashing 'X' for close. Bright orange has been used for all hint bubbles.

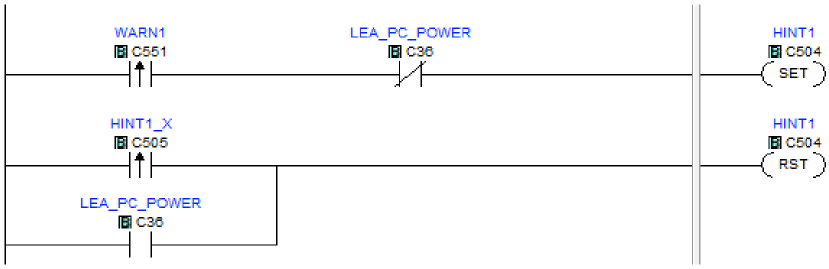


Figure 40: Small block of code demonstrating Hint 1 bubble

Hint 1 will become visible when the warning pop up is closed and the pump power is still off. Hint 1 refers to turning the power on, therefore by turning the pump on or clicking the close 'X' the hint will reset to invisible.

The following two figures showcase multiple hint bubbles and current progress level of learning mode (not all screens shown).

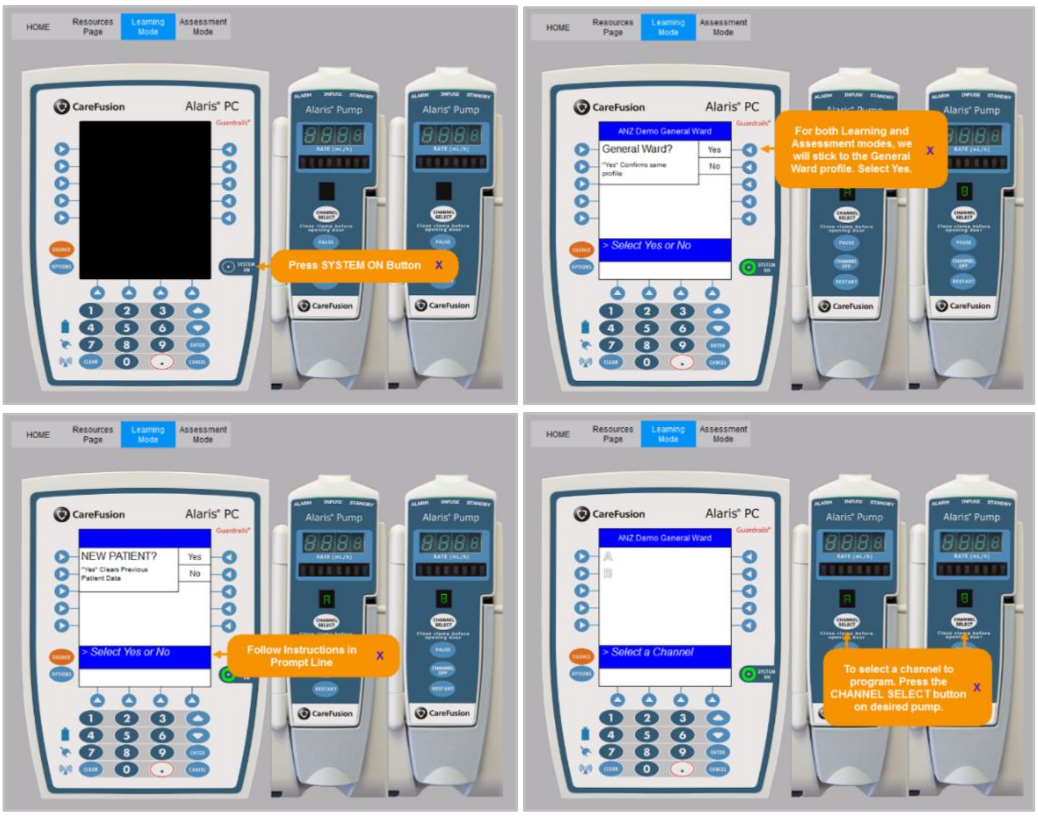


Figure 41: Four Screens within Learning Mode showing Orange Hint Bubbles

Figure 42: Learning Mode screen shots

6.6.2. Assessment Mode

Beginning Sequence

- Assessment mode system welcome bubble, press “>>” to continue
- Select case study
- Countdown: 3, 2, 1, START
- Timer begins, case study is available for drop down

Figure 43: Assessment mode progress

6.6.3. Survey

After completing learning and assessment modes, a survey option is available for the user to share their thoughts and experiences. The survey was to target visual design, realism, ease of use, level of difficulty, comprehension, and overall rating of each learning and assessment modes; however, due to time constraints it was not been completed to its full potential.

Figure 44: Incomplete Survey Page

After much consideration, it might be that the HMI's data logging feature is an effective way to retain survey data between users and power loss. The data logging features are aimed for presenting line trend graphs and saving their data in log files on SD card storage.

An average rating for each category over all the surveys would be the most helpful feedback. In order to get this information, extra tags are needed for calculations and storage. Accumulate data by summing up rating from the one category, also need to track how many surveys have been completed. Total summed rating divided by the number of surveys will give an average rating for each category.

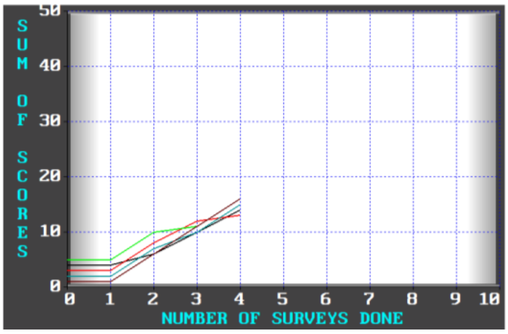


Figure 45: Data logging features

6.7. Phase 5: Final Stages

Due to time constraints Phase 4 remains incomplete, thus, final stages of testing and debugging cannot be completed.

6.7.1. Remote Access - Webserver Configuration

The built-in webserver function of the panel required configuration through the HMI software. In Ethernet connection setup the IP address of the panel was changed to 192.168.2.3 with a default gateway of 192.168.2.2 and remote access was enabled in the panel network systems dialog box. See Appendix M – Webserver Setup for extra screen shots.

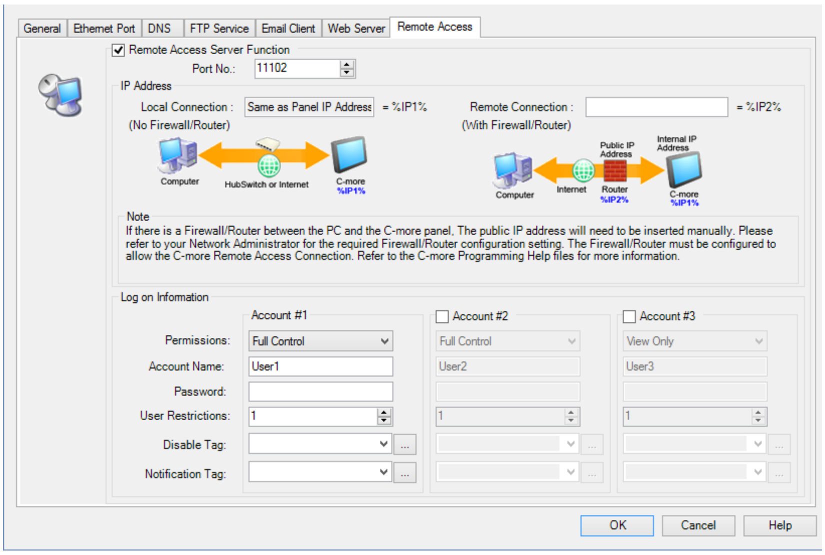


Figure 46: Remote Access panel settings

Panel Communications Details:

IP Address: 192.168.2.3

Subnet mask: 255.255.255.0

Default Gateway: 192.168.2.2

To check connections are working, command prompt window was used to ping (handshake) panel IP address from PC. PC Ethernet port status/settings can be checked in the Windows Control Panel -> Network and Internet -> Network and Connections. Theoretically, entering the panel IP Address (192.168.2.3) into a browser should show just the panel screen in real time and can interact with it but instead the below figure occurs.

Figure 47: C-more Panel IP address in browser

The top two menu items contained lists of screen names and statics screen shots of HMI screens - no interaction, no live updates. The menu item “Remote Access” proved to be unhelpful communications instructions.

Figure 48: C-more Panel IP address in browser - remote access page

7. Results & Discussion

This chapter discusses and evaluates outcomes such as the extent to which project objectives were met, the general performance of the emulator, and the IVPE's effectiveness as an enhanced training system.

Results will be obtained through evaluating the level of completion attained by the final stages of the project, and the level to which the system meets design and project objectives. Additional evaluation will stem from my own qualitative analysis of the system, peer and supervisor feedback, survey results obtained from IVPE, and responses to research questions.

7.1. Technical & Non-technical Challenges

A range of technical and non-technical hurtles were encountered with varying severity. Non-technical issues that arose were illness (multiple times), stress & personal issues. These problems plus the misjudgement of task time frames unfortunately disrupted the prepared Gantt chart timeline.

In the technical areas most issues that arose were able to be solved. Initially, the HMI was set to EA9-T15CL (15 inch model) to ensure high quality images, the software would adjust the programmed screen size down to the actual size for the panel. Unfortunately, this increased the runtime size over the 26MB limit, thus the HMI software was downsized to the 12 inch model - now the runtime is sitting at approximately 21MB. Therefore, if time permitted to continue developing the IVPE the runtime would increase with the project size again resulting in another downsize in image quality. Downsizing is also very inconvenient as it resizes and/or moves objects in the software project. If cost wasn't an issue the 12 or 15 inch would be the best option as the runtime limit rises to 82MB. Also, compared to the Baxter pump, the Alaris system is a lot larger thus requiring a larger screen area to maintain visibility of small buttons and screen details.

Replicating Guardrails software was out of the scope of this project. In both assessment and learning mode, menus such as *Guardrails IV Fluids* or *Guardrails Drugs* options have been left empty as access to the drug dosage programming was difficult and unnecessary for basic training - *Basic IV Fusion* is sufficient to get to a rate/volume programming screen.

Another unresolved technical issue was the configuration of the webserver technology. Communications configuration was successful, yet it was assumed the webserver would duplicate systems functions and interactions - not a list of static screen captures of each screen in the program. The information provided by Automation Direct unclearly implied a website may have to be created to configure the style of remote access tech that was hoped for initially.

7.2. Achievement of Objectives

Develop an accurate and user-friendly PLC and HMI emulation of the CareFusion Alaris™ IV pump system

- Visuals and functions are essential for a successful emulator, the accurate, high quality pump graphics accentuate the realism of the IVPE; however, the functions still require further work to be emulated in full.

- Operation of IVPE has been extremely simple to follow.

Incorporate learning resources and, training and assessment modes

- Educational materials were incorporated into the resource page for users to view pump information from the Alaris manual, the '6 Rights' of medication administration, and a selection of general help gallery. Both the programming and design was successful for this page, although further material could be added.

- Training mode was the Learning mode which incorporated hints with pointers to guide the user through the IV set up and programming procedures. This mode allows for a little freedom for users to navigate around the pump and allow alarms to trigger without damaging equipment, causing a patient harm or being assessed.

- Assessment mode has not been completed, it has all the pump functions of the learning mode (minus the hints) plus a successful countdown to start time, drop down case study panel and a timer to display the length of the user's assessment period.

Incorporate the capability of a short survey on the final page of the HMI before exiting to gain valuable feedback

- The survey was to target visual design, realism, ease of use, level of difficulty, comprehension, and overall rating of each learning and assessment modes; however, due to time constraints it was not been completed to its full potential. Considerations have been made into how to store survey data in the panel to calculate average ratings for each category.

Explore HMI panel web server technology and configure for remote access

- As mentioned earlier the webserver remote access technology was so far unsuccessful and failed to replicate the interactive programming, instead a list of static screen captures of each HMI screen were provided. The information provided by Automation Direct unclearly implied a website may have to be created to configure the style of remote access tech that was hoped for initially.

- Built-in webserver technology does still seem like the right direction for this remote access application; however, perhaps with a different model of panels or turn the follow on project towards a software engineering student.

Evaluate outcomes, functionality and realism from feedback provided by nursing staff and/or student survey feedback

- Since the system isn't complete, qualitative feedback data through the survey option was not obtained in time. These areas were previously discussed and evaluated through other means.

7.3. Overall System Evaluation

Overall if time had allowed further work to be completed, this project would have been significantly more successful. Although incomplete, development work so far has been moderate quality, phases or sections that received additional attention performed/were displayed significantly better.

8. Conclusions & Further Work

This chapter evaluates the final conclusions that can be made from the research completed. It will also comment on the further work that needs to be completed to further support this research.

Due to time constraints and unfortunate delays, the IVPE is yet to be fully completed. Main navigation tools and the resources page have been completed although there is always room for improvement. The majority of learning and assessment modes have been completed, while the survey page and its capabilities are still under construction with panel testing still required in regards to data logging the survey results. Other technical problems occurred with the webserver configuration, thus remote access is so far unsuccessful. Overall, the system is still in development but shows significant potential for further work by myself or future research students.

Recommendations & Further work

- Completion of final tasks in learning and assessment modes, including administration tube insertion animation and/or better detailed instructions,

- Complete construction of survey page in order to gain invaluable feedback as there is limited evaluation without the qualitative survey results

- Evaluate realism, functionality, operation from feedback provided by nursing staff/students

- Investigate how to configure built-in webserver

Learning Experiences & Personal Reflection

Completing this research project has been an extreme challenge to remain motivated for a full year and manage the workload that is required for a satisfactory dissertation. Although challenging, I have certainly enjoyed the struggles of graphical software design, improving my communications knowledge and gaining vital PLC skills for my future career. If I had the option I would be happy to continue working on this project until it can be implemented for USQ use or until it's at an appropriate level to pass on to another pumped research student.

References

Anaheim Automation 2016, *HMI Guide*, <http://www.anaheimautomation.com/manuals/forms/hmi-guide.php#sthash.kmd28iNN.dpbs>.

Anderson, P & Townsend, T 1999, 'Preventing high-alert medication errors in hospital patients', *Journal of Pharmacy Practice*, vol 12, no. 5, pp. 373-373.

Anderson, P & Townsend, T 2010, 'Medication errors: Don't let them happen to you', *American Nurse Today*, vol 5, no. 3, pp. 23-28.

Aronson, JK 2009, 'Medication errors: what are they, how they happen, and how to avoid them', *Q J Med*, vol 102, no. 8, pp. 513-521.

Australian Government 2013, *History of Commonwealth involvement in the nursing and midwifery workforce*, <http://www.health.gov.au/internet/publications/publishing.nsf/Content/work-review-australian-government-health-workforce-programs-toc~appendices~appendix-iv-history-commonwealth-involvement-nursing-midwifery-workforce>.

Ausubel, DP 1963, *The psychology of meaningful verbal learning.*, Grune & Stratton, New York.

Automation Direct 2015, *History of the PLC*, <http://library.automationdirect.com/history-of-the-plc/>.

Automation Direct 2016, *Automation Direct: Home Page*, <http://www.automationdirect.com/adc/Home/Home>.

Automation Direct 2016, 'C0-02DD2-D Click PLC Specifications', Manual.

Automation Direct 2016, 'EA9-6CL C-more Specifications', Manual.

Barak, M 2006, 'Instructional principles for fostering learning with ICT: teachers' perspectives as learners and instructors', *Education and Information Technologies*, vol 11, no. 2, pp. 121-135.

Berragan, L 2011, 'Simulation: an effective pedagogical approach for nursing?', *Nurse Education Today*, vol 31, no. 7, pp. 660-663.

Bowtell, L, Kist, AA, Osbourne, D & Parker, V 2013, 'Improving clinical practice outcomes for nurses with an interactive emulator', *Global Engineering Education Conference (EDUCON), 2013 IEEE*, pp. 1103-1108.

Bowtell, L, Kist, AA, Osbourne, D & Parker, V 2013, 'Interactive emulator system to aid clinical practice outcomes for nurses', *International Journal of Online Engineering*, vol 9, no. S5, pp. 32-37.

Bowtell, L, Moloney, C, Kist, AA, Parker, V, Maxwell, A & Reedy, N 2012, 'Enhancing nursing education with remote access laboratories', *International Journal of Online Engineering*, vol 8, pp. 52-59.

Breeding, J, Welch, S, Whittam, S, Buscher, H, Burrows, F, Frost, C, Jonkman, M, Mathews, N, Wong, KS & Wong, A 2013, 'Medication Error Minimization Scheme (MEMS) in an adult tertiary intensive care unit (ICU) ', *Australian Critical Care*, vol 26, no. 2, pp. 58-75.

CareFusion 2016, *Our Products*, <http://www.carefusion.com.au/our-products/infusion/infusion-system/alaris-system-with-guardrails-safety-software/alaris-pc-unit>.

Computer History Museum 2016, *1926: Field Effect Semiconductor Device Concepts Patented*, <http://www.computerhistory.org/siliconengine/field-effect-semiconductor-device-concepts-patented/>.

Crookes, K 2015, 'Meaningful and engaging teaching in nursing education', PhD Thesis, School of Nursing, University of Wollongong.

Dowling, D, Carew, A & Hadgraft, R 2010, *Engineering Your Future: An Australasian Guide*, 1st edn, John Wiley & Sons Australia Ltd, Milton.

Encyclopædia Britannica, *Industrial Revolution*, <http://www.britannica.com/event/Industrial-Revolution>.

Engineers Australia 2010, *Code of Ethics*, <https://www.engineersaustralia.org.au//sites/default/files/shado/About%20Us/Overview/Governance/codeofethics2010.pdf>.

George Brown College 2015, *The World of PLCs is Closer than You Think: PLC Applications in our Everyday Lives*, <http://www.gbctechtraining.com/blog/PLC-Applications-in-our-Everyday-Lives>.

Gillespie, H, Boulton, H, Hramiak, AJ & Williamson, R 2007, *Learning and Teaching with Virtual Learning Enivornments*, Learning Matters Ltd, Exeter, England.

Grabe, M & Grabe, C 2007, *Integrating Technology for Meaningful Learning*, 5th edn, Houghton Mifflin Company, Boston.

Han, PY, Coombes, ID & Green, B 2005, 'Factors predictive of intravenous fluid administration errors in Australian surgical care wards.', *Quality & Saftey in Health Care*, vol 14, no. 3, pp. 179-184.

Harwood, M 2011, 'Transition Shock – Hitting the Ground Running', *Nuritinga: ELECTRONIC JOURNAL OF NURSING*, no. 10, <http://www.utas.edu.au/health/about-us/school-of-health-sciences>.

Hayden, E, Assante, M & Conway, T 2014, *An Abbreviated History of Automation & Industrial Controls Systems and Cybersecurity*, SANS.

Hoefel, HH, Lautert, L, Schmitt, C, Soares, T & Jordan, S 2008, 'Vancomycin administration: mistakes made by nursing staff', *Nursing Standard*, vol 22, no. 39, pp. 35-42.

Katzel, J 2012, *Information systems: The evolution of the HMI*, <http://www.controleng.com/single-article/information-systems-the-evolution-of-the-hmi/d643c1d8644f73884df2c0827cb31f38.html>.

Mater Education 2016, *Diploma of Nursing*, <http://matereducation.qld.edu.au/Courses/Nursing/Diploma-of-Nursing>.

Murray, C, Grant, MJ & Howarth, M 2008, 'The use of simulation as a teaching and learning approach to support practice learning.', *Nurse education in practice*, vol 8, no. 1, pp. 5-8.

NCCMERP 2016, *About Medical Errors: What is a Medical Error?*, viewed 2016, <http://www.nccmerp.org/about-medication-errors>.

Nichols, P, Copeland, T-S, Craib, IA, Hopkins, P & Bruce, DG 2008, 'Learning from error: identifying contributory causes of medication errors in an Australian hospital', *The Medical Journal of Australia*, vol 188, no. 5, pp. 276-279, <https://www.mja.com.au/journal/2008/188/5/learning-error-identifying-contributory-causes-medication-errors-australian>.

Nursing and Midwifery Board of Australia 2015, 'National competency standards for the registered nurse'.

Nursing and Midwifery Board of Australia 2016, 'Registered nurse standards for practice'.

NWBA 2016, 'Nursing and Midwifery Board of Australia Registrant Data'.

Oliver, R 2002, 'The role of ICT in higher education for the 21st century: ICT as a change agent for education', *ICTs Strategic Planning*, vol 14.

Osbourne, DB 2012, 'IV infusion pump training emulator', Ugrd Dissertation, University of Southern Queensland.

Pang, RK, Kong, D, Clifford, J-M, Lam, SS & Leung, BK 2011, 'Smart infusion pumps reduce intravenous medication administration errors at an Australian teaching hospital', *Journal of Pharmacy Practice and Research*, vol 41, no. 3, pp. 192-195.

Purdue University 2016, *How has technology changed education?*, <http://online.purdue.edu/ldt/learning-design-technology/resources/how-has-technology-changed-education>.

Rohee, B, Riera, B & Carré-Ménétrier, V 2007, 'Manufacturing human machine interface design using plant models', *IFAC Proceedings Volumes*, vol 40, no. 16, pp. 212-217.

Roughead, EE & Semple, SJ 2009, 'Medication safety in acute care in Australia: where are we now? Part 1: a review of the extent and causes of medication problems 2002-2008', *Australia and New Zealand Health Policy*, vol 6, no. 1, p. 1.

Roughead, L, Semple, S & Rosenfeld, E 2013, 'Literature review: medication safety in Australia', *Australian Commission on Safety and Quality in Health Care*.

Russell, L 2005, *From hospital to university - the transfer of nurse education*, University of Sydney, <http://www.cdnm.edu.au/wp-content/uploads/2011/09/HistoryNursingEducation.pdf>.

Sinclair, PM, Kable, A, Levett-Jones, T & Booth, D 2016, 'The effectiveness of Internet-based e-learning on clinician behaviour and patient outcomes: A systematic review', *International Journal of Nursing Studies*, no. 57, pp. 70-81.

Singh, NR 2013, *NURSING: The Ultimate Study Guide*, Springer Publishing Company, LLC, New York.

Tan, DS 2014, *Human-machine interface*, <https://www.britannica.com/technology/human-machine-interface>.

Taxis, K & Barber, N 2004, 'Incidence and severity of intravenous drug errors in a German hospital', *European Journal of Clinical Pharmacology*, vol 59, no. 11, pp. 815–817.

Terry, VR 2015, 'Online versus face-to-face: development, refinement, implementation, and evaluation of an online intravenous pump emulator, including outcomes for clinical practice for nursing students', PhD Dissertation, University of Southern Queensland.

Terry, VR, Moloney, C, Bowtell, L & Terry, PC 2016, 'Online intravenous pump emulator: As effective as face-to-face simulation for training nursing students', *Nurse Education Today*, vol 40, pp. 198-203.

University of Southern Queensland 2015, *Engineering Labs*, <http://www.usq.edu.au/hes/facilities-and-services/engineering-labs>.

University of Southern Queensland 2016, *Study Online*, <http://www.usq.edu.au/study/modes/online-study>.

Weldon, MK 2016, *The Future X Network: A Bell Labs Perspective*, CRC Press.

Westbrook, JI, Rob, MI, Woods, A & Parry, D 2011, 'Errors in the administration of intravenous medications in hospital and the role of correct procedures and nurse experience.', *BMJ Quality & Safety*, vol 20, no. 12, pp. 1027-34.

Young, T 2005, *The Birth of the PLC*, <http://www.plcdev.com/the_birth_of_the_plc>.

Appendix A – Project Specification

ENG4111/ENG4112 Research Project
Project Specification

For: Jorja Wicks

Title: Remote Access I.V. Pump Emulator Training System

Major: Electrical and Electronic

Supervisor: Catherine Hills

Enrolment: ENG4111 – ONC S1, 2016; ENG4112 – ONC S2, 2016

Project Aim: To develop a flexible multi user remotely accessible IV pump emulator (IVPE) for nursing students based on a web server enabled operator panel and PLC.

Programme: Issue B, 6^{th} April 2016

1. Complete literature review; particularly literature in regards to existing systems with similar design and/or purpose, pump documentation and educational aspects.

2. Liaise with USQ Nursing Staff to determine any requirements. Also arrange access to an appropriate IV pump for recording and studying, and educational content to be included in the pump emulator system.

3. Develop an accurate and realistic PLC and HMI emulation of IV Pump with training and assessment modes incorporated.

4. Incorporate the capability of a short survey on the final page of the HMI before exiting to gain valuable feedback.

5. Evaluate functionality and operation from nursing staff/student feedback from survey option.

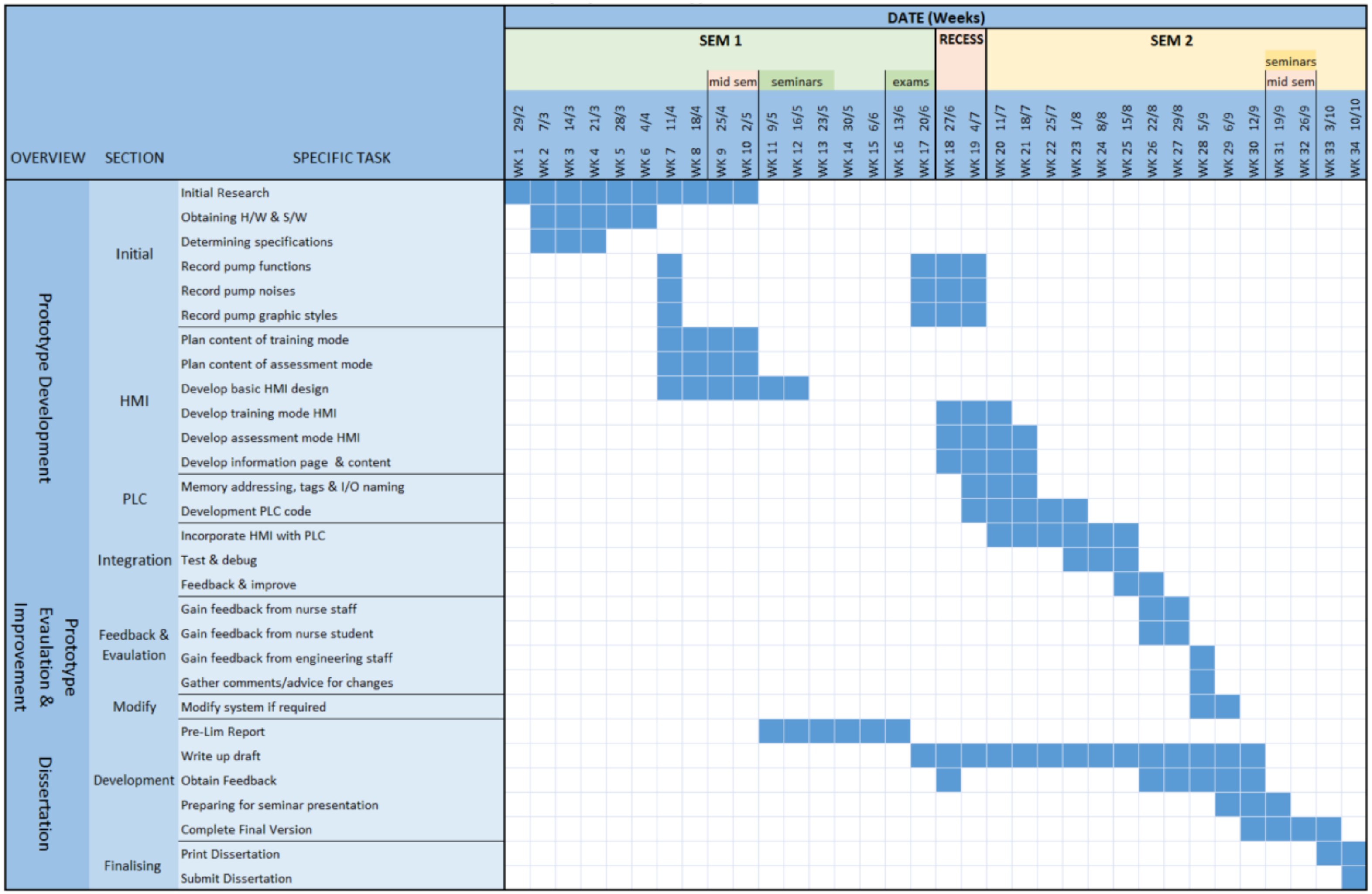
6. Explore HMI panel web server technology and configure for remote access.

If time and resources permit:

7. Develop Extra Information/Resources Page for further help and understanding.

8. Voice hints to go with pop up hints in training mode.

Appendix B – Project Timeline



Appendix C – PLC Specifications

(Automation Direct 2016)

Memory Types

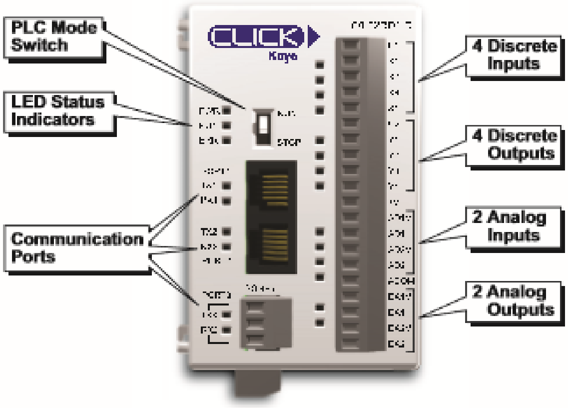
The following is the list of the memory types that the CLICK PLC system supports. See the memory map later in this chapter.

Memory Type	Symbol	Data Type	S/W Icon	Definition
Input Point	X	Bit	B	The Discrete Input points are represented by the "X" symbol.
Output Point	Y			The Discrete Output points are represented by the "Y" symbol.
Control Relay	C			The Control Relay bits are represented by the "C" symbol. These internal bits are typically used for ladder program control. They do not represent any real world inputs or outputs.
Timer	T			The Timers are represented by the "T" symbol. The Timer status bit is used to indicate when the Current Value of the timer equals its Preset Value.
Counter	CT			The Counters are represented by the "CT" symbol. The Counter status bit is used to indicate when the Current Value of the counter equals its Preset Value.
System Control Relay	SC			The internal System Control Relays, represented by the "SC" symbol, are pre-defined bits which represent the status of specific system functions.
Data Register	DS	Integer	I	Single word integer data registers are represented by the "DS" symbol.
	DD	Integer2	I2	Double word integer data registers are represented by the "DD" symbol.
	DH	HEX	H	Single word Hex data registers are represented by the "DH" symbol.
	DF	Floating Point	F	Data Floating Point registers are IEEE format Real number values represented by the "DF" symbol as 32 bit words.
Input Register	XD	HEX	H	The Input Registers, represented by the "XD" symbol, contain groups of Discrete Input points in a 16 bit word format.
Output Register	YD			The Output Registers, represented by the "YD" symbol, contain groups of Discrete Output points in a 16 bit word format.
Timer Register	TD	Integer	I	The Timer Registers, represented by the "TD" symbol, contain the corresponding Timer's accumulative value in a 16 bit data register.
Counter Register	CTD	Integer2	I2	The Counter Registers, represented by the "CTD" symbol, contain the corresponding Counter's accumulative value in a 32 bit data register.
System Data Register	SD	Integer	I	The internal System Data Registers, represented by the "SD" symbol, are pre-defined words which represent the status of specific system functions.
Text	TXT	Text	T	The Text data registers, represented by the "TXT" symbol, are used to store and manipulate ASCII text data.

Analog PLC Units

The Analog CLICK PLC units are available with different combinations of DC in, DC sinking, sourcing or relay out, and analog in and out.

They also have an RS-485 port for Modbus and ASCII communications, and the battery backup feature which will retain the data in SRAM for 5 years.



Built-in I/O (Analog CPUs)

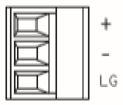
There are three different configurations of I/O types available for the Analog CLICK PLC units. The table below lists the part numbers showing the various I/O types.

Analog PLCs					
Part Number	Discrete Input Types	Discrete Output Types	Analog Input Types	Analog Output Types	External Power
C0-02DD1-D	4 DC (sink/ source)	4 DC (sink)	2 channel; voltage (0-5 VDC) / current (4-20 mA); selectable separately per channel, 12 bit	2 channel; voltage (0-5 VDC) / current (4-20 mA); selectable separately per channel, 12 bit	24 VDC (required for all CPUs)
C0-02DD2-D		4 DC (source)			
C0-02DR-D		4 relay			

***NOTE:** There is a dedicated terminal for each voltage or current type, but you must also select the voltage or current type in the CLICK programming software. See the Analog I/O Configuration section in Chapter 3.*

W-3 W-3: Com Port 3 Wiring

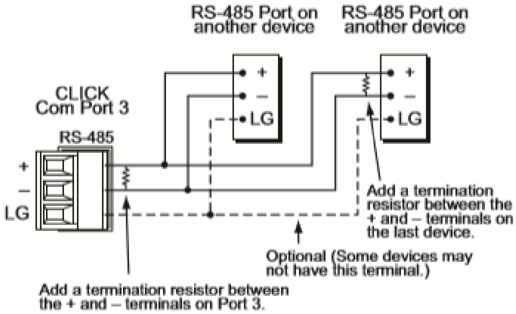
Com Port 3 supports 2-wire RS-485.



Port 3 Pin Descriptions		
1	+ (plus)	Signal A (RS-485)
2	- (minus)	Signal B (RS-485)
3	LG	Logic Ground (0 V)

Wiring Strategy

You need to connect all + signal terminals in the network together. You will also need to connect all – signal terminals together. It is optional to connect the logic ground.



NOTE: *The resistance of the termination resistors needs to match the impedance of the communication cable.*

NOTE: *Use a repeater if connecting more than 32 slaves to Port 3.*

Appendix D – HMI Specifications (EA9-T6CL)

(Automation Direct 2016)

Specification \ Model	6" TFT color w/ base features	6" TFT color w/ full features	8" TFT color w/ full features	10" TFT color w/ full features	12" TFT color w/ full features	15" TFT color w/ full features
Part Number	EA9-T6CL-R	EA9-T6CL	EA9-T8CL	EA9-T10CL	EA9-T12CL	EA9-T15CL
Price	<-->	<-->	<-->	<-->	<-->	<-->
Display Actual Size and Type	5.7" TFT color		8.4" TFT color	10.4" TFT color	12.1" TFT color	15.0" TFT color
Display Viewing Area	4.54" x 3.40" [115.2 mm x 86.4 mm]		6.71" x 5.03" [170.4 mm x127.8mm]	8.31" x 6.24" [211.2 mm x 158.4 mm]	9.69" x 7.26" [246.0 mm x 184.5 mm]	11.97" x 8.98" [304.1 mm x 228.0 mm]
Weight	1.56 lb [710g]	1.59 lb [720g]	2.93 lb [1330g]	4.19 lb [1900g]	4.89 lb [2200g]	6.50 lb [2950g]
Screen Pixels	320 x 240 (QVGA)		800 x 600 (SVGA)			1024 x 768 (XGA)
Display Brightness	280 nits (typ)		310 nits (typ)	280 nits (typ)		
LCD Panel Dot Pitch	0.18 mm x 0.18 mm		0.213 mm x 0.213 mm	0.264 mm x 0.264 mm	0.3075 mm x 0.3075 mm	0.297 mm x 0.297 mm
Color Scale	65,536 colors					
Backlight Average Lifetime*	50,000 hours @ 25°C					
Touch Panel Type	Four-wire analog resistive					
Project Memory	26MB				82MB	
Number of Screens	Up to 999 screens – limited by project memory					
Realtime Clock	Realtime Clock Built into panel, backed up for 30 days at 25°C					
Calendar - Month / Day / Year	Yes - monthly deviation 60 sec (Reference)					
Serial Port 1	15-pin D-sub female - RS232C, RS-422/485					
Serial Port 2	N/A	3-wire terminal block - RS-485				
Serial Port 3	N/A	RJ-12 modular jack - RS-232C				
USB Port - Type B	USB 2.0 High speed (480 Mbps) Type B - Download/Program					
USB Port - Type A	USB 2.0 High speed (480 Mbps) Type A -for USB device options					
Ethernet Port	N/A	Ethernet Port Ethernet 10/100 Base-T, auto MDI/MDI-X				
Audio Line Out	N/A	3.5 mm mini jack – requires amplifier and speaker(s)				
Mic In	N/A	3.5 mm mini jack				
SD Card Slot	1 slot supports max 2 GB (SD,) max 32 GB (SDHC)				2 slots support max 2 GB (SD), max 32 GB (SDHC)	
HDMI Out	N/A				Yes	
Supply Power	12-24 VDC Class 2, or use the AC/DC Power Adapter, EA-AC, to power the touch panel from a 100-240 VAC, 50/60 Hz power source. Reverse Polarity Protected					
Power Consumption	16.0 W 1.30 A @ 12VDC 0.66 A @ 24VDC		18.0 W 1.50 A @ 12VDC 0.75 A @ 24VDC	18.0 W 1.50 A @ 12VDC 0.75 A @ 24VDC	21.0 W 1.75 A @ 12VDC 0.88 A @ 24VDC	29.0 W 2.40 A @ 12VDC 1.20 A @ 24VDC
Internal Fuse (non-replaceable)	4.0 A		6.3 A			
Operating Temperature	0 to 50 °C (32 to 122 °F) Maximum surrounding air temperature rating: 50°C (122°F) IEC 60068-2-14 (Test Nb, Thermal Shock)					
Storage Temperature	–20 to +60°C (–4 to +140 °F) IEC 60068-2-1 (Test Ab, Cold) IEC 60068-2-2 (Test Bb, Dry Heat) IEC 60068-2-14 (Test Na, Thermal Shock)					
Humidity	5–95% RH (non-condensing)					
Environment	For use in Pollution Degree 2 environment, no corrosive gases permitted					
Noise Immunity	NEMA ICS3-304 (EN61131-2) RFI, (145MHz, 440Mhz 10W @ 10cm) Impulse 1000V @ 1mS pulse EN61000-4-2 (ESD), EN61000-4-3 (RFI) EN61000-4-4 (FTB) EN61000-4-5 (Serge) EN61000-4-6 (Conducted) EN61000-4-8 (Power frequency magnetic field immunity)					
Withstand Voltage	1000 VAC, 1 min. (FG to Power supply)					
Insulation Resistance	> 10M ohm @ 500VDC (FG to Power supply)					
Vibration	IEC60068-2-6 (Test Fc)					
Shock	IEC60068-2-27 (Test Ea)					
Emission	EN55011 Class A (Radiated RF emission)					
Enclosure	NEMA 250 type 4/4X indoor use only UL50 type 4X indoor use only IP-65 indoor use only (When mounted correctly)					
Agency Approvals	UL508, E157382 CE (EN61131-2), RoHS (2011/65/EU) CUL Canadian C22.2					

****NOTE:* The backlight average lifetime is defined as the average usage time it takes before the brightness becomes 50% of the initial brightness. The lifetime of the backlight depends on the ambient temperature. The lifetime will decrease under low or high temperature usage.***

C-more 6" TFT Color Touch Panel - Full Model

Part No. EA9-T6CL

<---->

C-more EA9 series touch screen interface panel, 6-inch color TFT (5.7 inch viewable screen), 64k colors, 320 x 240 pixel QVGA screen resolution, 800 MHz CPU, 12-24 VDC powered, NEMA 4/4X, IP65 (when mounted correctly; for indoor use only), non-replaceable LED backlight. Includes (3) serial ports, USB 2.0 Type A and B ports and Ethernet port; supports SD memory card. Compatible with EA9-PGMSW programming software version 5.0 or later.

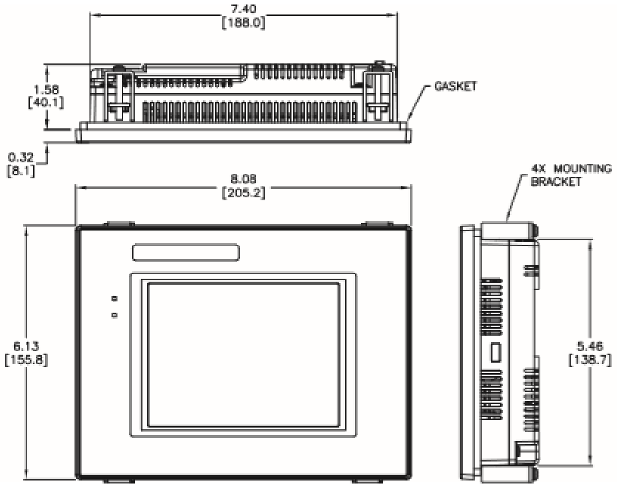
Features

- 5.7" diagonal color TFT (Thin Film Transistor) LCD display with 64K colors
- 320 x 240 pixel resolution
- 280 NITS display brightness
- 50,000 hour average backlight half-life
- Analog resistive (1024 X 1024) touch screen allowing unlimited touch areas
- USB port B (program/download) and USB port A (USB device options)
- Ethernet 10/100 Base-T port (program/download & PLC communication)
- Remote Internet Access
- Serial PLC interface (RS-232/422/485)
- One built-in SD memory card slot
- 12–24 VDC powered, 110VAC power adapter (optional)
- Audio Line Out, stereo - requires amplifier and speaker(s)
- Microphone in
- 26MB project memory
- Data logging
- 0 to 50°C [32 to 122°F] operating temperature range
- NEMA 4/4X, IP65 compliant when mounted correctly, indoor use only
- Slim design saves panel space
- UL, cUL, CSA & CE agency approvals
- 2-year warranty from date of purchase

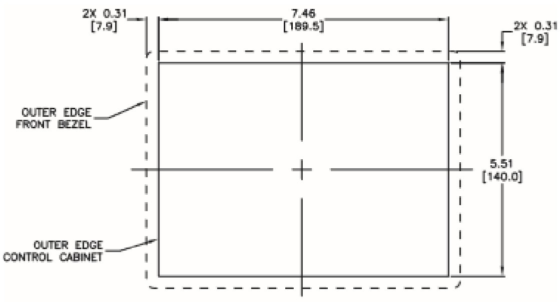
Function	Available
Ethernet	Yes
USB	Yes
SD Card	Yes
Audio Out	Yes
Mic In	Yes
HDMI Out	No

Dimensions

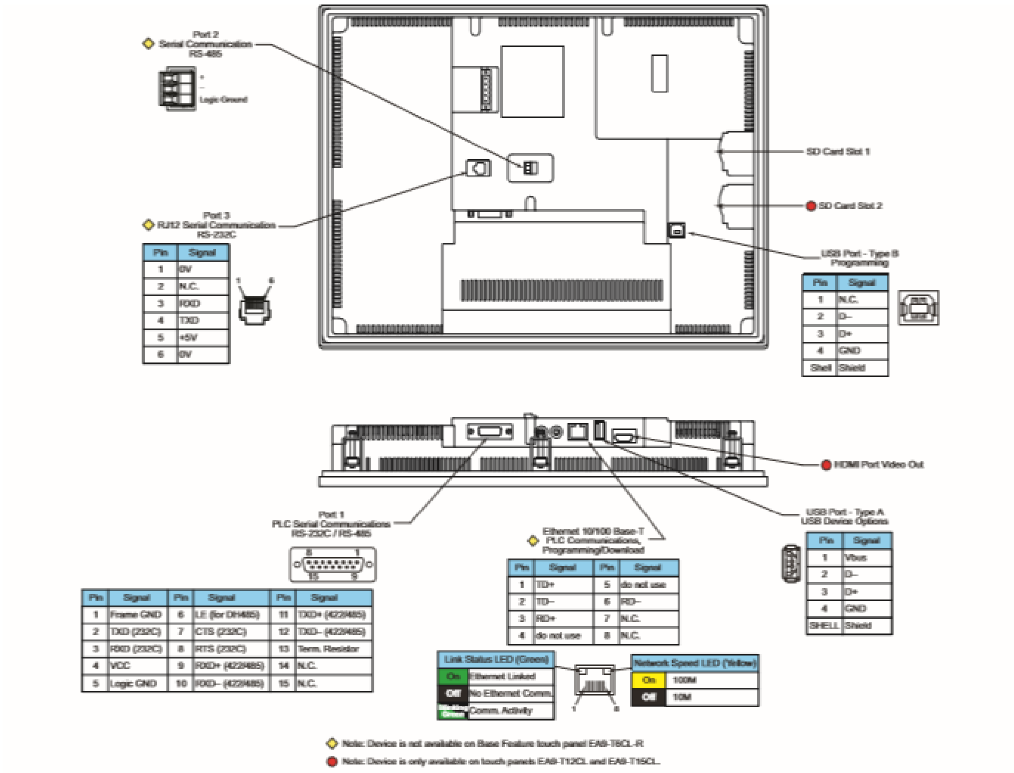
inches / [mm]



Mounting Cutout



C-more Communication Ports



Port 3 – RJ12 Serial Communication RS-232C

Pin	Signal
1	0V
2	N.C.
3	RXD
4	TXD
5	+5V
6	0V

USB Port - Type B Programming

Pin	Signal
1	N.C.
2	D–
3	D+
4	GND
Shell	Shield

Port 1 – PLC Serial Communications RS-232C / RS-485

Pin	Signal	Pin	Signal	Pin	Signal
1	Frame GND	6	LE (for DH485)	11	TXD+ (422/485)
2	TXD (232C)	7	CTS (232C)	12	TXD– (422/485)
3	RXD (232C)	8	RTS (232C)	13	Term. Resistor
4	VCC	9	RXD+ (422/485)	14	N.C.
5	Logic GND	10	RXD– (422/485)	15	N.C.

Ethernet 10/100 Base-T

Pin	Signal	Pin	Signal
1	TD+	5	do not use
2	TD–	6	RD–
3	RD+	7	N.C.
4	do not use	8	N.C.

Link Status LED (Green)	
On	Ethernet Linked
Off	No Ethernet Comm.
[illegible]	Comm. Activity

Network Speed LED (Yellow)	
On	100M
Off	10M

USB Port - Type A USB Device Options

Pin	Signal
1	Vbus
2	D–
3	D+
4	GND
SHELL	Shield

Ethernet Port

The Ethernet port has several uses:

- Download program to panel
- Communicate to PLCs/PCs
- Send e-mail
- Access FTP server
- Act as a Web server
- Remote Internet Access

The Ethernet port has an RJ-45 8-wire modular connector with green and yellow LEDs.

- The yellow LED indicates network speed; off for a 10 Mbps connection and illuminated for a 100 Mbps connection.
- The green LED indicates link status and illuminates when a link is established.

Note: The base panels (-R part numbers) do not include an Ethernet port, and do not have these capabilities.

USB Port B

Program *C-more* via the USB programming port. It's fast and easy, with no baud rate settings, parity, or stop bits to worry about. We stock standard USB cables for your convenience. USB Port B can be used to upload or download projects to and from a PC.

USB Port A

The Universal Serial Bus (USB) Port A is a standard feature for all models and can be used to connect various USB HID (Human Input Device) devices to the panel, such as:

- USB pen drives, (USB-FLASH)
- USB keyboards
- USB barcode scanners
- USB card scanners

C-more can log data to the USB pen drive as well as load projects to the panel from the pen drive. You can also back up project files and panel firmware.

Sound Interface (Audio Line Out)

When attached to an amplifier and speaker(s), *C-more* can play warning sounds or pre-recorded messages such as: "conveyor is jammed". *C-more* supports WAV type files. The output is stereo.

Serial Port

Port 1 - Connect to your serial controller network via Port 1. Port 1 is a 15-pin port that supports RS-232 or RS-422/485.

Port 2 - Connect your RS-485 network via Port 2. Port 2 is provided with a 3-wire removable terminal block.

Port 3 - Connect to your RS-232C device via Port 3. Port 3 is an RJ12 connection.

HDMI Port

EA9-T12CL and EA9-T15CL include an HDMI Type A port to provide video output to a projector or remote monitor.

Appendix E – Consequential Effects

4.4. Consequential Effects

Depending on the project's success, it could regularly utilised in USQ student nurse and midwifery training. A possible consequential effect could be the future development of education emulation systems for other devices, or the IVPE is improved further and shared with other universities or hospitals for their respective learning cohorts, for example, as a refresher tool for already registered nurses.

4.4.1. Ethics

Ethical behaviour is a large part of engineering practices, Engineers Australia provides a Code of Ethics to be upheld nationally. EA's Code of Ethics defines the values and principles that shape the decisions we make in engineering practice. The key elements are to: demonstrate integrity, practise competently, exercise leadership, and promote sustainability (Engineers Australia 2010). (See Appendix G – Engineers Australia Code of Ethics). At the completion of this project, the equipment will continue to be used (either for this project or reused in another research project), thus there won't be any equipment wastage.

Like engineers, registered nurses also have a code of ethics to uphold. For this project it is imperative that the assessment of user performance is defined objectively, clearly and fairly. Due to the likelihood of the IVPE having survey options incorporated, a human research ethics approval needs to be sought from the USQ Ethics Team before any surveys or testing with nursing students can begin. (See Appendix F – Ethics Consent Form (Over 18)).

4.4.2. Risk Analysis, Evaluation & Control

Risk assessment involves identification, evaluation and management strategies of all potential risks. A number of key risks have been identified before undertaking the practical components of this project.

Risk Analysis

Electricity

- low voltage shocks possible from PLC and HMI devices if not handled appropriately (remote to possible)

Working conditions

- sitting for extended periods of time, seating conditions and poor lighting can cause headaches and decreased productivity (likely)

Stress

- stress levels will affect mental health and thus, the performance and progress of the project
- assuming stress will be common but in a variety of severities

Hazards to the project itself

All of the above plus:

- lost or damaged software files (unlikely)
- illness (possible)
- unable to access required resources (unlikely)
- some of the newer technology areas (e.g. setting up HMI web server) may not work smoothly at first - troubleshooting may take extra time (possible)

Risk Evaluation

Using a risk evaluation matrix, a rating can be obtained to determine the level of risk the scenario poses. Low risk rating ranges from 1-5, medium from 6-12, high risk from 13-25.

LOW RISK	MED RISK	Likelihood				
HIGH RISK		1 Remote	2 Unlikely	3 Possible	4 Likely	5 Certain
Severity	1 Negligible	1	2	3	4	5
	2 Minor	2	4	6	8	10
	3 Lost time	3	6	9	12	15
	4 Major	4	8	12	16	20
	5 Fatal	5	10	15	20	25

Figure 49: Risk evaluation matrix

Table 9: Risk Evaluation

Safety Hazard	Likelihood	Severity	Rating
Electricity	1 to 2	2	2 to 4
Lighting and posture while working	4 to 5	2	8 to 10
Stress	3	4	12
	4	3	
Hazards to the project itself	2 to 4	3	6 to 12

Evaluation ratings can be seen above in Error! Reference source not found., the project is predicted to present only low to moderate risk levels. The highest risk rating originated from stress factors and hazards to the completion of the project such as file damage/loss or more indirectly, inability to configure new technology.

Risk Management & Control

The most difficult risk in terms of management is stress which can be minimised by maintaining a healthy lifestyle with ample sleep. Electricity risks can be managed via safe handling techniques and appropriate behaviour around power supplies, open wires and terminals. When working on campus, maintaining a tidy work environment and following laboratory safety procedures and guidelines will ensure paramount safety. Furthermore, risk of file damage and/or loss can be minimised by maintaining multiple file backups on two separate storage spaces, i.e. on PC and in a cloud.

Appendix F – Ethics Consent Form (Over 18)

University of Southern Queensland

UNIVERSITY OF SOUTHERN QUEENSLAND AUSTRALIA

Consent Form for USQ Research Project Questionnaire

Project Details

Title of Project:	Remotely Accessible IV Pump Emulator Training System
Human Research Ethics Approval Number:	HXXREAXXX

Research Team Contact Details

Principal Investigator Details
Miss Jorja Wicks
Email: u1032747@umail.usq.edu.au
Mobile: 0429 976 782

Supervisor Details
Mrs. Catherine Hills
Email: Catherine.Hills@usq.edu.au
Telephone: (07) 4631 1420
Office: Z315C

Statement of Consent

By signing below, you are indicating that you:

- Have read and understood the information document regarding this project.
- Have had any questions answered to your satisfaction.
- Understand that if you have any additional questions you can contact the research team.
- Understand that you are free to withdraw at any time, without comment or penalty.
- Understand that you can contact the University of Southern Queensland Ethics Coordinator on (07) 4631 2690 or email ethics@usq.edu.au if you do have any concern or complaint about the ethical conduct of this project.
- Are over 18 years of age.
- Agree to participate in the project.

Participant Name	
Participant Signature	
Date	

Please return this sheet to a Research Team member prior to undertaking the questionnaire.

Appendix G – Engineers Australia Code of Ethics

(Engineers Australia 2010)

our CODE of ETHICS

ENGINEERS AUSTRALIA

As engineering practitioners, we use our knowledge and skills for the benefit of the community to create engineering solutions for a sustainable future. In doing so, we strive to serve the community ahead of other personal or sectional interests.

Our ***Code of Ethics*** defines the values and principles that shape the decisions we make in engineering practice. The related Guidelines on Professional Conduct provide a framework for members of Engineers Australia to use when exercising their judgment in the practice of engineering.

As members of Engineers Australia, we commit to practise in accordance with the *Code of Ethics* and accept that we will be held accountable for our conduct under Engineers Australia's disciplinary regulations.

In the course of engineering practice we will:

1. DEMONSTRATE INTEGRITY

1.1 Act on the basis of a well-informed conscience

1.2 Be honest and trustworthy

1.3 Respect the dignity of all persons

2. PRACTISE COMPETENTLY

2.1 Maintain and develop knowledge and skills

2.2 Represent areas of competence objectively

2.3 Act on the basis of adequate knowledge

3. EXERCISE LEADERSHIP

3.1 Uphold the reputation and trustworthiness of the practice of engineering

3.2 Support and encourage diversity

3.3 Communicate honestly and effectively, taking into account the reliance of others on engineering expertise

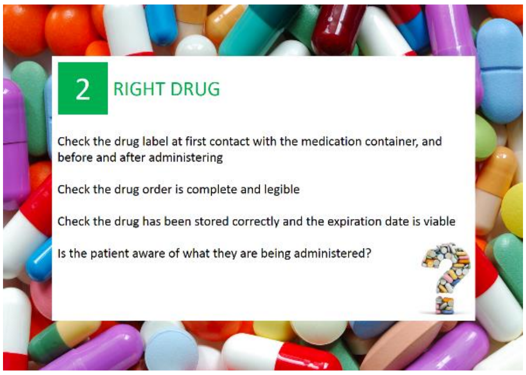
4. PROMOTE SUSTAINABILITY

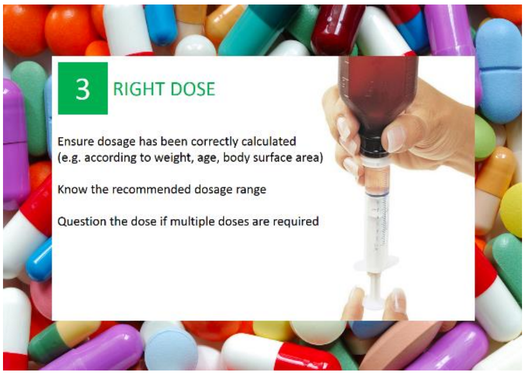
4.1 Engage responsibly with the community and other stakeholders

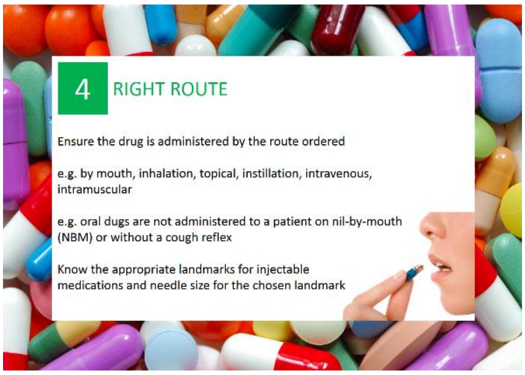
4.2 Practise engineering to foster the health, safety and wellbeing of the community and the environment

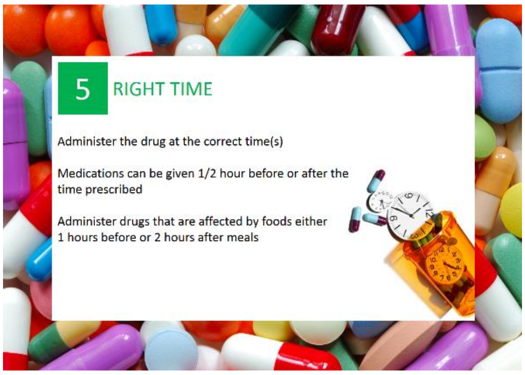
4.3 Balance the needs of the present with the needs of future generations

Appendix H – IVPE '6 Rights' Resources









Appendix I – IVPE Assessment Case Studies

(Osbourne 2012)

Case Study 1

Mr White aged 26, has been admitted to the USQ surgical ward suffering severe acute right lower quadrant (RLQ) abdominal pain. After an initial examination his medical officer has ordered Nil by Mouth (NBM) and IV therapy 1000mls of Sodium Chloride to run over 6 hours (6/24).

Part 1)

How many ml/hr?

…Answer 166mls/hr

What should be the volume to be infused?

…Set vtbi between 500ml and 900ml.

"Always set the volume to be infused (vtbi) 10% less than what is being infused".

Part 2)

Over the next couple of hours, Mr White vomits continuously large amounts of fluid and his pain increases. His temperature is recorded at 38.5 and he looks and feels listless.

His doctor orders the following:

Run 250mls of Sodium Chloride over one hour and prepare for Operating theatre (OT).

How many ml/hr?

…Answer 250ml/hr

What should be the volume to be infused?

…Answer 250ml being the exact volume ordered

Case Study 2

Miss Black, aged 38 has been admitted to USQ orthopaedic ward with a compound fracture of her tibia resulting from being hit by a car while crossing the road this morning. She has returned from the operating theatre (OT) and has IV fluids and IV antibiotics ordered.

The doctor has ordered: IV 1000mls of Sodium Chloride to run over 10 hours (10/24).

Part 1)

How many ml/hr?

…Answer 100mls/hr

What should be the volume to be infused?

…Set vtbi between 500ml and 900ml.

" Always set the volume to be infused (vtbi) 10% less than what is being infused".

The doctor has also ordered: IV Timentin 3.1g to be reconstituted in 13mls of Sterile Water for Injection and diluted in 100mls Sodium Chloride over 1 hour.

Visit the image gallery to see IV Timentin and a Burette connected to the bag of IV fluid.

Part 2)

How many ml/hr?

…Answer 100ml/hr

What should be the volume to be infused?

…Answer 100ml

Case Study 3

Mr Pink, aged 68, weighs 96kgs, has been admitted to USQ CCU with dyspnoea and atrial fibrillation (AF). His HR is 156/min.

He has been ordered an IV Amiodarone Infusion as follows:

600mgs Amiodarone in 500mls 5% Dextrose to run at: 0.5mgs/kg/hr for HR between 100 – 160/min.

Part 1)

How many ml/hr?

…Answer is 40ml/hr

What should be the volume to be infused?

…Set vtbi between 40 – 450mls. If student programs > 450 ml bring up alert to say…

"Always set the volume to be infused (vtbi) 10% less than what is being infused".

Part 2)

The doctor has ordered the following:

If Mr Pink's HR increases to > 160/min, increase the infusion to: 0.075/kg/hr

How many ml/hr?

…Answer is 60ml/hr

…No need to alter vtbi.

Part 3)

If Mr Pink's HR decreases to <100/min, decrease the infusion to 0.25/kg/hr

How many ml/hr?

…Answer is 20ml/hr

…No need to alter vtbi.

Part 4)

If Mr Pink's HR decreases to <60/min, cease the infusion.

Case Study 4

Mrs Brown, aged 68, has been admitted to USQ CCU following major abdominal surgery with an epidural infusion insitu for continuous pain relief.

She has been ordered: Marcaine .125% 100mls with 500mcgs Fentanyl @ 20cmgs/hr:

Part 1)

How many ml/hr?

…Answer is 4 mls/hr

What should be the volume to be infused?

…Set vtbi between 4 – 8 mls/hr.

If student programs <4 or >8 bring up alert to say…

"As a safety precaution, always set the volume to be infused (vtbi) for Epidural infusions for only 1 – 2 hours' worth of pain relief.

Part 2)

The doctor has ordered the following:

If Mrs Brown's pain increases to > 5/10. Administer bolus as follows:

Increase infusion to 30mls/hr for a total of 5mls.

How many ml/hr

…Answer is 30ml/hr

What should be the volume to be infused?

…Answer is 5ml

Part 3)

To what do you set rate after the bolus has been delivered?

…Answer is 4 ml/hr

What should be the volume to be infused?

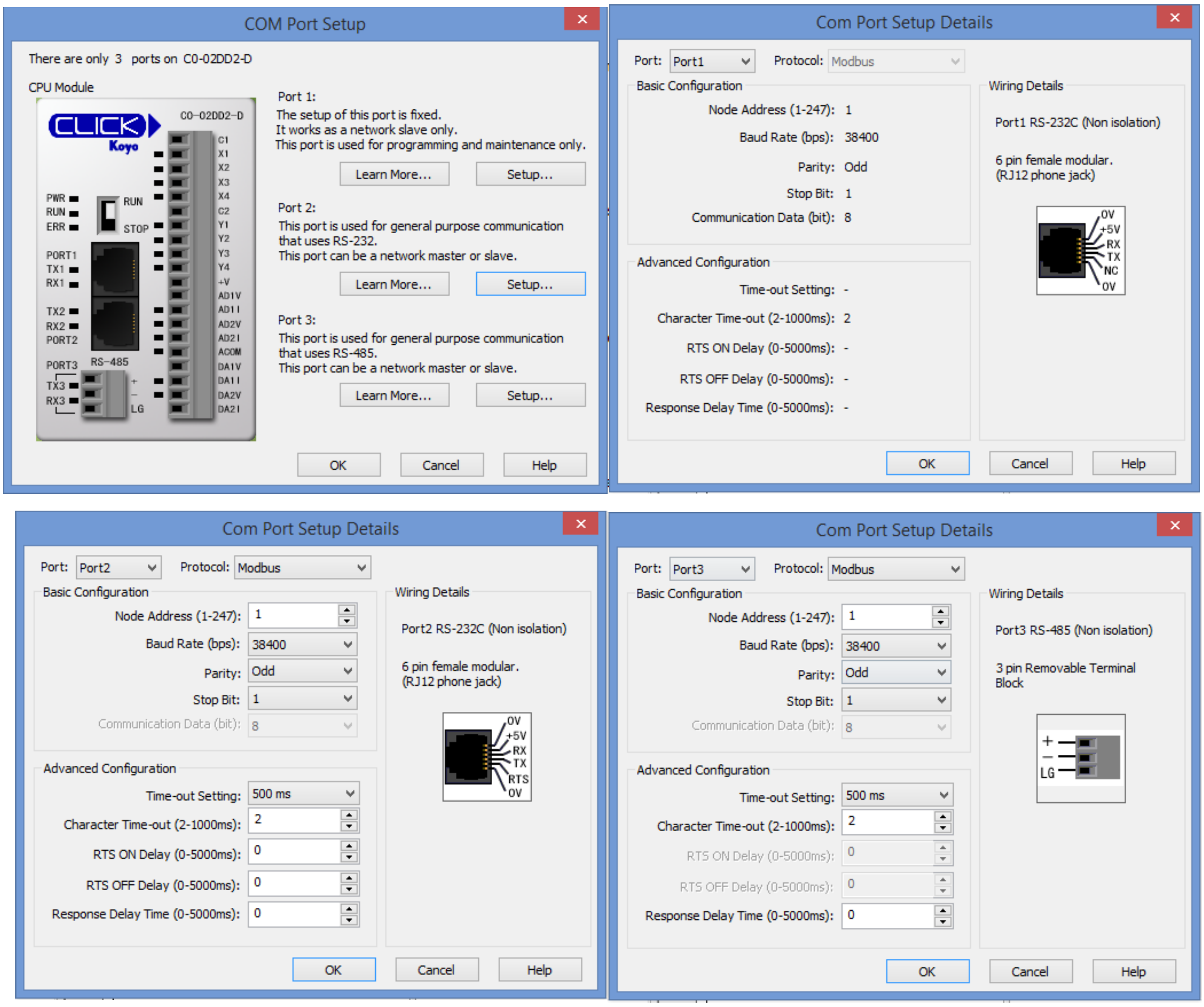
…Set vtbi between 4 – 8 ml/hr.

If student programs <4 or >8 bring up alert to say…

"As a safety precaution, always set the volume to be infused (vtbi) for Epidural infusions for only 1 – 2 hours' worth of pain relief.

Appendix J – HMI PC & Pump Graphics Development

Appendix K – PLC Comm Ports setup



Appendix L – Data Tags & Memory Plan

Binary Plans

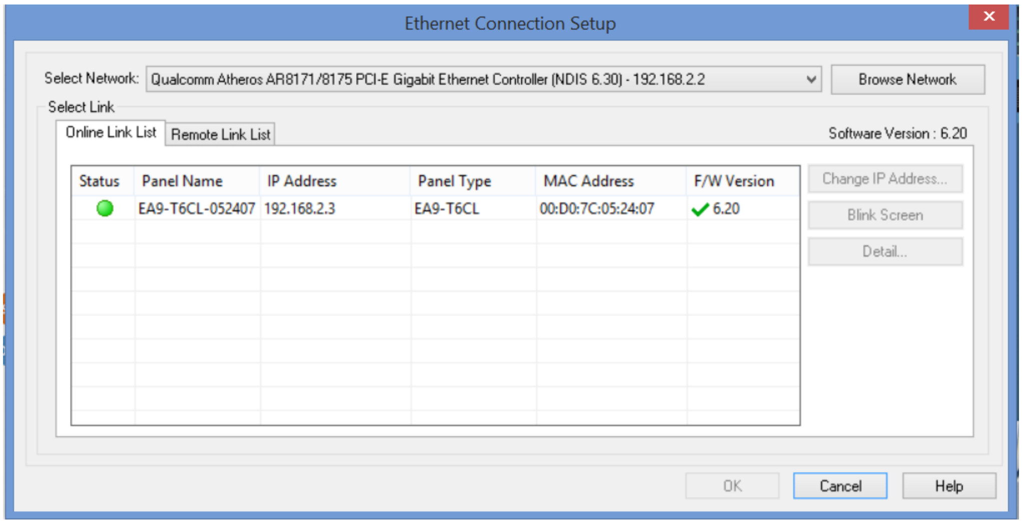
GROUP and Item/s	RANGE	NOTES
PUMP SETUP	**C1 - 250**	**Bitmap buttons, only mome**
PC: Keypad buttons	C1 - C35	0-9, decimal point, clear, cancel, enter, arrows
PC: Other physical buttons	C36 - C70	Around screen arrows for on screen selections, silence, options
PUMP: Physical buttons	C71 - C100	**2 x** Channel Select, pause, channel off, restart
PUMP: Text displaying	C181 - C200	
GENERAL	**C251 - C300**	
"RECT#" rectangles that go with cont buttons	C251	Rectangle fill sometimes need a tag RECT1 is for blue filled start of mode bubble
Random bits for set/reset issues	C261 - C300	
RESOURCE PAGE	**C301 - C500**	**Gallery, Pump info, "6 rights", pop-up windows**
CONTINUE: CONT1	C301 - C302	Click arrows to continue to page/mode/section
Menu buttons	C311 - C313	Menu buttons within resource page
Popup windows	C321 - C340	Pop-up windows of resources screens, screen within popup window is actually 3 other screens, 6 arrows, one exit button and 3 multistate pic (INT)
General gall	C341 - C350	Gallery pics if integer multistate isn't used. "6 rights" uses multistate integer pic number
Pump info	C361 - C370	
LEARNING MODE	**C501 - C1000**	**Run through of how to use IVPE**
CONTINUE: CONT2	C501	Click arrows to continue to page/mode/section
Shading Bubbles	C502, C503	Rate and VTBI on entering values screen (6)
Hint Bubbles	C504 - C550	HINT# is for visibility, EXIT# is to close the hints
Warning Bubbles	C551 - C560	e.g. Warning - have you read 6 rights?
PUMP: Status colours	C561 - C566	**2 x** Red - error/alarm, green - running, yellow - standby (checking pump/line before beginning)
Line in pop up window	C119, C120	Exit button tag, window trigger tag
Pump A/B Line In	C121 - C122	Changing background image of pumps to with tubing
ASSESSMENT MODE	**C1001 - C1500**	**Timed and assessed mode, 4 case options**
CONTINUE: CONT3	C1001	Click arrows to continue to page/mode/section
Case study select window	C1002	CASE
Case study select buttons	C1003 - C1006	CASE1, CASE2, CASE3, CASE4
Case study bubbles	C1011 - C1020	Bubbles with actual case study in them. Minimise-able
Case study display	C1021	Minimise tag
Shading Bubbles	C1031, C1032	Rate and VTBI on entering values screen
Pump A/B Line In	C1041 - C1042	Changing background image of pumps to with tubing
PUMP: Status colours	C1061 - C1066	**2 x** Red - error/alarm, green - running, yellow - standby (checking pump/line before beginning)
SURVEY	**C1501 - C2000**	**Category based feedback with sliders 1-5 values**
CONT4	C1501	Click arrows to continue to page/mode/section
SAVE/EXIT BUTTONS	C1502, C1503	Save and exit or discard and exit

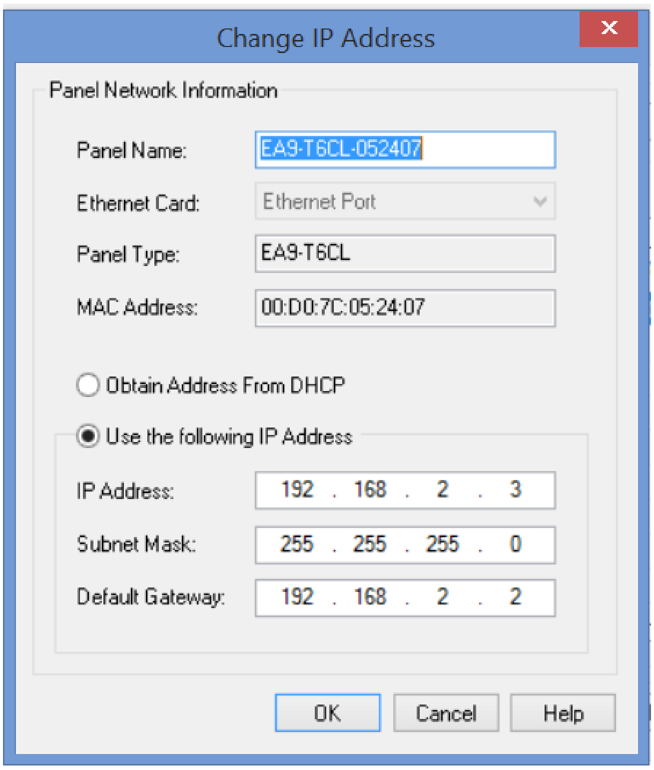
Integer Plans

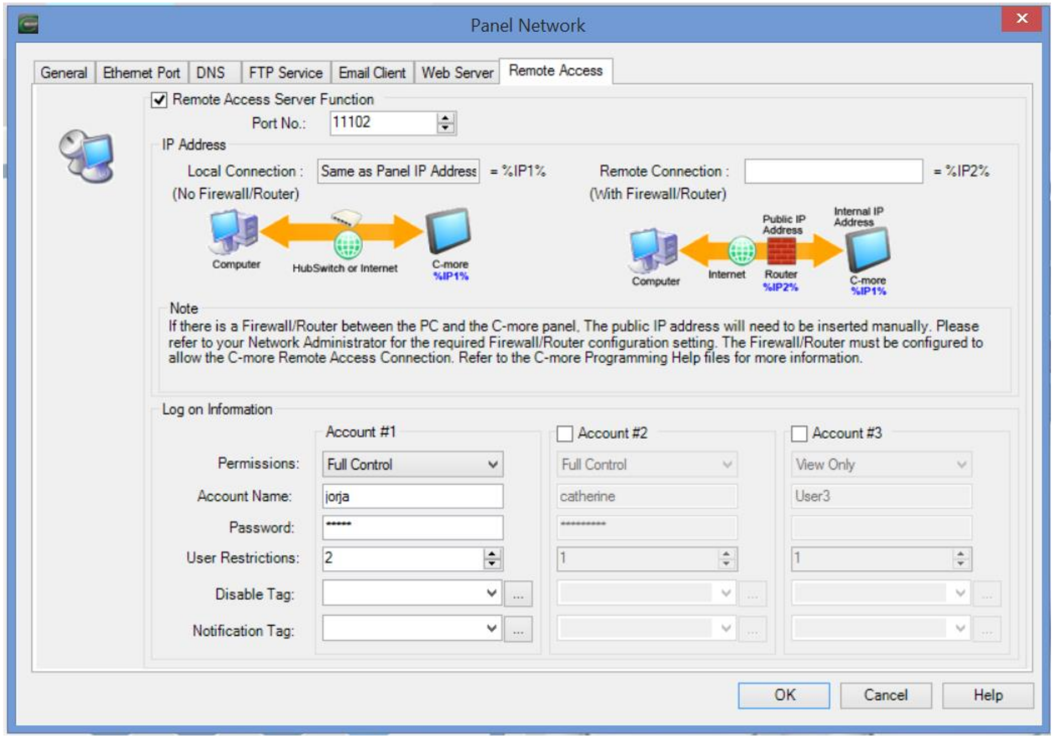
GROUP	RANGE	NOTES/NICKNAMES/USE
GENERAL	**DS1 - DS30**	
HMI Current Screen Number	DS1	For PLC to track current screen number to reset un used / closed objects/screens
PUMP SETUP	**DS31 - DS200**	**Basics common to learning and assessment**
PC: Screens	DS31	Screens within PC
RESOURCE PAGE	**DS151 - DS200**	**Gallery, Pump info, “6 rights”, pop-up windows**
GALLERY image number	DS151	Multistate bitmaps. Incrementing or decrementing the image number based on the setting of the arrow buttons
PATIENT RIGHTS image number	DS152	
PUMP INFO image number	DS153	
LEARNING MODE	**DS201 - DS300**	**Run through of how to use IVPE**
Pump Functions	DS232 - DS236	PUMP_CHAN, PUMP_STATUS_A/B, STATUS_TEXT_A/B. PUMP_CHAN: Chan a = 1, Chan b = 2, 0 = nothing selected
Entering RATE	DS241 - DS250	RATE_VAL_1ST, RATE_VAL_2ND, RATE_VAL_3RD, RATE_VAL_4TH, RATE_VAL, RATE_VAL_A/B
Entering VTBI	DS251 - DS260	VTBI_VAL_1ST, VTBI_VAL_2ND, VTBI_VAL_3RD, VTBI_VAL, VTBI_VAL_A/B
ASSESSMENT MODE	**DS301 - DS400**	**Timed and assessed mode, 4 case options**
COUNTDOWN	DS301	Countdown before beginning timer in assessment mode 3,2,1,start = 3,2,1,4
Case study number	DS301	Case study is use
Case study display number	DS302	Is the case study in use num BUT is 0 when display is minimised
Assessment timers	DS305 - DS306	ASS_TIME_MIN, ASS_TIME_SEC
Pump Functions	DS332 - DS336	PUMP_CHAN, PUMP_STATUS_A/B, STATUS_TEXT_A/B. PUMP_CHAN: Chan a = 1, Chan b = 2, 0 = nothing selected
Entering RATE	DS351 - DS360	RATE_VAL_1ST, RATE_VAL_2ND, RATE_VAL_3RD, RATE_VAL_4TH, RATE_VAL, RATE_VAL_A/B
Entering VTBI	DS361 - DS370	VTBI_VAL_1ST, VTBI_VAL_2ND, VTBI_VAL_3RD, VTBI_VAL, VTBI_VAL_A/B
SURVEY	DS401 - DS500, DD1 - DD5	QUESTIONARE RESULTS
Slider integer values	DS401 - DS405	SUR_Q# integer value of 1 to 5
Number of surveys done	DS406	THESE NEED TO BE RETENTIVE
Sum of all survey values	DD1 - DD5	THESE NEED TO BE RETENTIVE

Appendix M – Webserver Setup

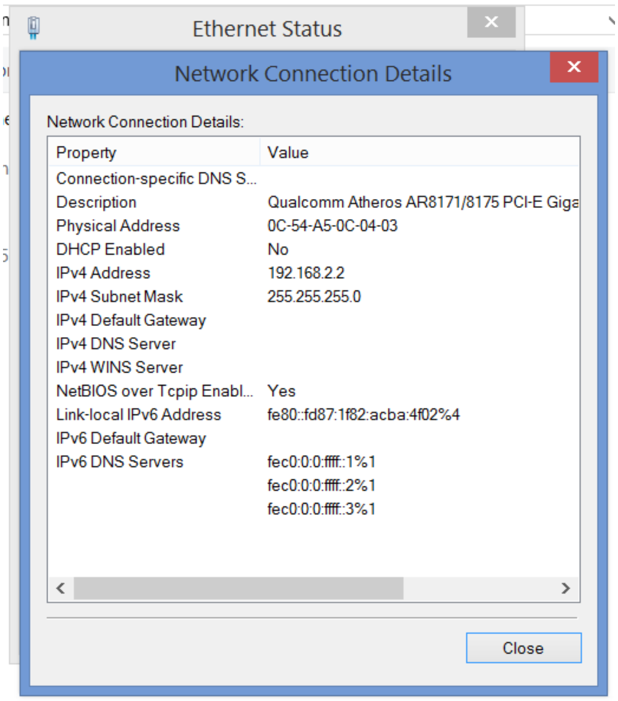
Communication configuration settings in HMI software:



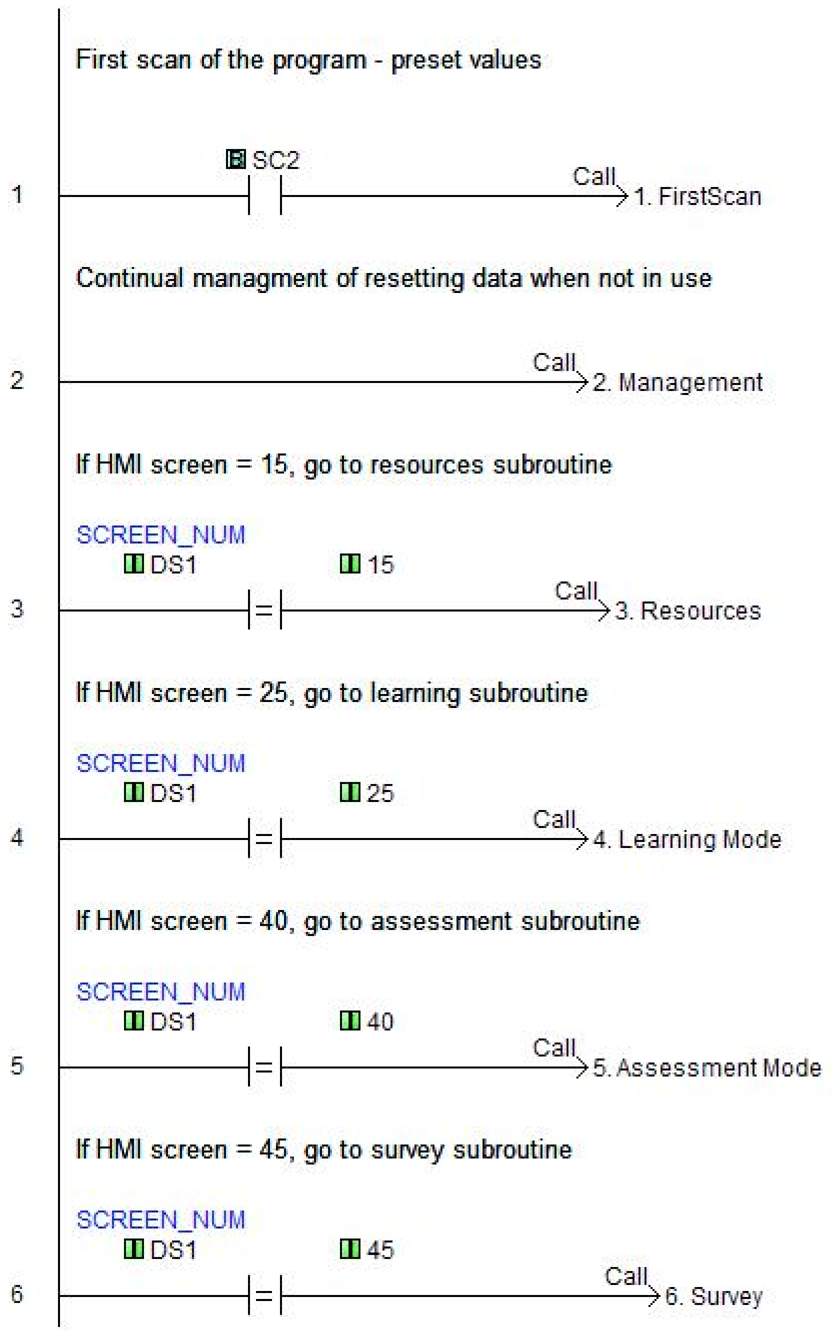




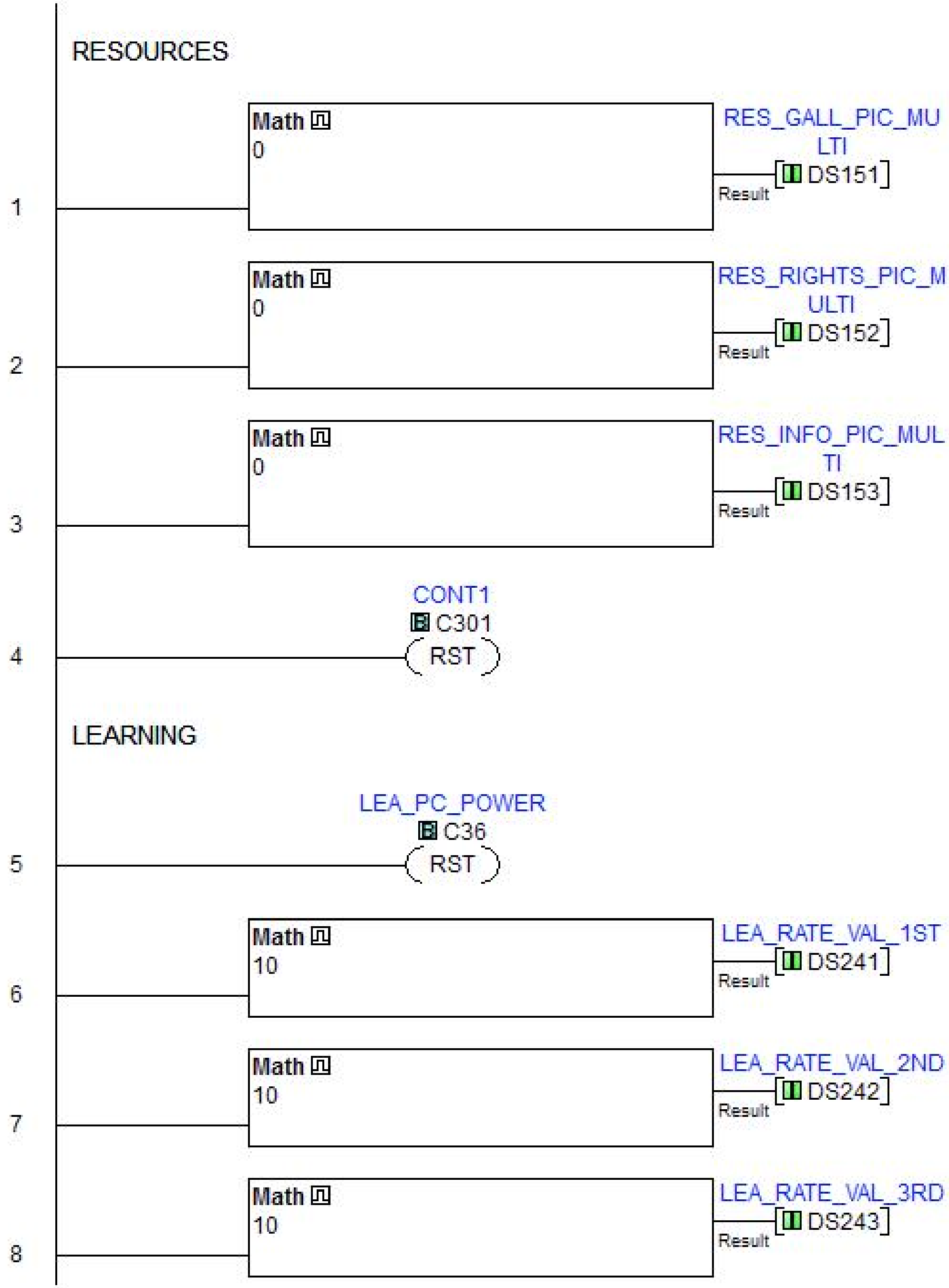
In Windows Control Panel:

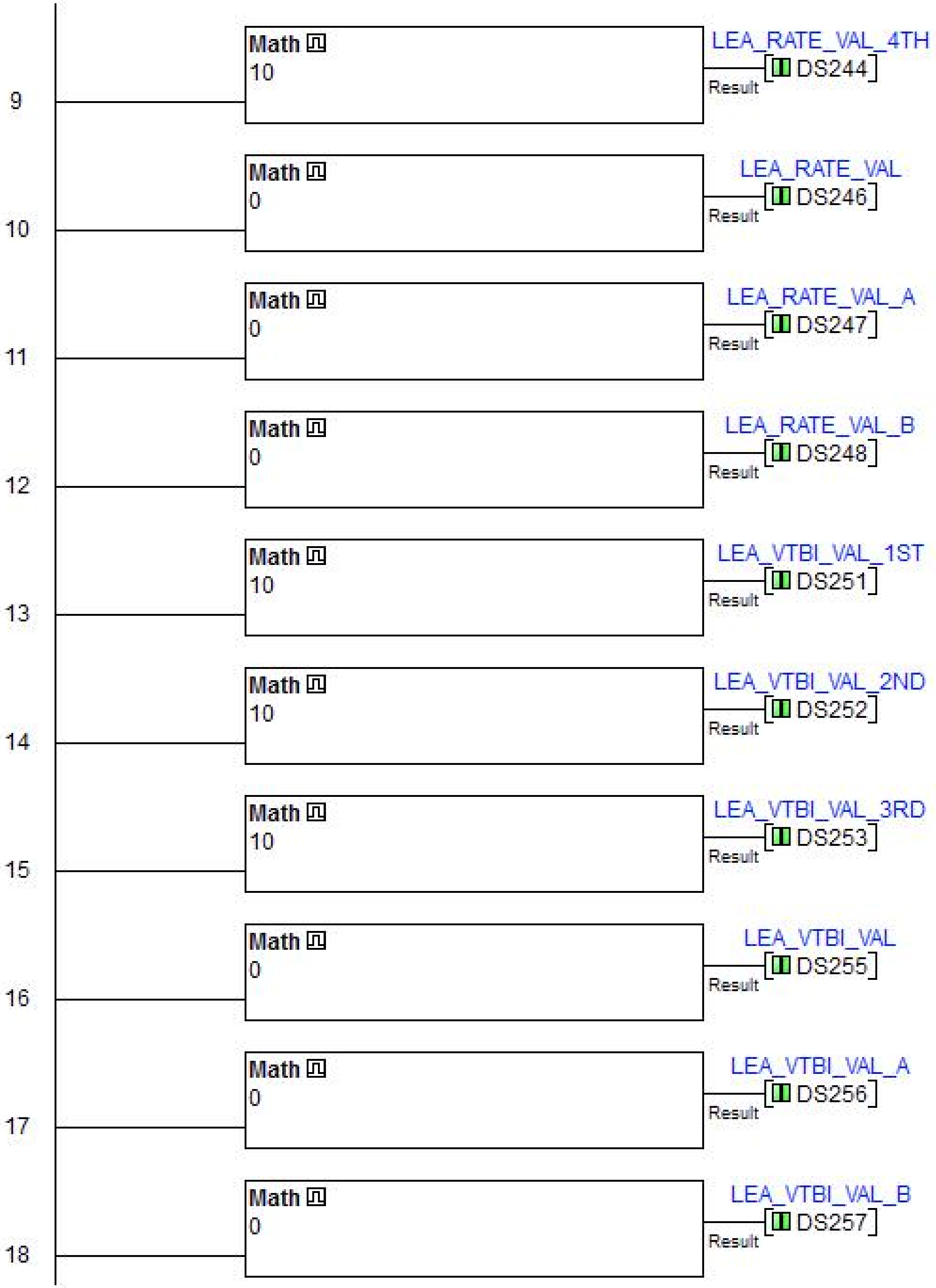


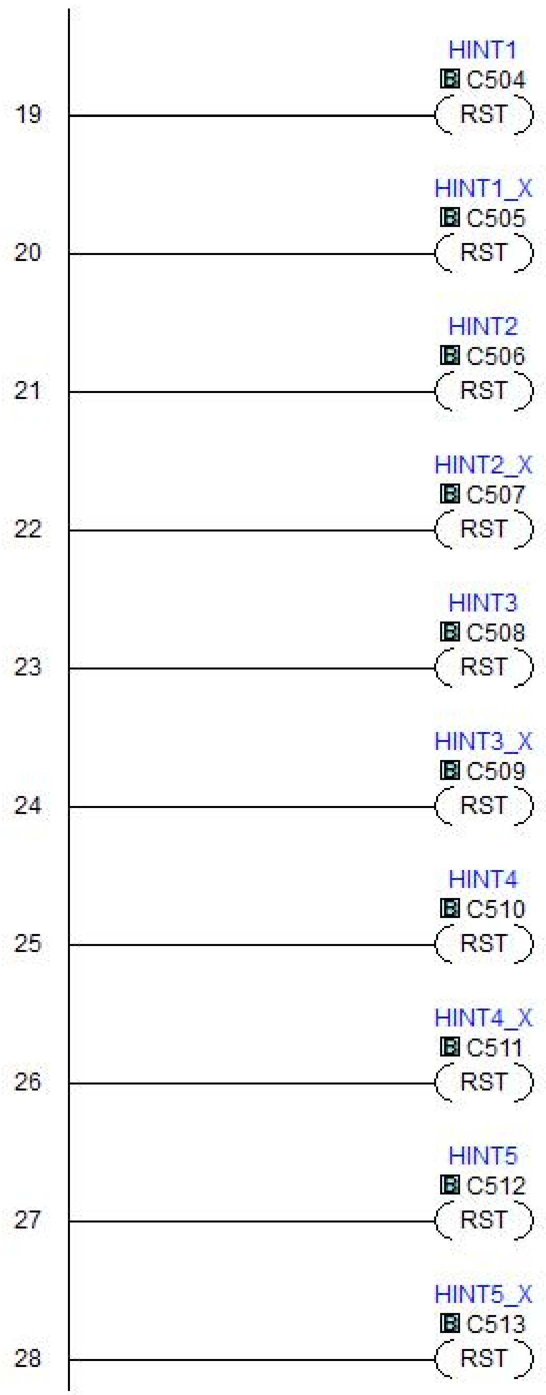
Appendix N – PLC Code Listing

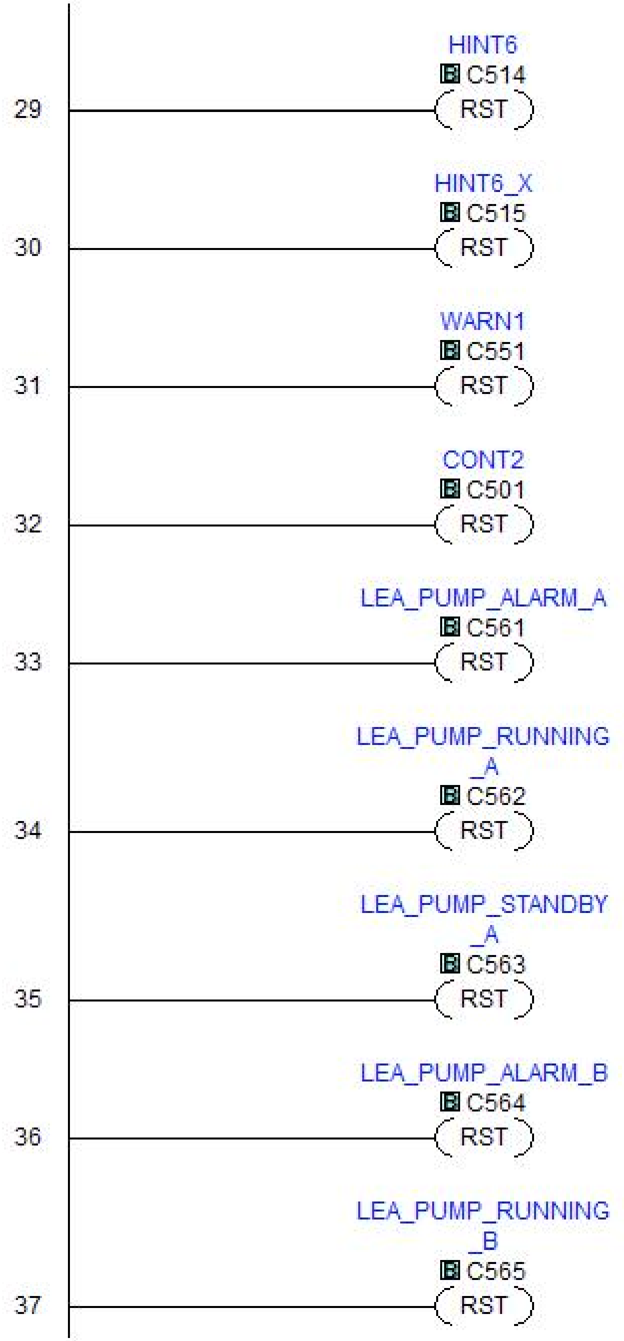

First scan of the program - preset values
1
SC2
Call
1. FirstScan
Continual managment of resetting data when not in use
2
Call
2. Management
If HMI screen = 15, go to resources subroutine
SCREEN_NUM
DS1
15
3
=
Call
3. Resources
If HMI screen = 25, go to learning subroutine
SCREEN_NUM
DS1
25
4
=
Call
4. Learning Mode
If HMI screen = 40, go to assessment subroutine
SCREEN_NUM
DS1
40
5
=
Call
5. Assessment Mode
If HMI screen = 45, go to survey subroutine
SCREEN_NUM
DS1
45
6
=
Call
6. Survey

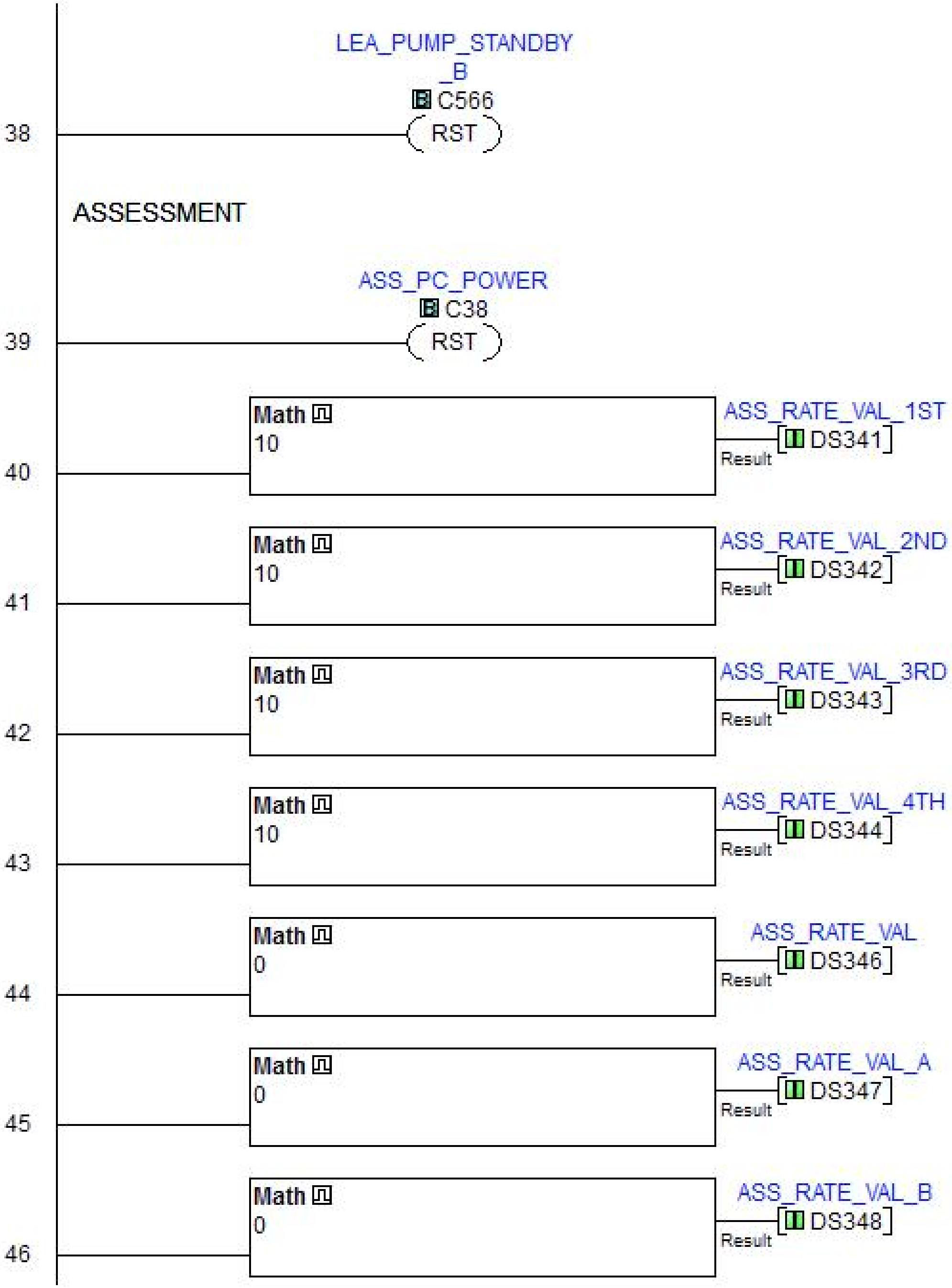
7

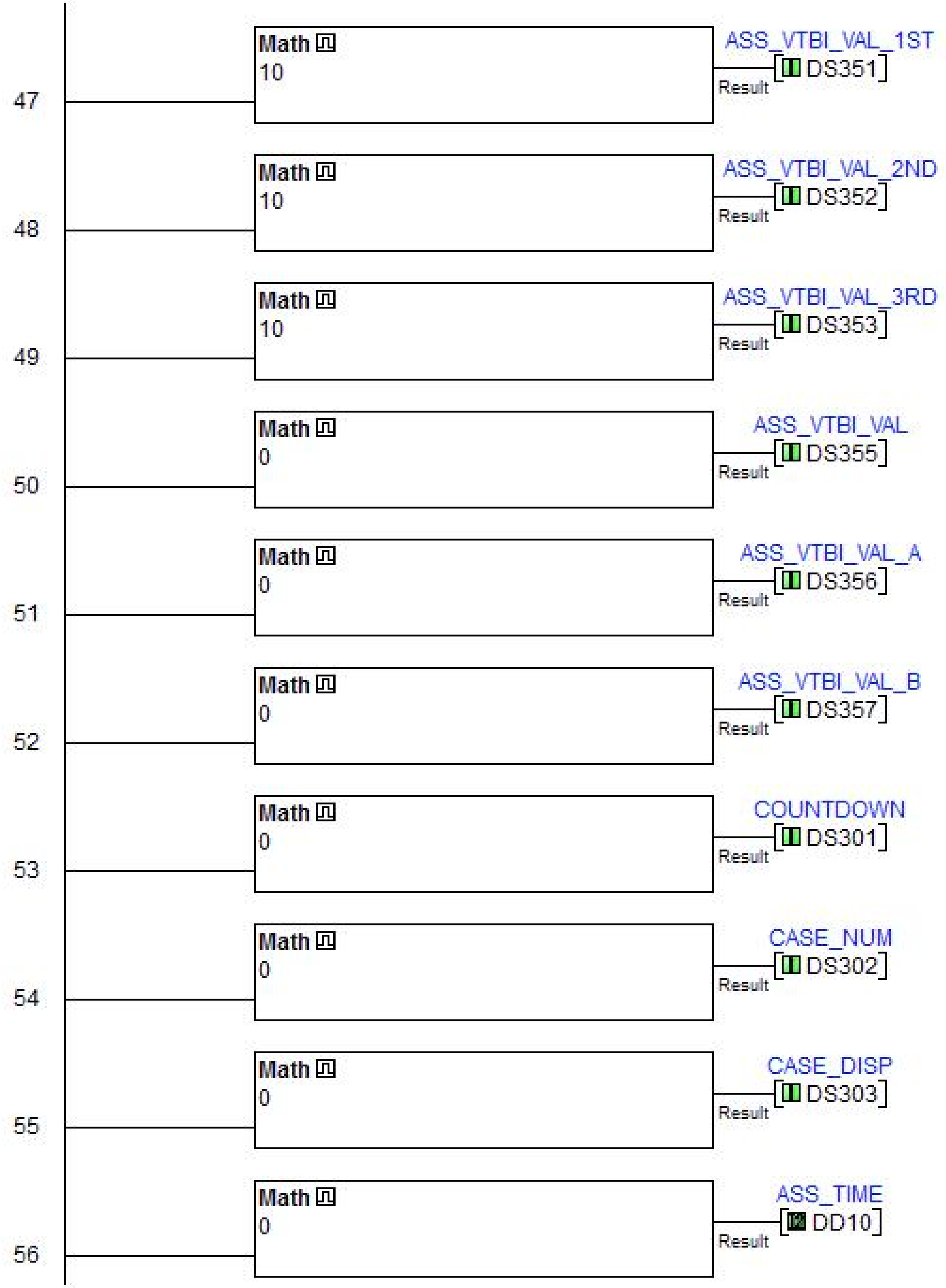

RESOURCES
1
Math
0
Result
RES_GALL_PIC_MULTI
DS151
2
Math
0
Result
RES_RIGHTS_PIC_MULTI
DS152
3
Math
0
Result
RES_INFO_PIC_MULTI
DS153
4
CONT1
C301
RST
LEARNING
5
LEA_PC_POWER
C36
RST
6
Math
10
Result
LEA_RATE_VAL_1ST
DS241
7
Math
10
Result
LEA_RATE_VAL_2ND
DS242
8
Math
10
Result
LEA_RATE_VAL_3RD
DS243

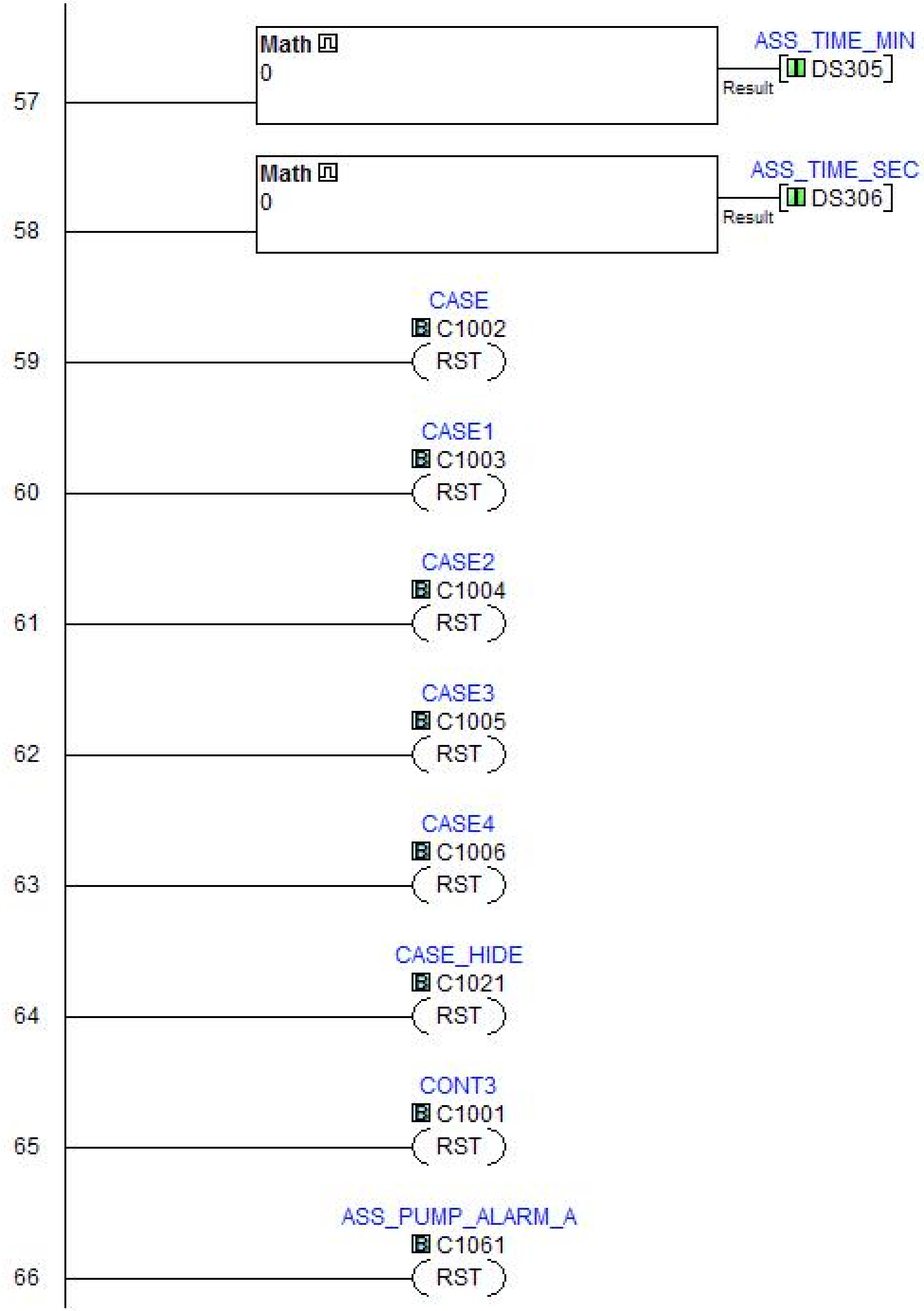

9
Math
10
Result
LEA_RATE_VAL_4TH
DS244
10
Math
0
Result
LEA_RATE_VAL
DS246
11
Math
0
Result
LEA_RATE_VAL_A
DS247
12
Math
0
Result
LEA_RATE_VAL_B
DS248
13
Math
10
Result
LEA_VTBI_VAL_1ST
DS251
14
Math
10
Result
LEA_VTBI_VAL_2ND
DS252
15
Math
10
Result
LEA_VTBI_VAL_3RD
DS253
16
Math
0
Result
LEA_VTBI_VAL
DS255
17
Math
0
Result
LEA_VTBI_VAL_A
DS256
18
Math
0
Result
LEA_VTBI_VAL_B
DS257

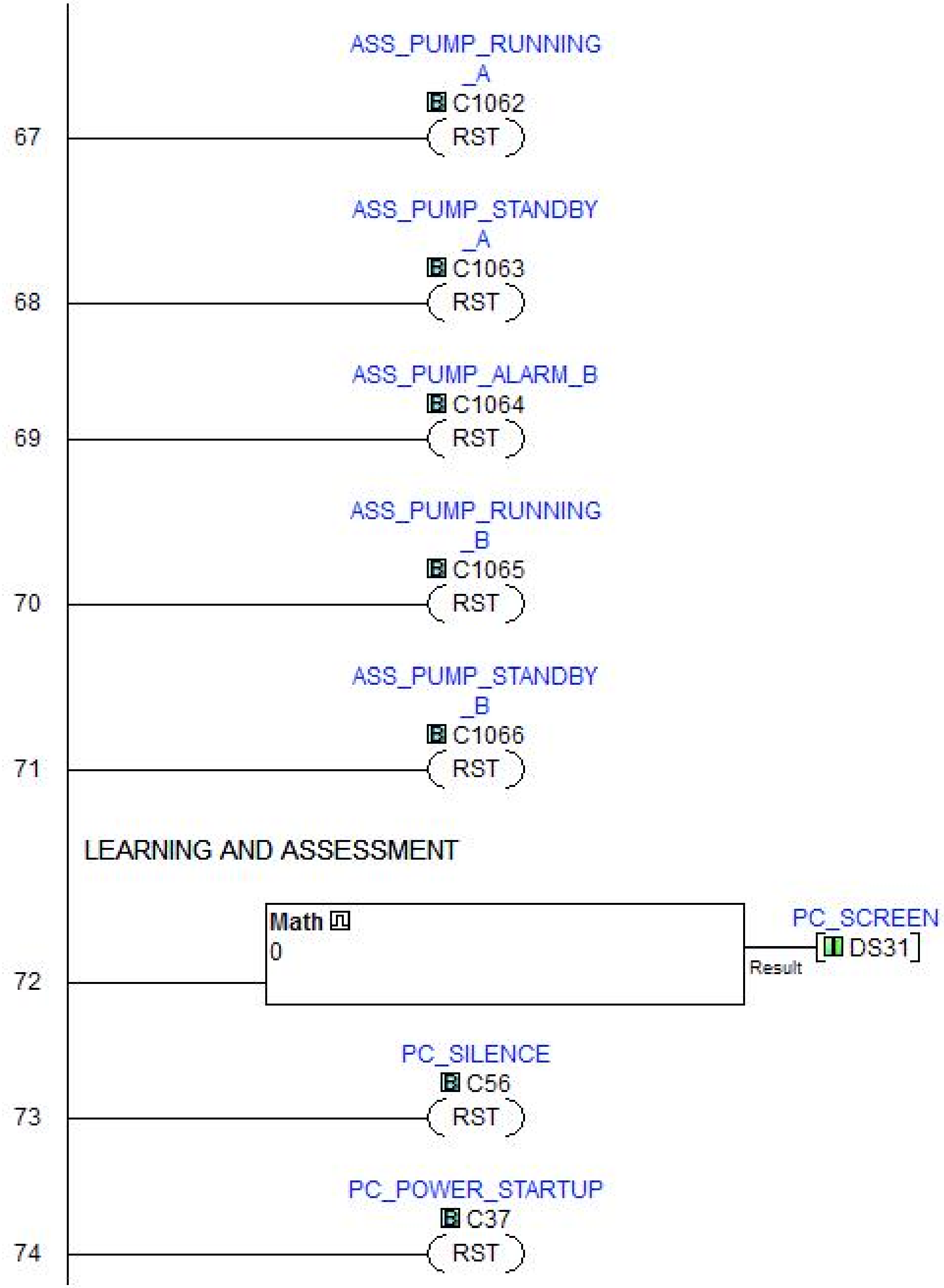

19
HINT1
C504
RST
20
HINT1_X
C505
RST
21
HINT2
C506
RST
22
HINT2_X
C507
RST
23
HINT3
C508
RST
24
HINT3_X
C509
RST
25
HINT4
C510
RST
26
HINT4_X
C511
RST
27
HINT5
C512
RST
28
HINT5_X
C513
RST

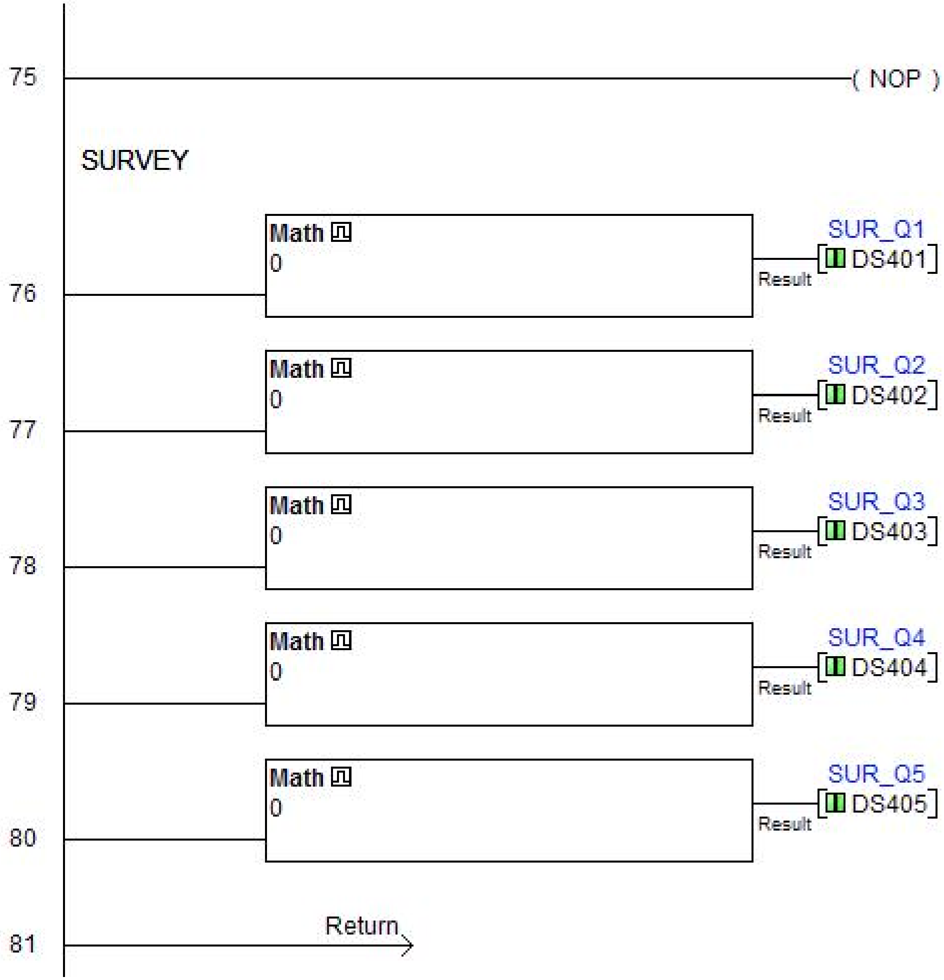

29
HINT6
C514
RST
30
HINT6_X
C515
RST
31
WARN1
C551
RST
32
CONT2
C501
RST
33
LEA_PUMP_ALARM_A
C561
RST
34
LEA_PUMP_RUNNING_A
C562
RST
35
LEA_PUMP_STANDBY_A
C563
RST
36
LEA_PUMP_ALARM_B
C564
RST
37
LEA_PUMP_RUNNING_B
C565
RST

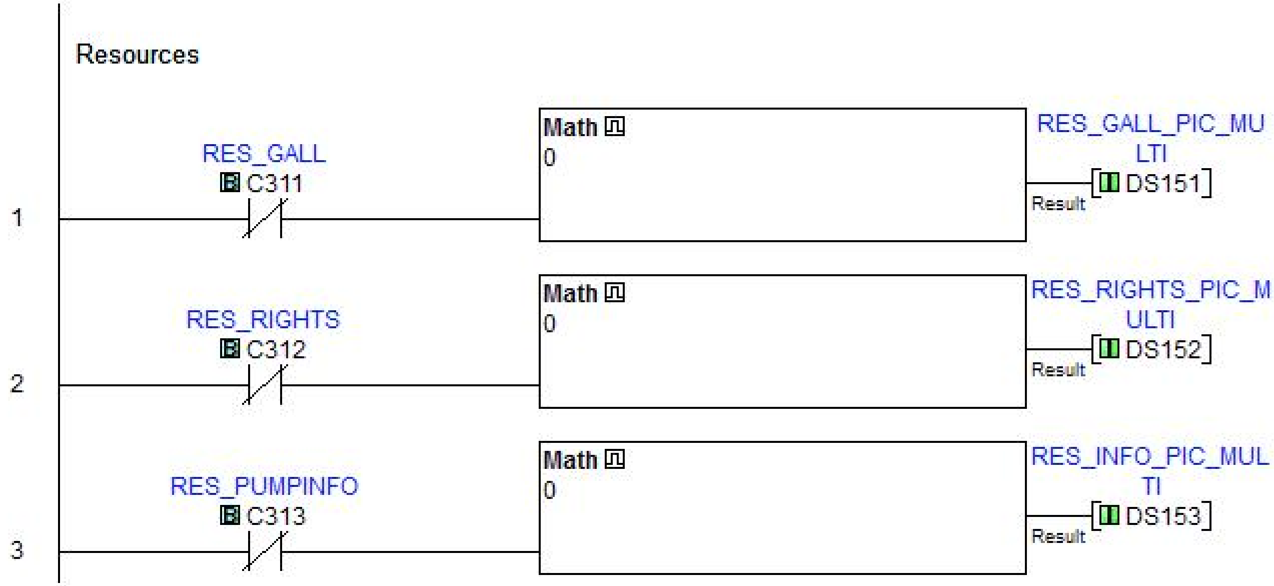

LEA_PUMP_STANDBY
_B
C566
38
RST
ASSESSMENT
ASS_PC_POWER
C38
39
RST
40
Math
10
ASS_RATE_VAL_1ST
DS341
Result
41
Math
10
ASS_RATE_VAL_2ND
DS342
Result
42
Math
10
ASS_RATE_VAL_3RD
DS343
Result
43
Math
10
ASS_RATE_VAL_4TH
DS344
Result
44
Math
0
ASS_RATE_VAL
DS346
Result
45
Math
0
ASS_RATE_VAL_A
DS347
Result
46
Math
0
ASS_RATE_VAL_B
DS348
Result

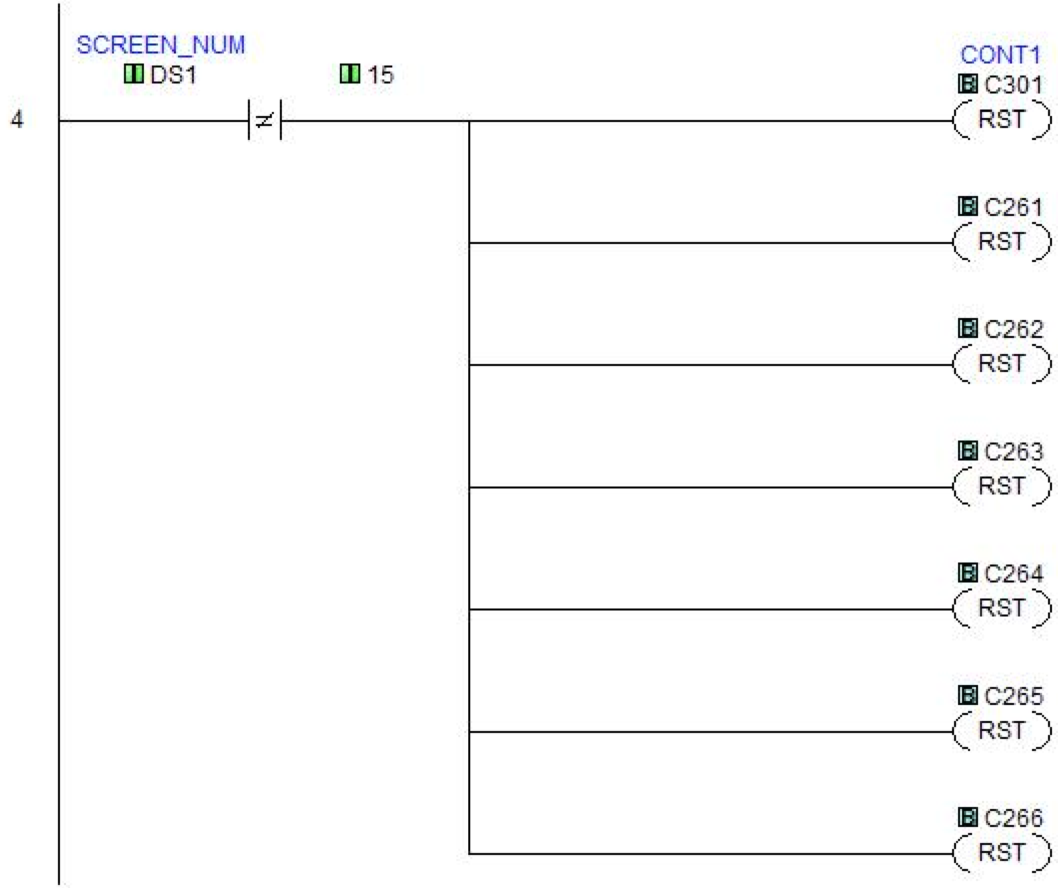

47
Math
10
Result
ASS_VTBI_VAL_1ST
DS351
48
Math
10
Result
ASS_VTBI_VAL_2ND
DS352
49
Math
10
Result
ASS_VTBI_VAL_3RD
DS353
50
Math
0
Result
ASS_VTBI_VAL
DS355
51
Math
0
Result
ASS_VTBI_VAL_A
DS356
52
Math
0
Result
ASS_VTBI_VAL_B
DS357
53
Math
0
Result
COUNTDOWN
DS301
54
Math
0
Result
CASE_NUM
DS302
55
Math
0
Result
CASE_DISP
DS303
56
Math
0
Result
ASS_TIME
DD10

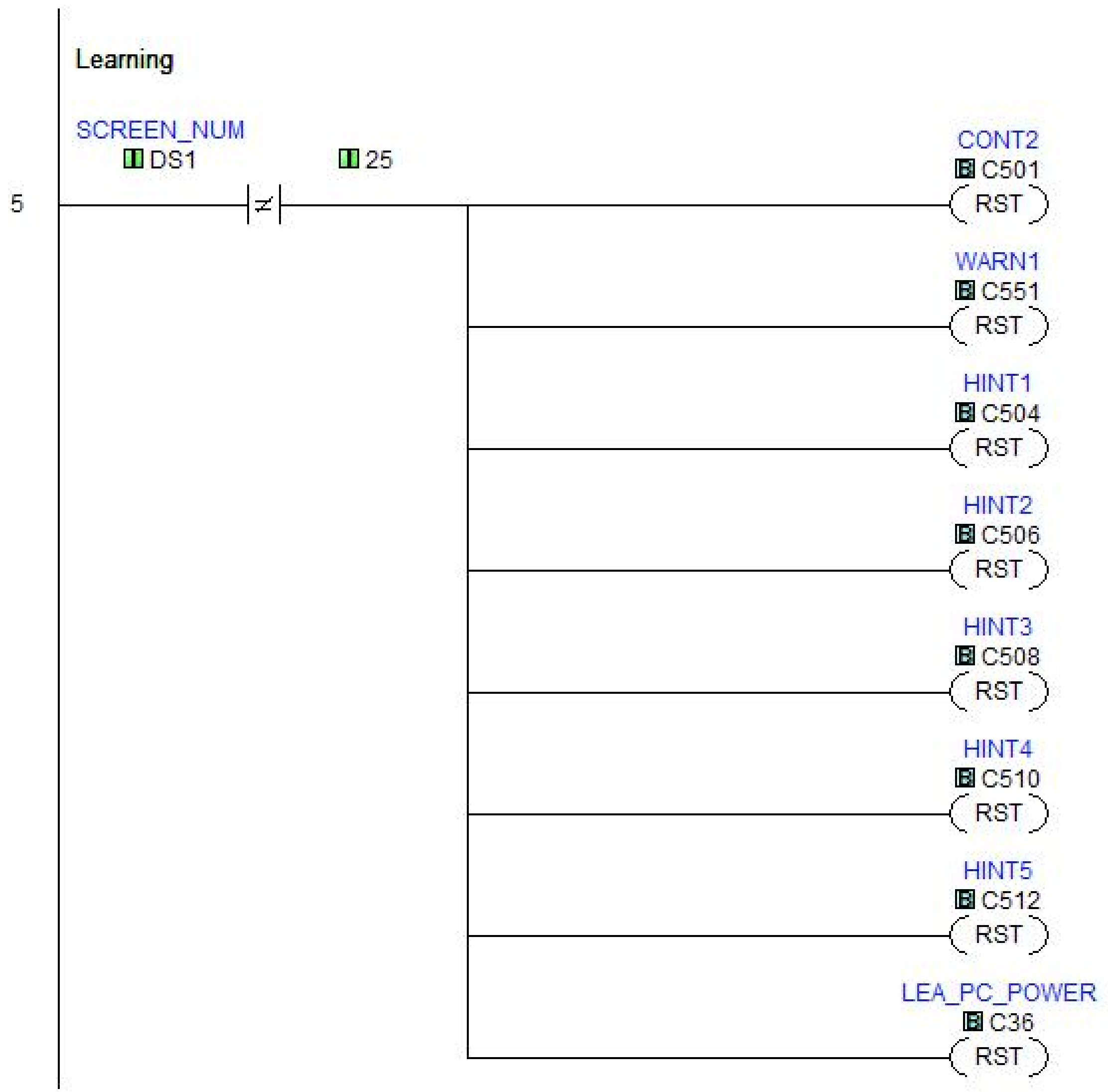

57
Math
0
Result
ASS_TIME_MIN
DS305
58
Math
0
Result
ASS_TIME_SEC
DS306
59
CASE
C1002
RST
60
CASE1
C1003
RST
61
CASE2
C1004
RST
62
CASE3
C1005
RST
63
CASE4
C1006
RST
64
CASE_HIDE
C1021
RST
65
CONT3
C1001
RST
66
ASS_PUMP_ALARM_A
C1061
RST


67
ASS_PUMP_RUNNING_A
C1062
RST
68
ASS_PUMP_STANDBY_A
C1063
RST
69
ASS_PUMP_ALARM_B
C1064
RST
70
ASS_PUMP_RUNNING_B
C1065
RST
71
ASS_PUMP_STANDBY_B
C1066
RST
LEARNING AND ASSESSMENT
72
Math
0
Result
PC_SCREEN
DS31
73
PC_SILENCE
C56
RST
74
PC_POWER_STARTUP
C37
RST

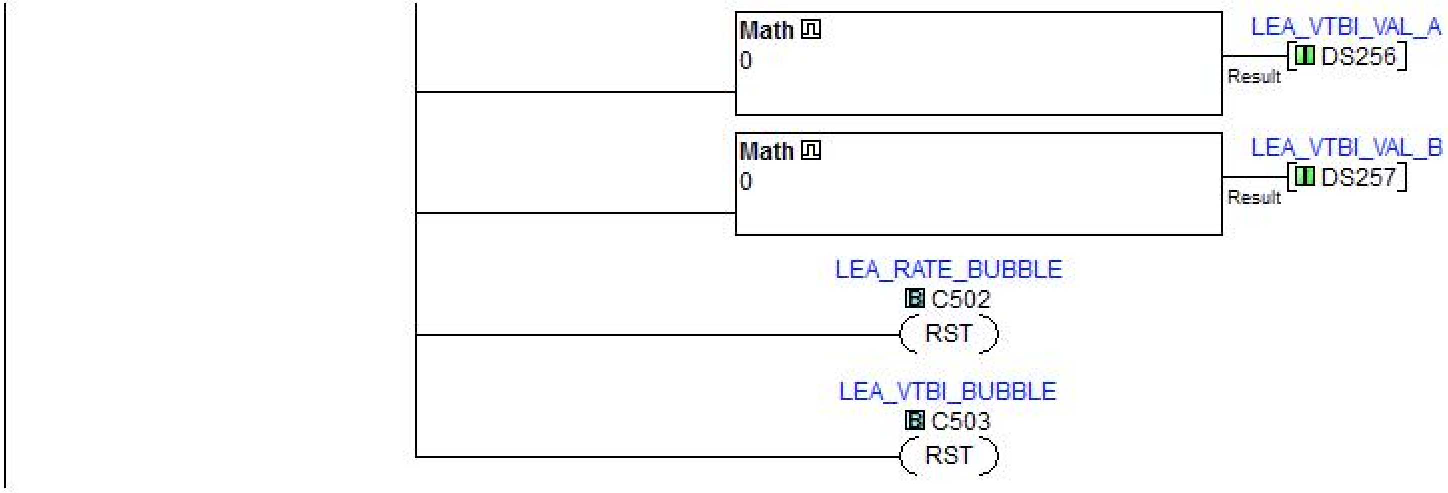

75
(NOP)
SURVEY
76
Math
0
Result
SUR_Q1
DS401
77
Math
0
Result
SUR_Q2
DS402
78
Math
0
Result
SUR_Q3
DS403
79
Math
0
Result
SUR_Q4
DS404
80
Math
0
Result
SUR_Q5
DS405
81
Return

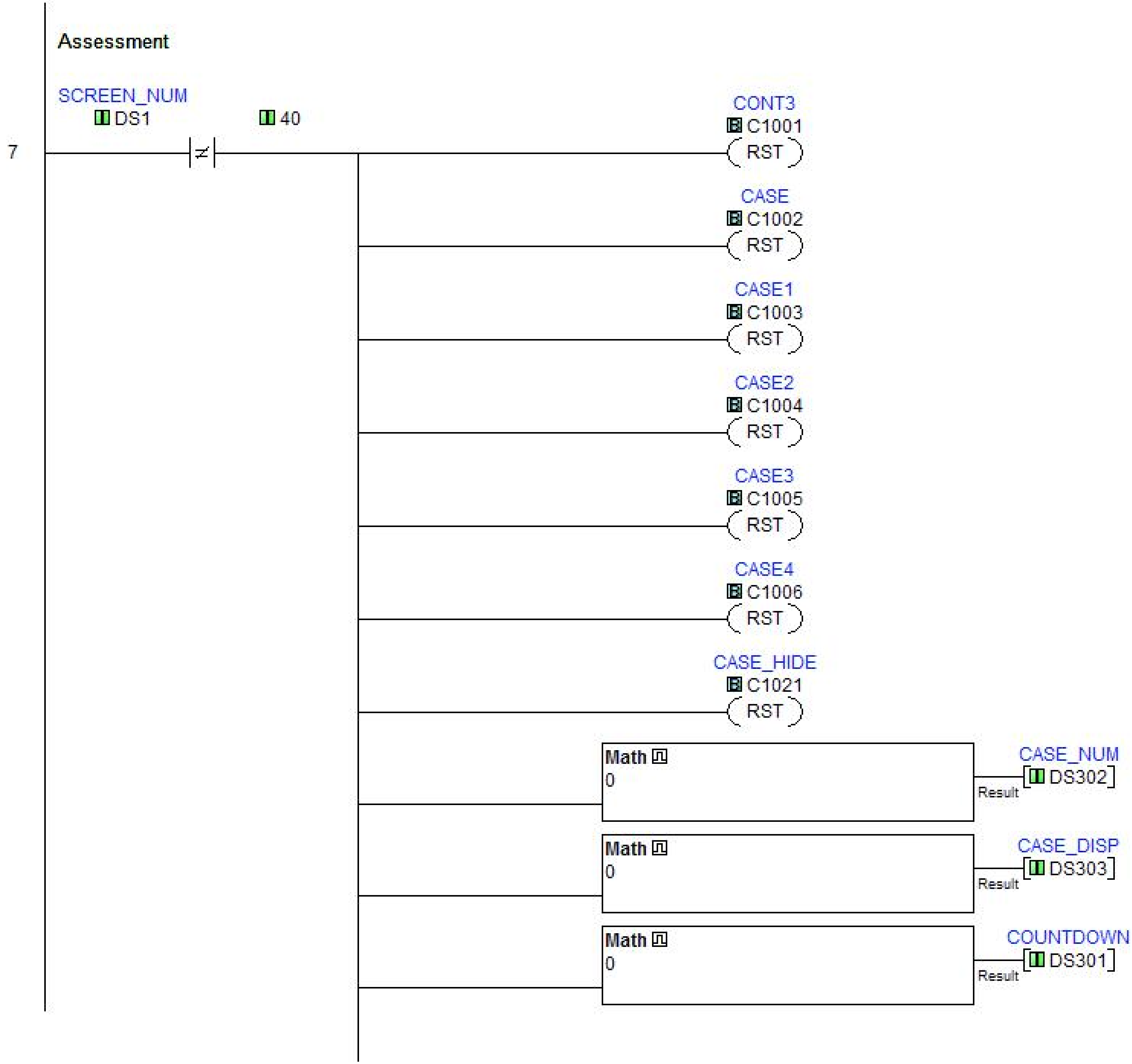

Resources
1
2
3
RES_GALL
C311
RES_RIGHTS
C312
RES_PUMPINFO
C313
Math
0
Math
0
Math
0
RES_GALL_PIC_MU
LTI
DS151
Result
RES_RIGHTS_PIC_M
ULTI
DS152
Result
RES_INFO_PIC_MUL
TI
DS153
Result

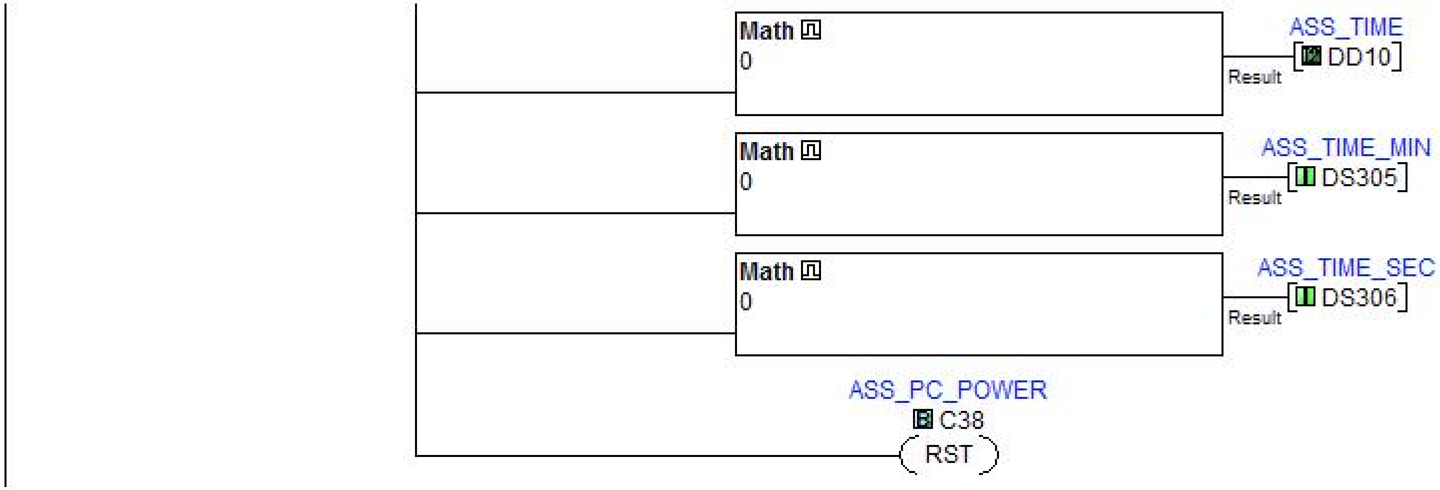

4
SCREEN_NUM
DS1
≠
15
CONT1
C301
RST
C261
RST
C262
RST
C263
RST
C264
RST
C265
RST
C266
RST


Learning
SCREEN_NUM
DS1
25
5
≠
CONT2
C501
RST
WARN1
C551
RST
HINT1
C504
RST
HINT2
C506
RST
HINT3
C508
RST
HINT4
C510
RST
HINT5
C512
RST
LEA_PC_POWER
C36
RST

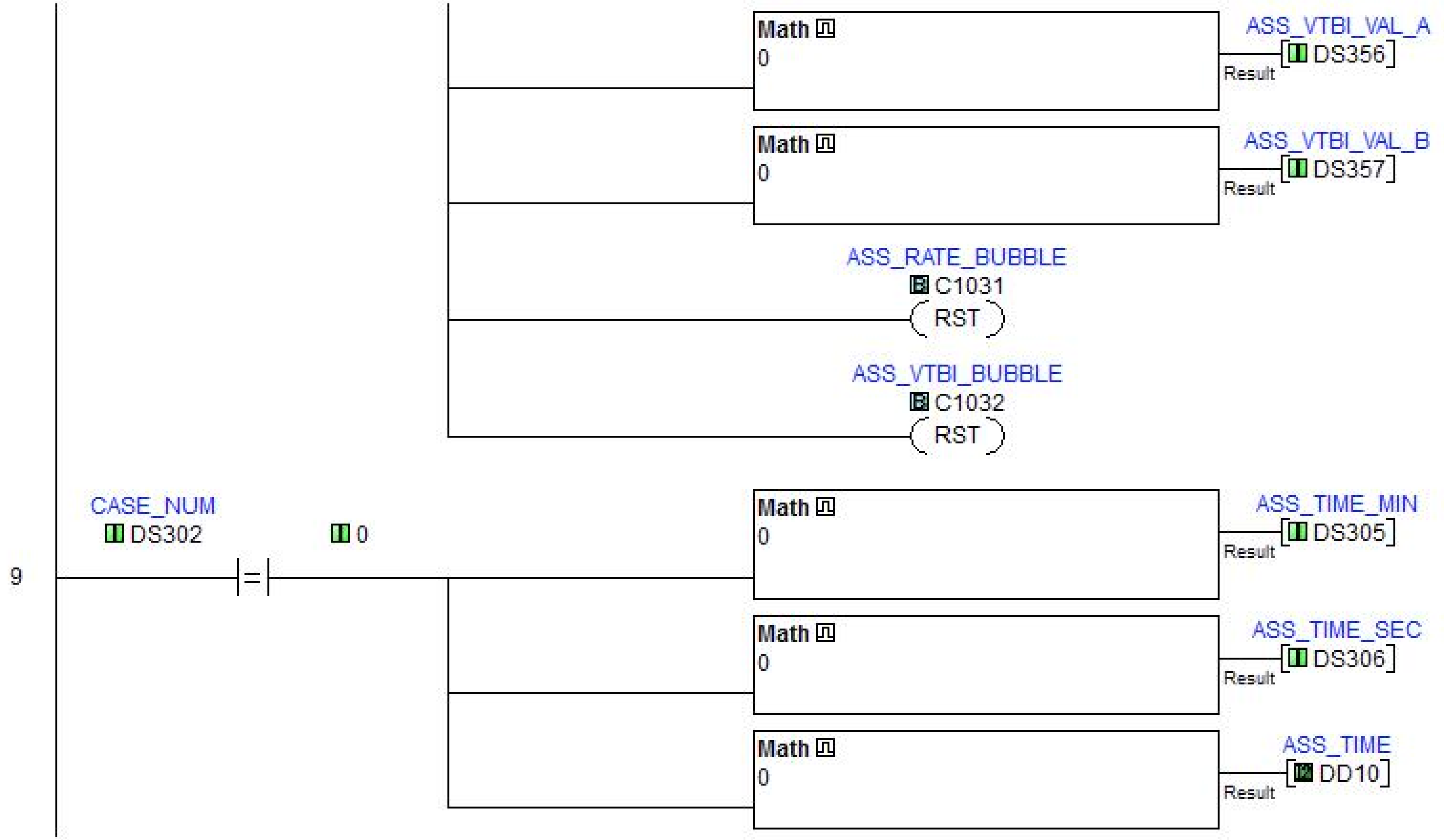

6
LEA_PC_POWER
C36
Math
10
Result
LEA_RATE_VAL_1ST
DS241
Math
10
Result
LEA_RATE_VAL_2ND
DS242
Math
10
Result
LEA_RATE_VAL_3RD
DS243
Math
10
Result
LEA_RATE_VAL_4TH
DS244
Math
0
Result
LEA_RATE_VAL
DS246
Math
0
Result
LEA_RATE_VAL_A
DS247
Math
0
Result
LEA_RATE_VAL_B
DS248
Math
10
Result
LEA_VTBI_VAL_1ST
DS251
Math
10
Result
LEA_VTBI_VAL_2ND
DS252
Math
10
Result
LEA_VTBI_VAL_3RD
DS253
Math
0
Result
LEA_VTBI_VAL
DS255

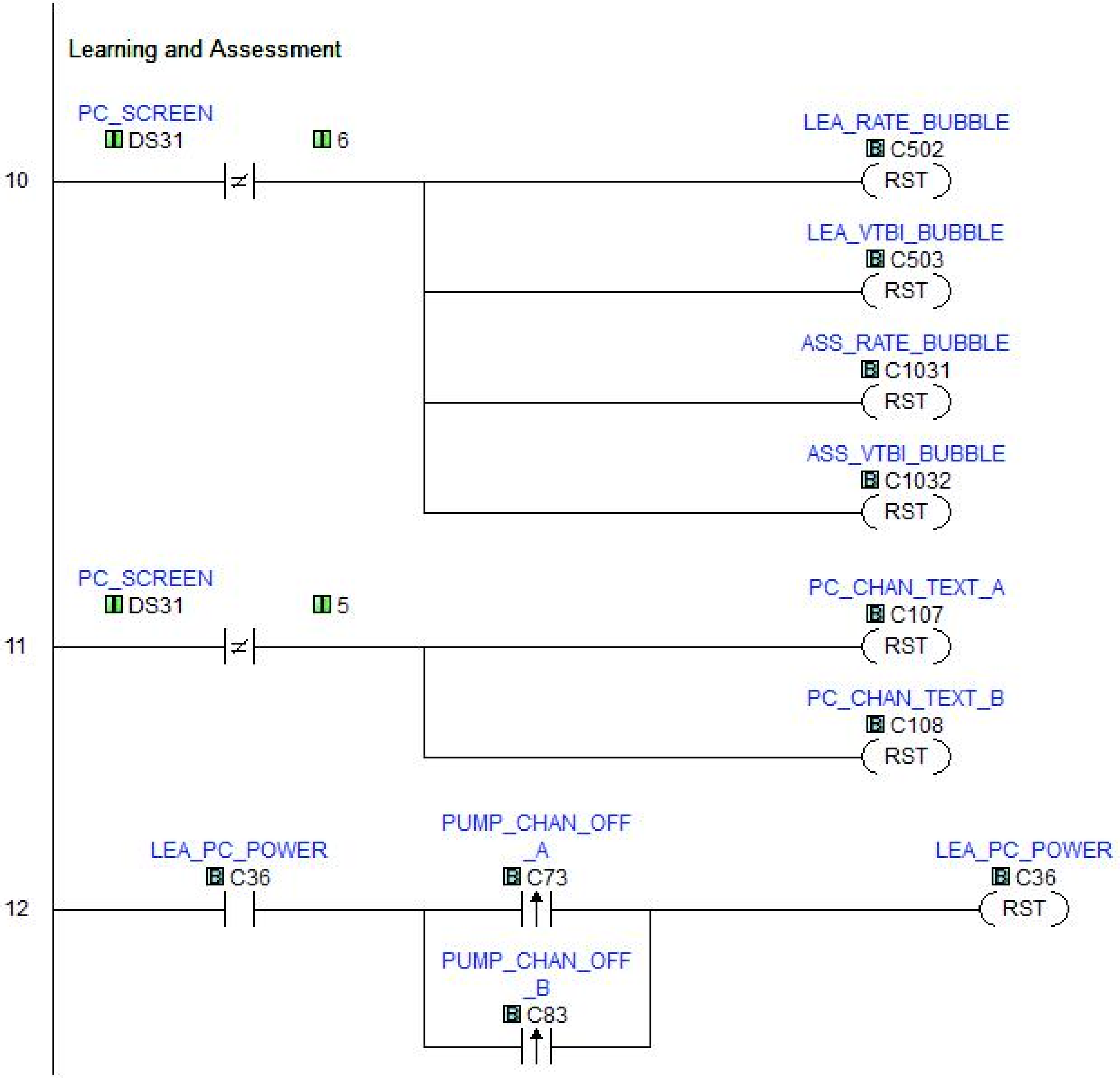

Math
0
Result
LEA_VTBI_VAL_A
DS256
Math
0
Result
LEA_VTBI_VAL_B
DS257
LEA_RATE_BUBBLE
C502
RST
LEA_VTBI_BUBBLE
C503
RST

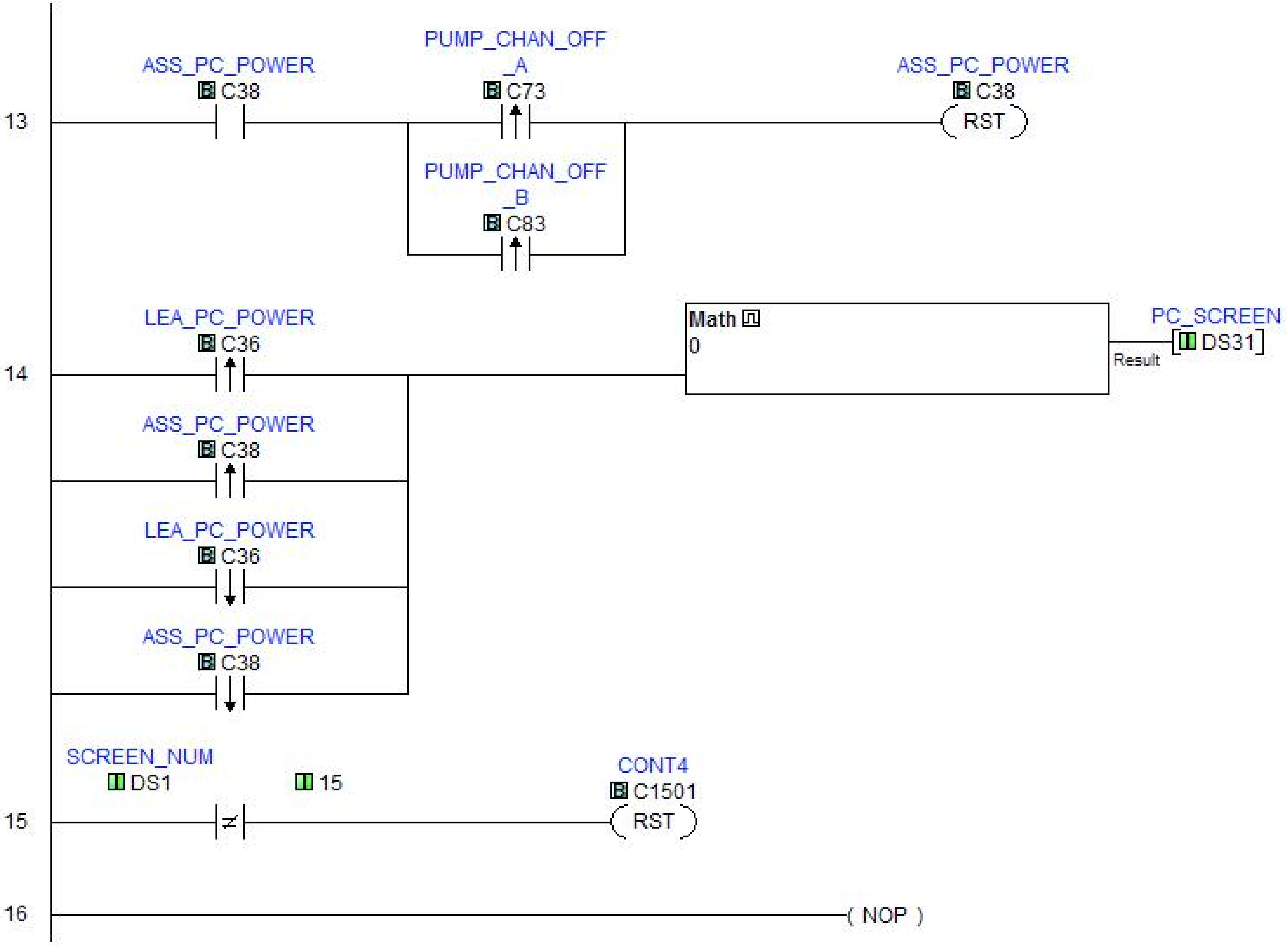

7
Assessment
SCREEN_NUM
DS1
≠
40
CONT3
C1001
RST
CASE
C1002
RST
CASE1
C1003
RST
CASE2
C1004
RST
CASE3
C1005
RST
CASE4
C1006
RST
CASE_HIDE
C1021
RST
Math
0
Result
CASE_NUM
DS302
Math
0
Result
CASE_DISP
DS303
Math
0
Result
COUNTDOWN
DS301

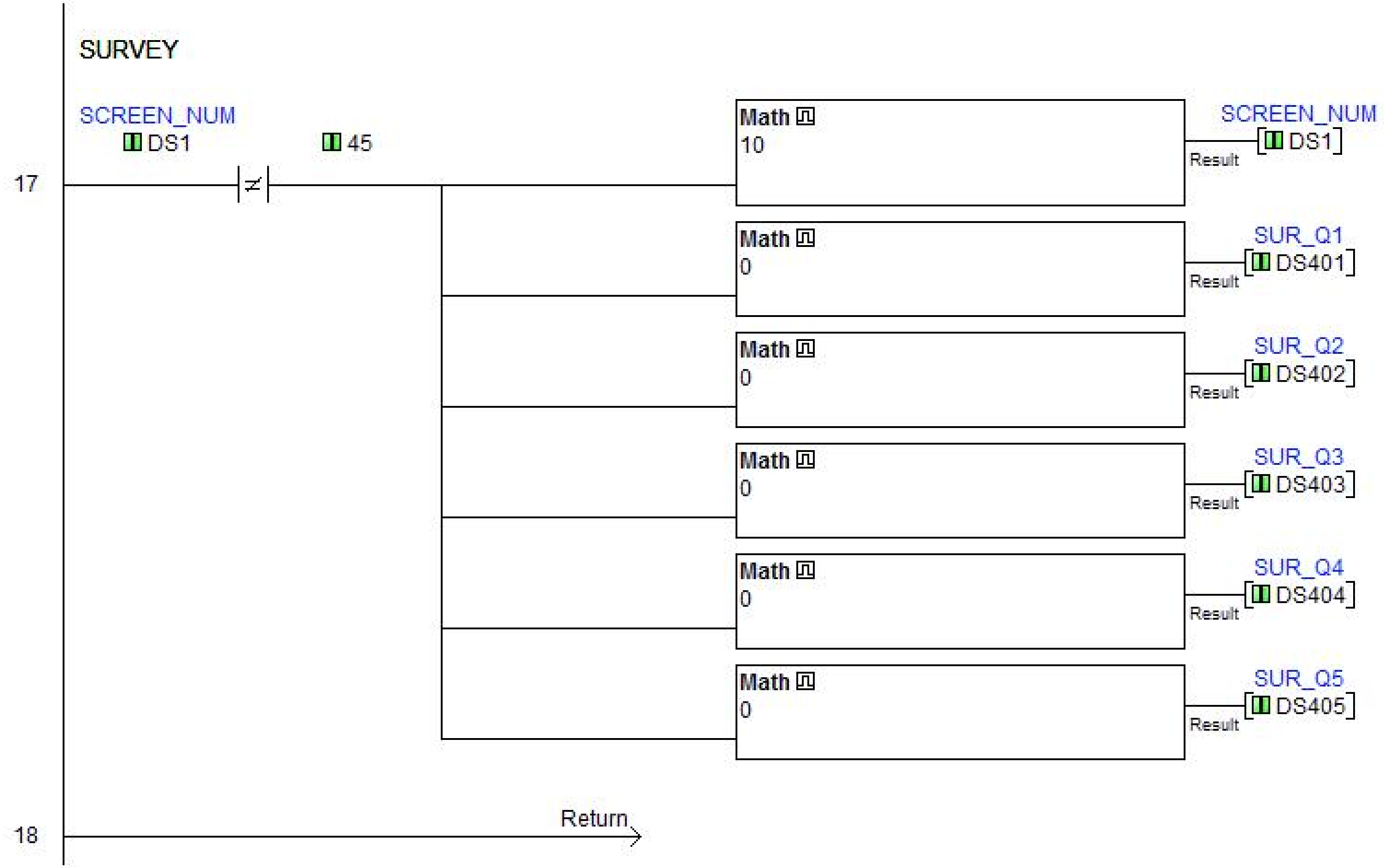

Math
0
Result
ASS_TIME
DD10
Math
0
Result
ASS_TIME_MIN
DS305
Math
0
Result
ASS_TIME_SEC
DS306
ASS_PC_POWER
C38
RST

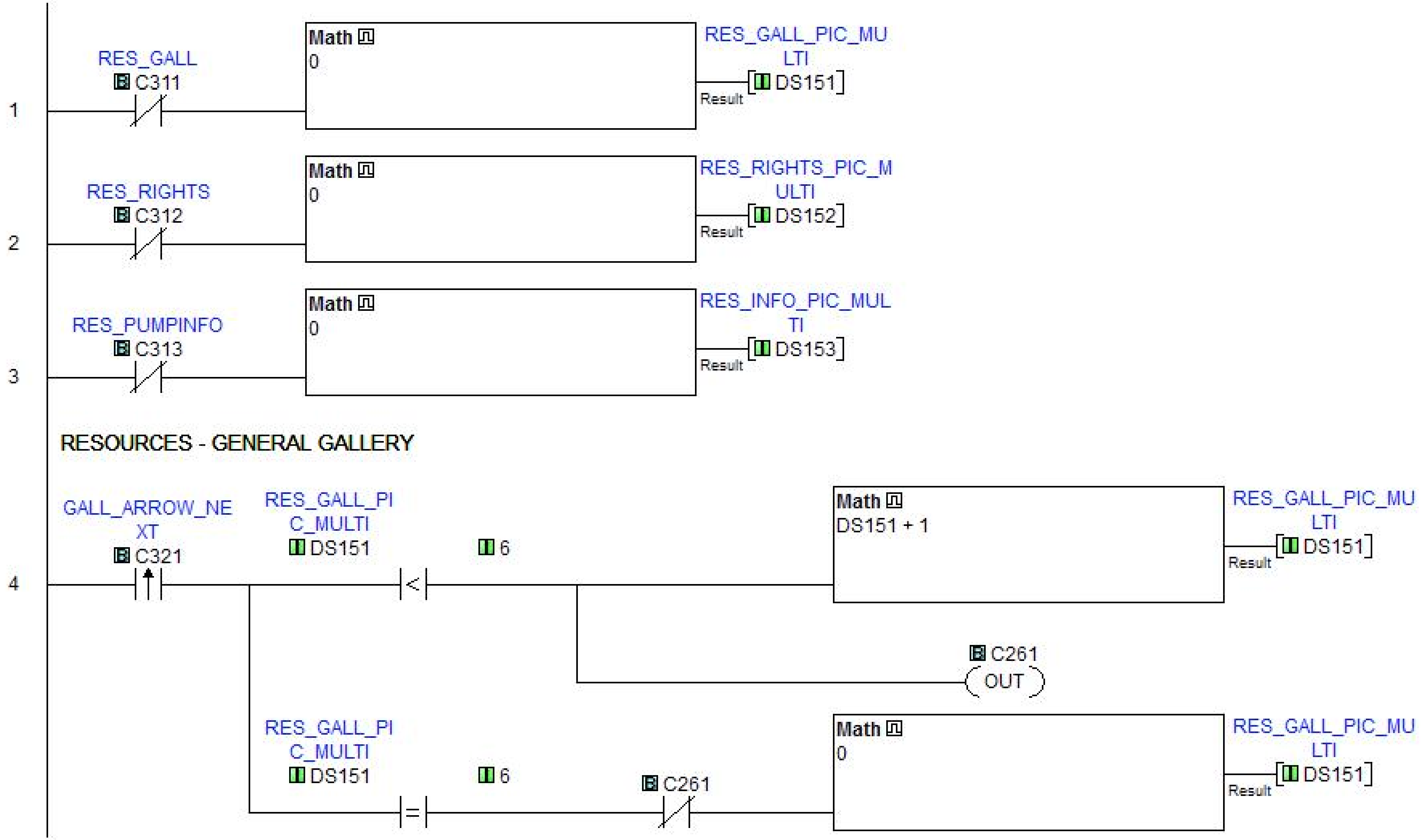

8
ASS_PC_POWER
C38
Math
10
ASS_RATE_VAL_1ST
DS341
Result
Math
10
ASS_RATE_VAL_2ND
DS342
Result
Math
10
ASS_RATE_VAL_3RD
DS343
Result
Math
10
ASS_RATE_VAL_4TH
DS344
Result
Math
0
ASS_RATE_VAL
DS346
Result
Math
0
ASS_RATE_VAL_A
DS347
Result
Math
0
ASS_RATE_VAL_B
DS348
Result
Math
10
ASS_VTBI_VAL_1ST
DS351
Result
Math
10
ASS_VTBI_VAL_2ND
DS352
Result
Math
10
ASS_VTBI_VAL_3RD
DS353
Result
Math
0
ASS_VTBI_VAL
DS355
Result

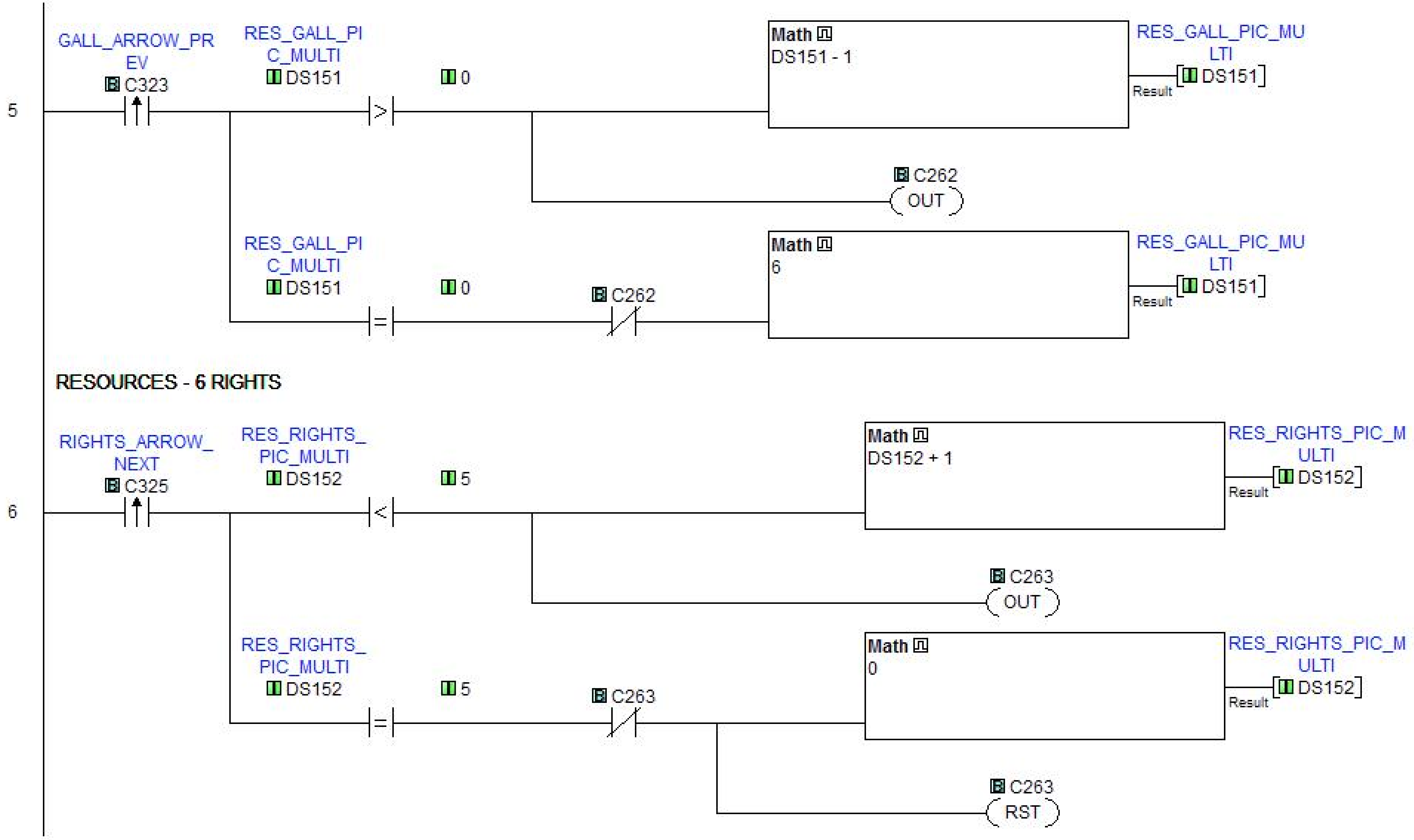

9
CASE_NUM
DS302
=
0
Math
0
Result
ASS_VTBI_VAL_A
DS356
Math
0
Result
ASS_VTBI_VAL_B
DS357
ASS_RATE_BUBBLE
C1031
RST
ASS_VTBI_BUBBLE
C1032
RST
Math
0
Result
ASS_TIME_MIN
DS305
Math
0
Result
ASS_TIME_SEC
DS306
Math
0
Result
ASS_TIME
DD10

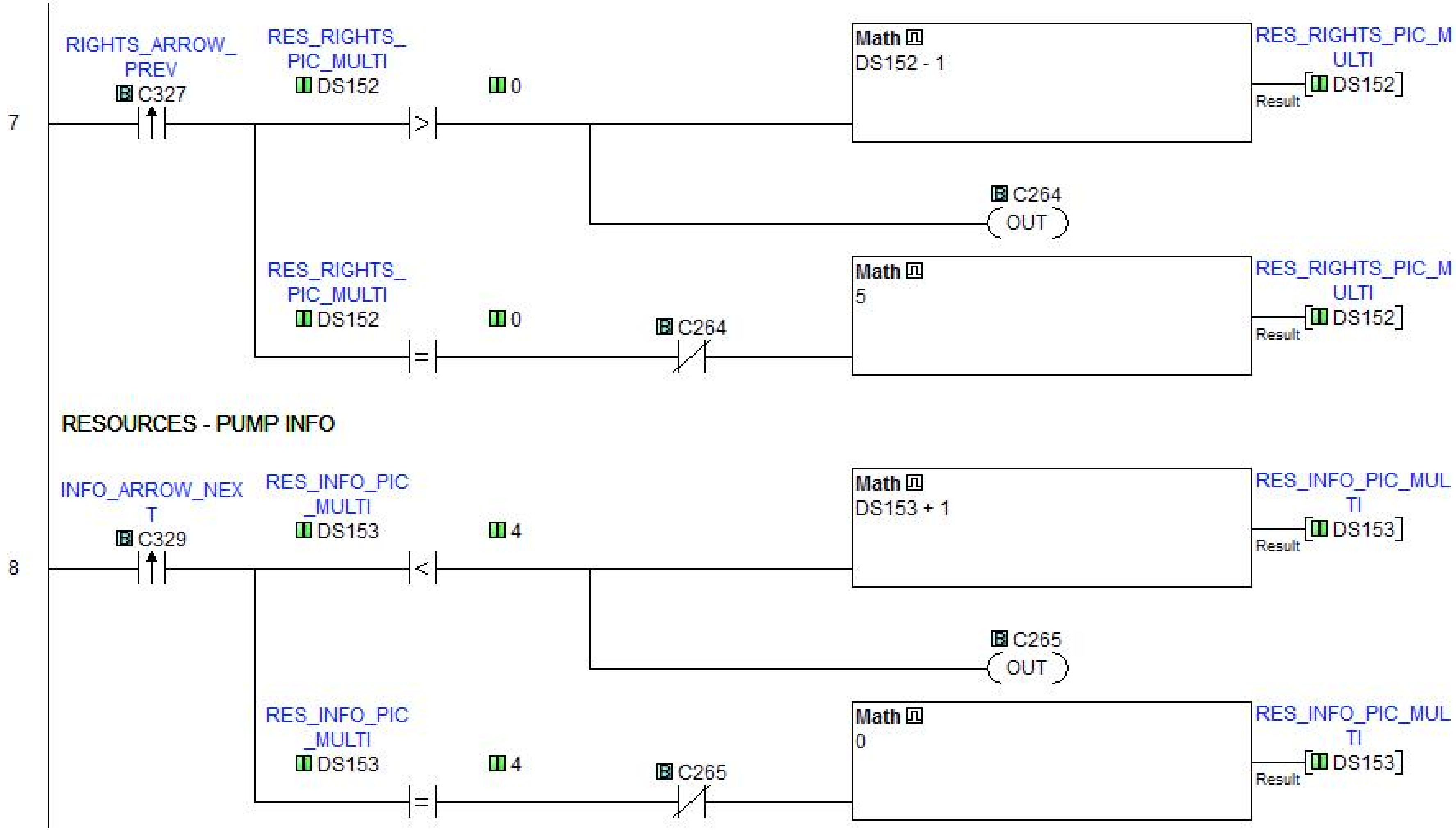

Learning and Assessment
10
PC_SCREEN
DS31
6
LEA_RATE_BUBBLE
C502
RST
LEA_VTBI_BUBBLE
C503
RST
ASS_RATE_BUBBLE
C1031
RST
ASS_VTBI_BUBBLE
C1032
RST
11
PC_SCREEN
DS31
5
PC_CHAN_TEXT_A
C107
RST
PC_CHAN_TEXT_B
C108
RST
12
LEA_PC_POWER
C36
PUMP_CHAN_OFF
_A
C73
PUMP_CHAN_OFF
_B
C83
LEA_PC_POWER
C36
RST

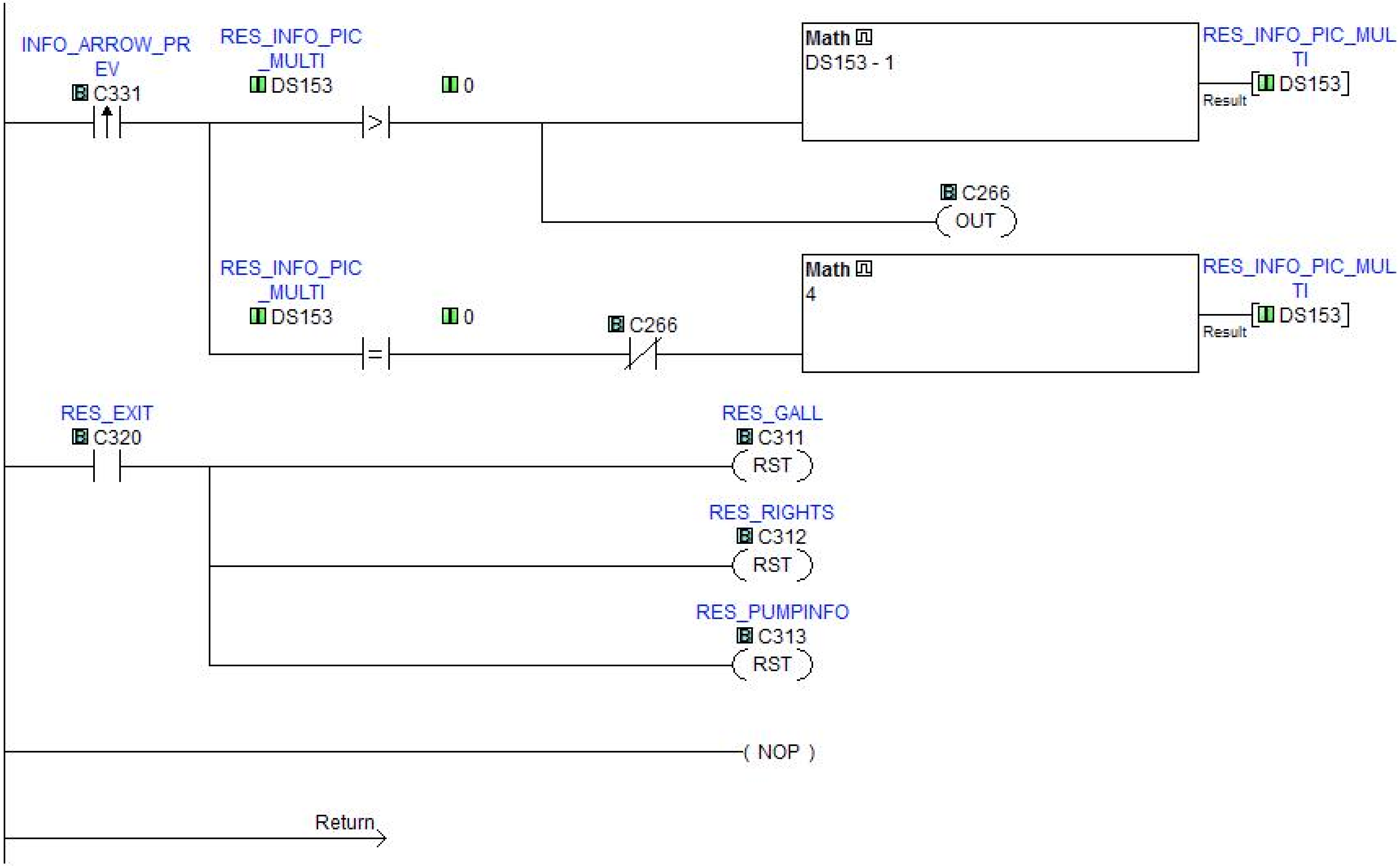

13
ASS_PC_POWER
C38
PUMP_CHAN_OFF_A
C73
PUMP_CHAN_OFF_B
C83
ASS_PC_POWER
C38
RST
14
LEA_PC_POWER
C36
ASS_PC_POWER
C38
LEA_PC_POWER
C36
ASS_PC_POWER
C38
Math
0
Result
PC_SCREEN
DS31
15
SCREEN_NUM
DS1
15
CONT4
C1501
RST
16
(NOP)

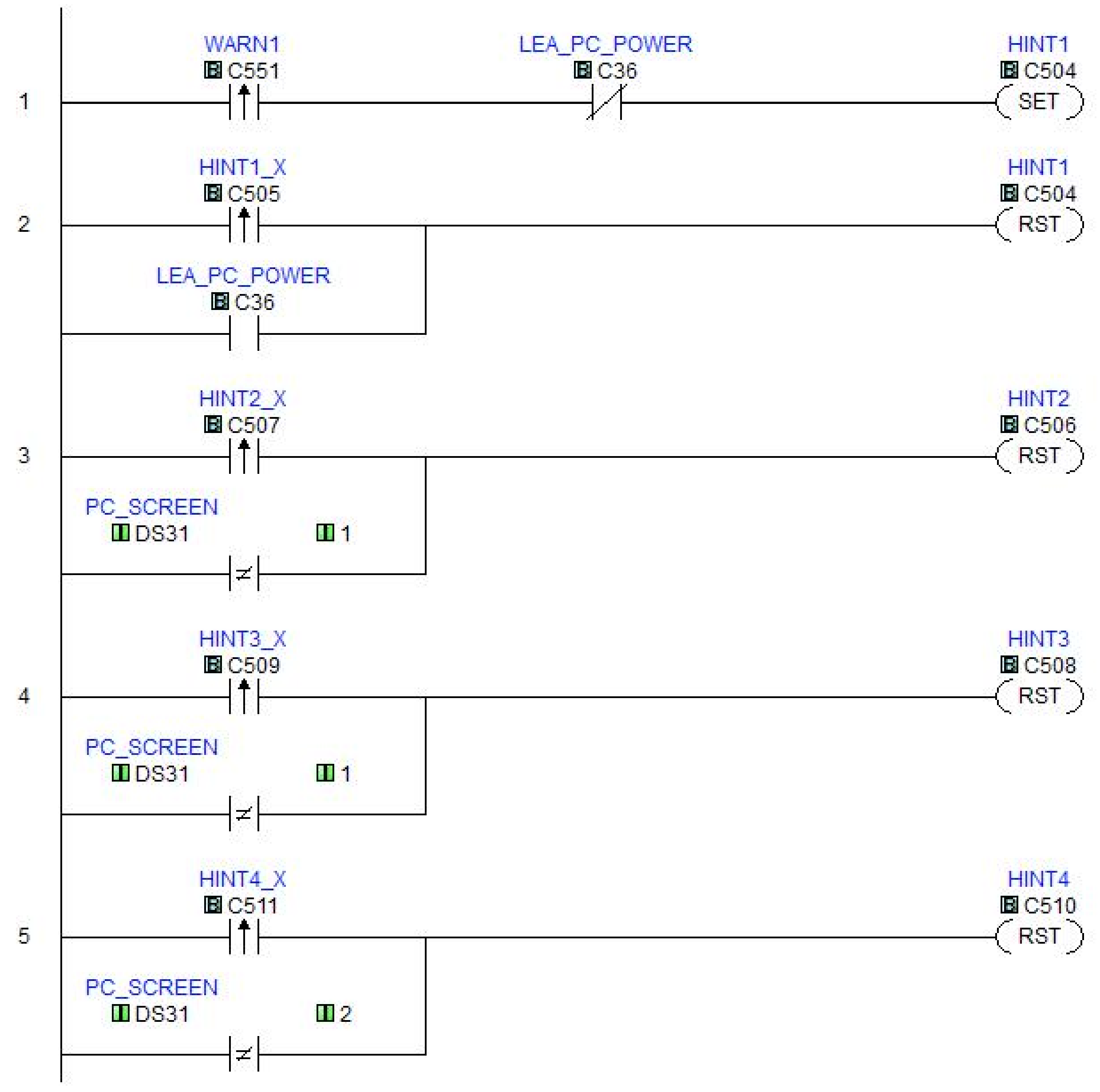

SURVEY
17
SCREEN_NUM
DS1
45
Math
10
Result
SCREEN_NUM
DS1
Math
0
Result
SUR_Q1
DS401
Math
0
Result
SUR_Q2
DS402
Math
0
Result
SUR_Q3
DS403
Math
0
Result
SUR_Q4
DS404
Math
0
Result
SUR_Q5
DS405
18
Return

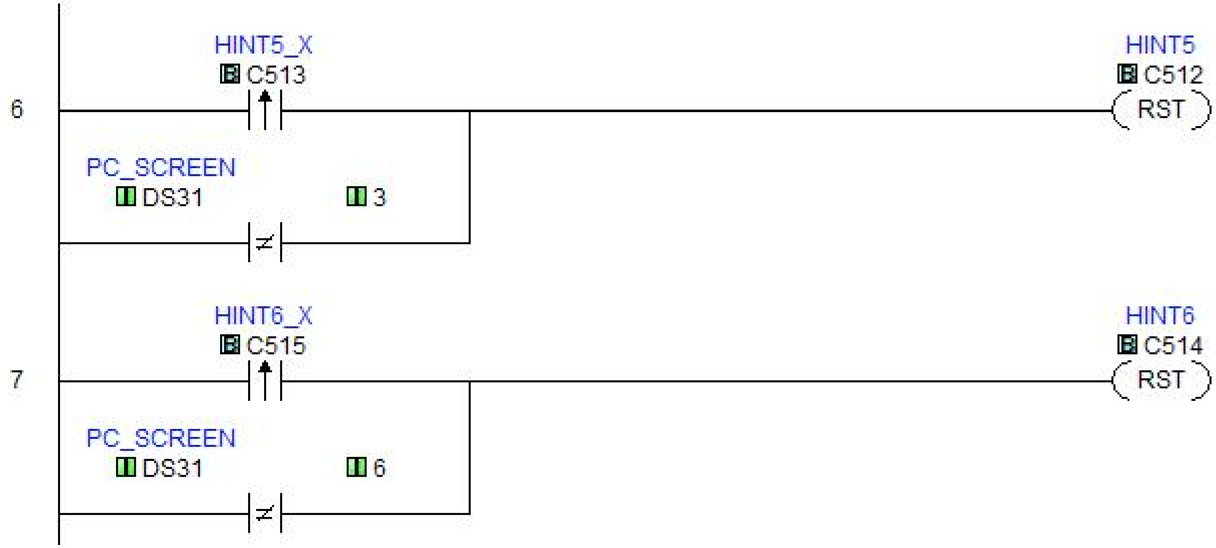

1
RES_GALL
C311
Math
0
RES_GALL_PIC_MULTI
Result
DS151
2
RES_RIGHTS
C312
Math
0
RES_RIGHTS_PIC_MULTI
Result
DS152
3
RES_PUMPINFO
C313
Math
0
RES_INFO_PIC_MULTI
Result
DS153
RESOURCES - GENERAL GALLERY
4
GALL_ARROW_NEXT
C321
RES_GALL_PIC_MULTI
DS151
<
6
Math
DS151 + 1
RES_GALL_PIC_MULTI
Result
DS151
C261
OUT
RES_GALL_PIC_MULTI
DS151
=
6
C261
Math
0
RES_GALL_PIC_MULTI
Result
DS151

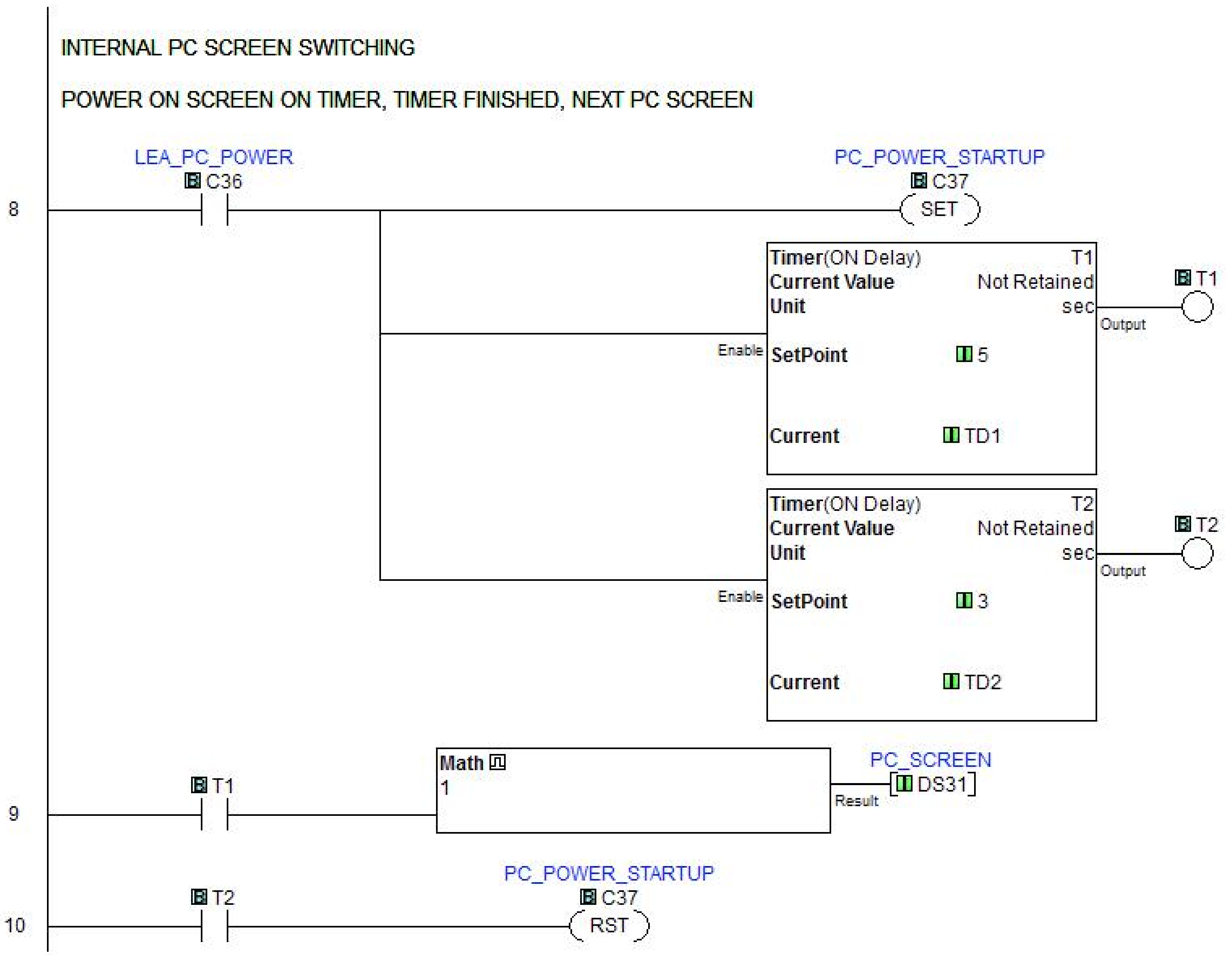

5
GALL_ARROW_PREV
C323
RES_GALL_PIC_MULTI
DS151
>
0
Math
DS151 - 1
Result
RES_GALL_PIC_MULTI
DS151
C262
OUT
RES_GALL_PIC_MULTI
DS151
=
0
C262
Math
6
Result
RES_GALL_PIC_MULTI
DS151
RESOURCES - 6 RIGHTS
6
RIGHTS_ARROW_NEXT
C325
RES_RIGHTS_PIC_MULTI
DS152
<
5
Math
DS152 + 1
Result
RES_RIGHTS_PIC_MULTI
DS152
C263
OUT
RES_RIGHTS_PIC_MULTI
DS152
=
5
C263
Math
0
Result
RES_RIGHTS_PIC_MULTI
DS152
C263
RST

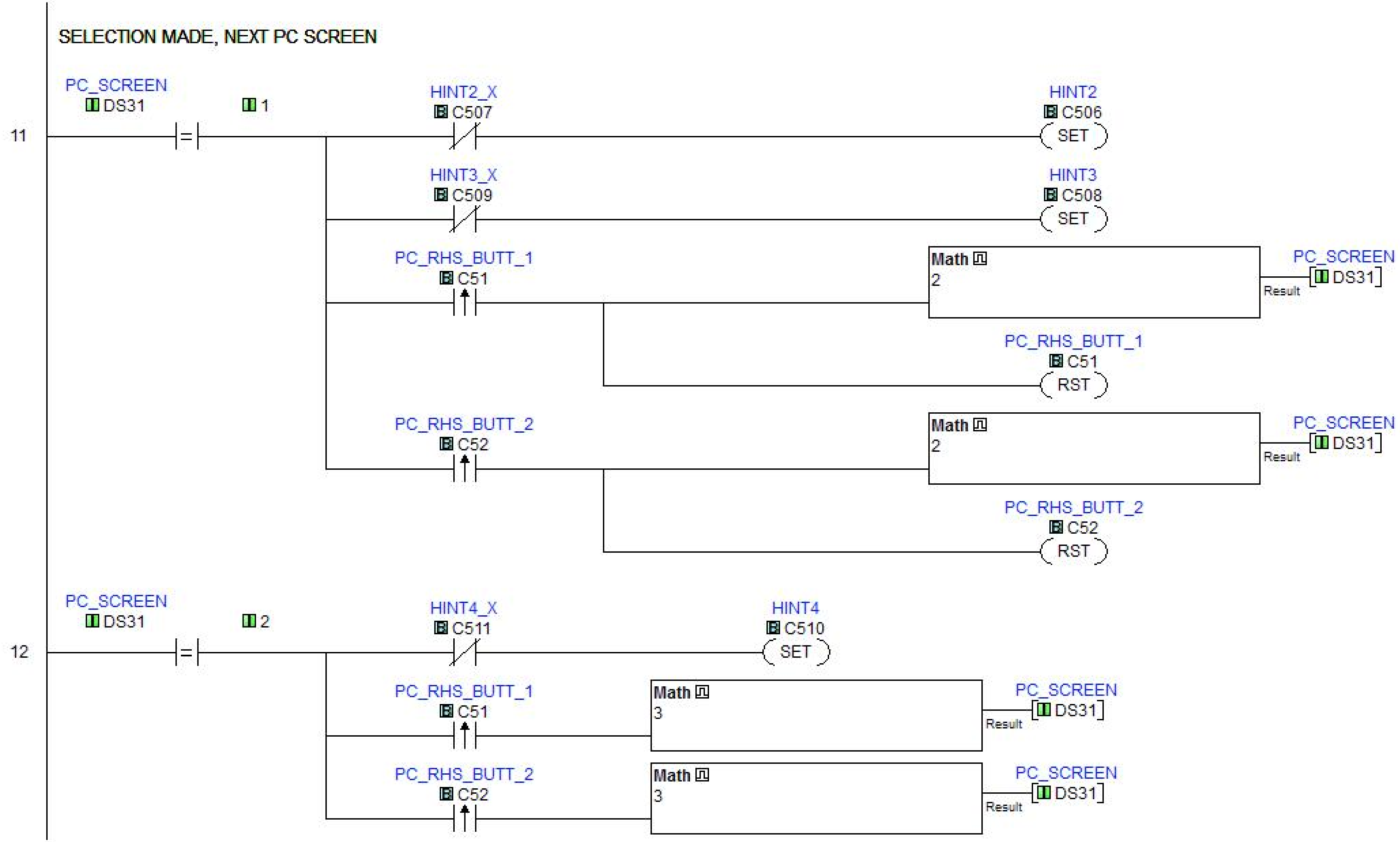

7
RIGHTS_ARROW_PREV
C327
RES_RIGHTS_PIC_MULTI
DS152
>
0
Math
DS152 - 1
RES_RIGHTS_PIC_MULTI
Result
DS152
C264
OUT
RES_RIGHTS_PIC_MULTI
DS152
=
0
C264
Math
5
RES_RIGHTS_PIC_MULTI
Result
DS152
RESOURCES - PUMP INFO
8
INFO_ARROW_NEXT
C329
RES_INFO_PIC_MULTI
DS153
<
4
Math
DS153 + 1
RES_INFO_PIC_MULTI
Result
DS153
C265
OUT
RES_INFO_PIC_MULTI
DS153
=
4
C265
Math
0
RES_INFO_PIC_MULTI
Result
DS153


9
INFO_ARROW_PREV
C331
RES_INFO_PIC_MULTI
DS153
>
0
Math
DS153 - 1
Result
RES_INFO_PIC_MULTI
DS153
C266
OUT
RES_INFO_PIC_MULTI
DS153
=
0
C266
Math
4
Result
RES_INFO_PIC_MULTI
DS153
10
RES_EXIT
C320
RES_GALL
C311
RST
RES_RIGHTS
C312
RST
RES_PUMPINFO
C313
RST
11
(NOP)
12
Return


1
WARN1
C551
LEA_PC_POWER
C36
HINT1
C504
SET
2
HINT1_X
C505
HINT1
C504
RST
LEA_PC_POWER
C36
3
HINT2_X
C507
HINT2
C506
RST
PC_SCREEN
DS31
1
4
HINT3_X
C509
HINT3
C508
RST
PC_SCREEN
DS31
1
5
HINT4_X
C511
HINT4
C510
RST
PC_SCREEN
DS31
2

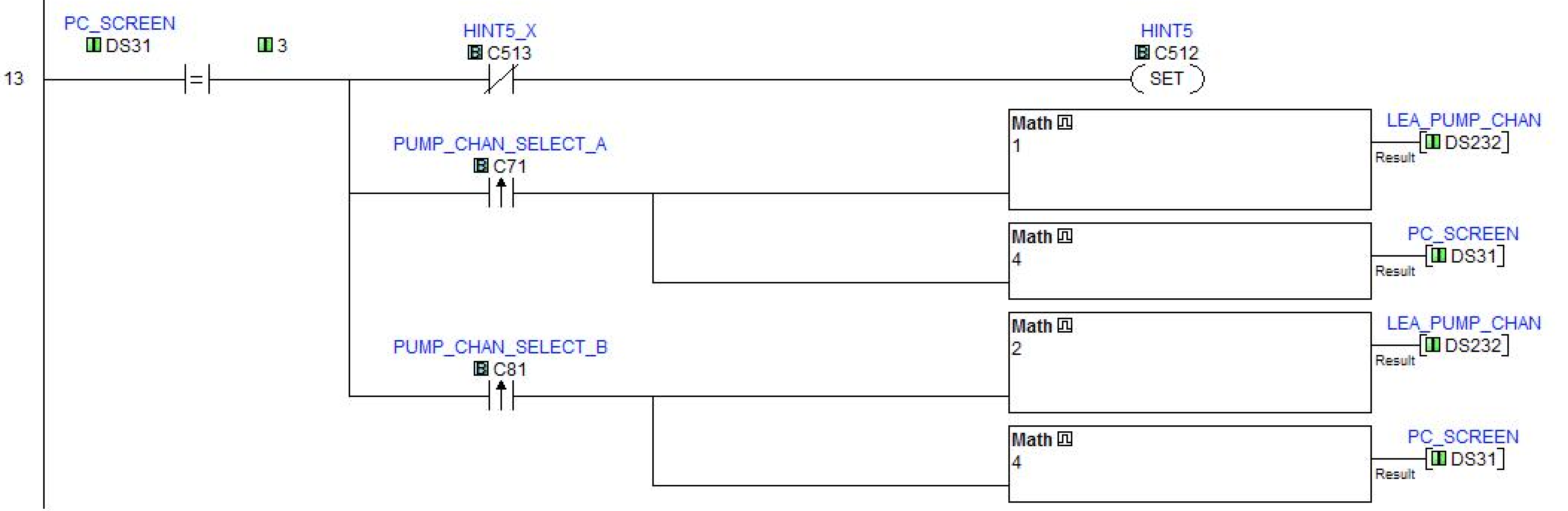

6
HINT5_X
C513
HINT5
C512
RST
PC_SCREEN
DS31
3
7
HINT6_X
C515
HINT6
C514
RST
PC_SCREEN
DS31
6

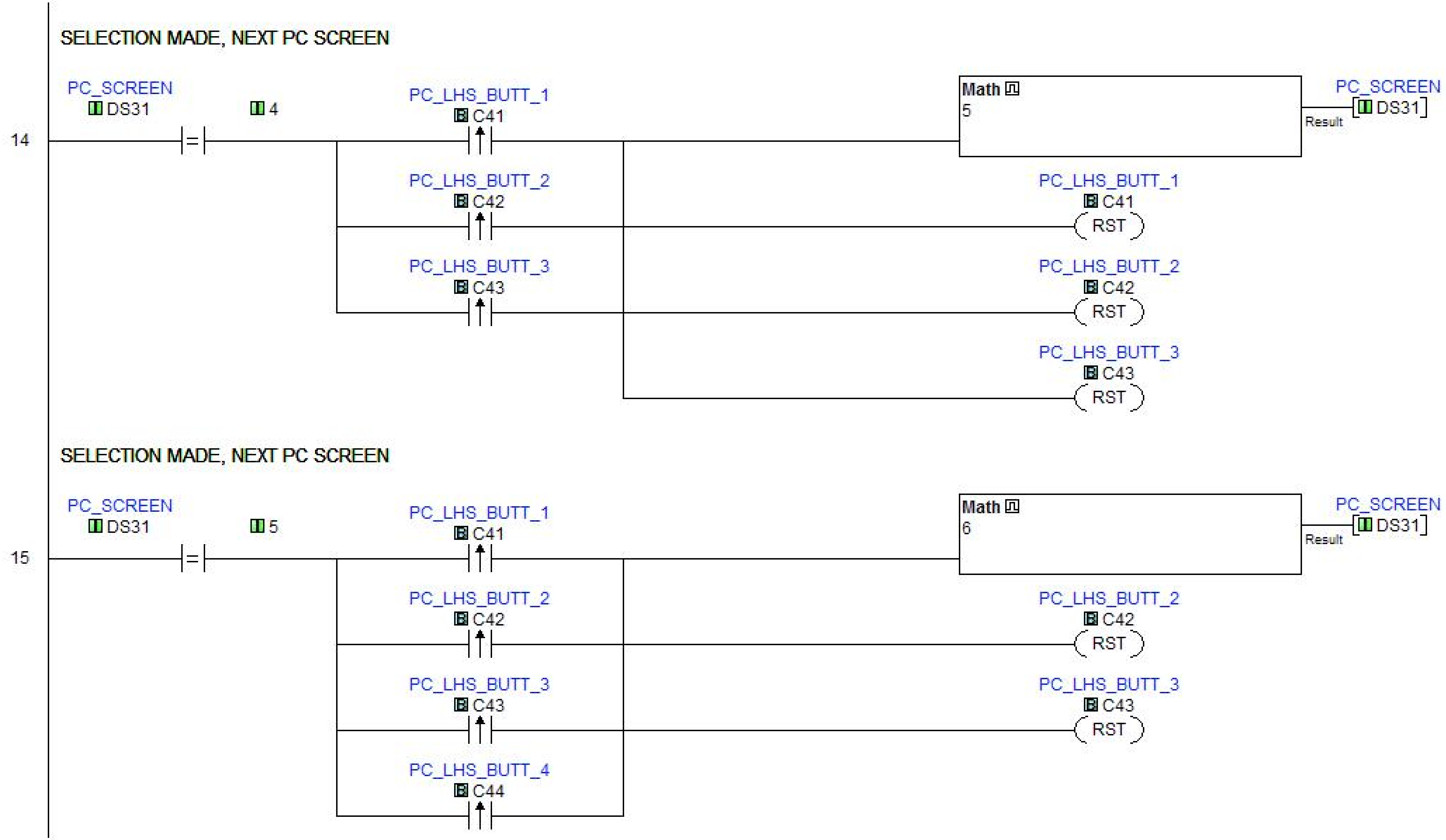

INTERNAL PC SCREEN SWITCHING
POWER ON SCREEN ON TIMER, TIMER FINISHED, NEXT PC SCREEN
8
LEA_PC_POWER
C36
PC_POWER_STARTUP
C37
SET
Timer(ON Delay) T1
Current Value Not Retained
Unit sec
Enable
SetPoint 5
Current TD1
Output
T1
Timer(ON Delay) T2
Current Value Not Retained
Unit sec
Enable
SetPoint 3
Current TD2
Output
T2
9
T1
Math
1
Result
PC_SCREEN
DS31
10
T2
PC_POWER_STARTUP
C37
RST

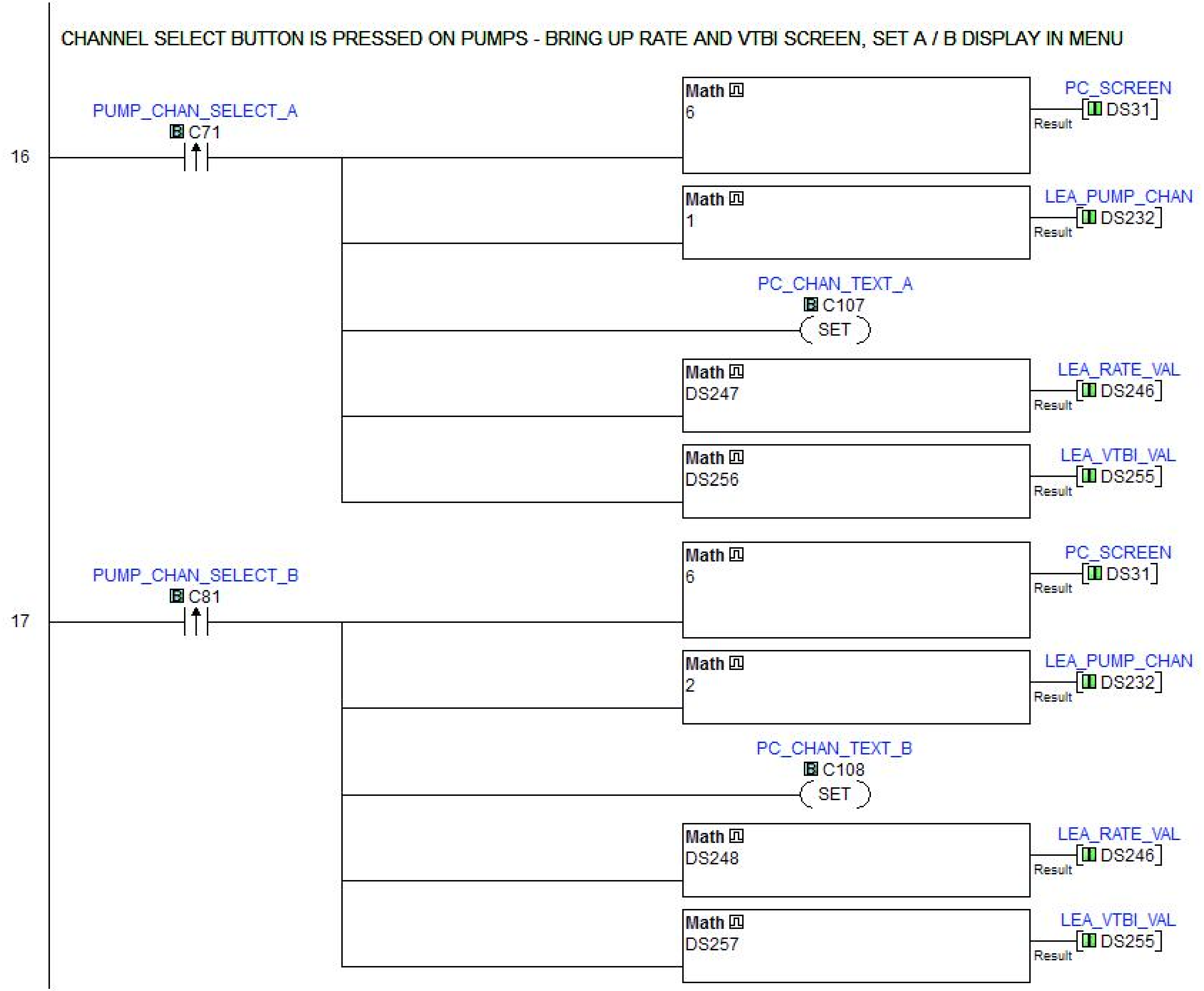

SELECTION MADE, NEXT PC SCREEN
11
PC_SCREEN
DS31
1
HINT2_X
C507
HINT2
C506
SET
HINT3_X
C509
HINT3
C508
SET
PC_RHS_BUTT_1
C51
Math
2
Result
PC_SCREEN
DS31
PC_RHS_BUTT_1
C51
RST
PC_RHS_BUTT_2
C52
Math
2
Result
PC_SCREEN
DS31
PC_RHS_BUTT_2
C52
RST
12
PC_SCREEN
DS31
2
HINT4_X
C511
HINT4
C510
SET
PC_RHS_BUTT_1
C51
Math
3
Result
PC_SCREEN
DS31
PC_RHS_BUTT_2
C52
Math
3
Result
PC_SCREEN
DS31

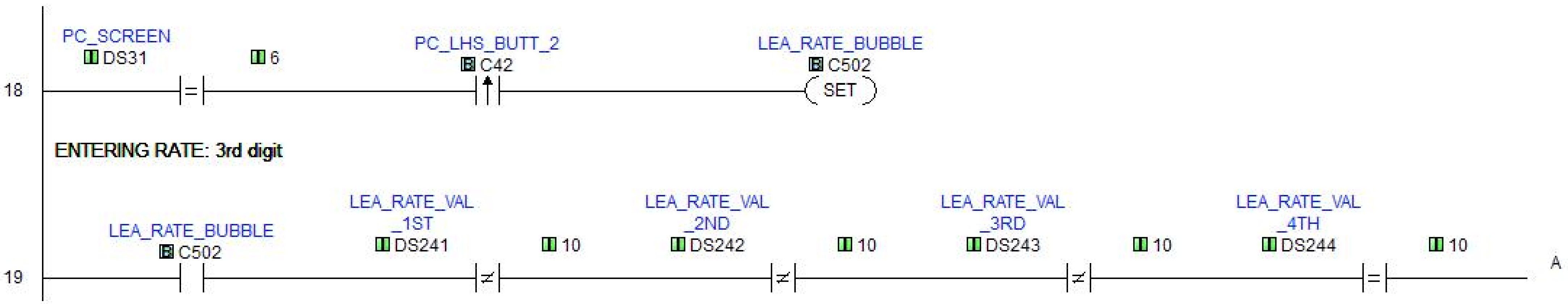
CHANNEL SELECTION SCREEN, PC BUTTONS AND PUMP BUTTONS FOR SELECTION

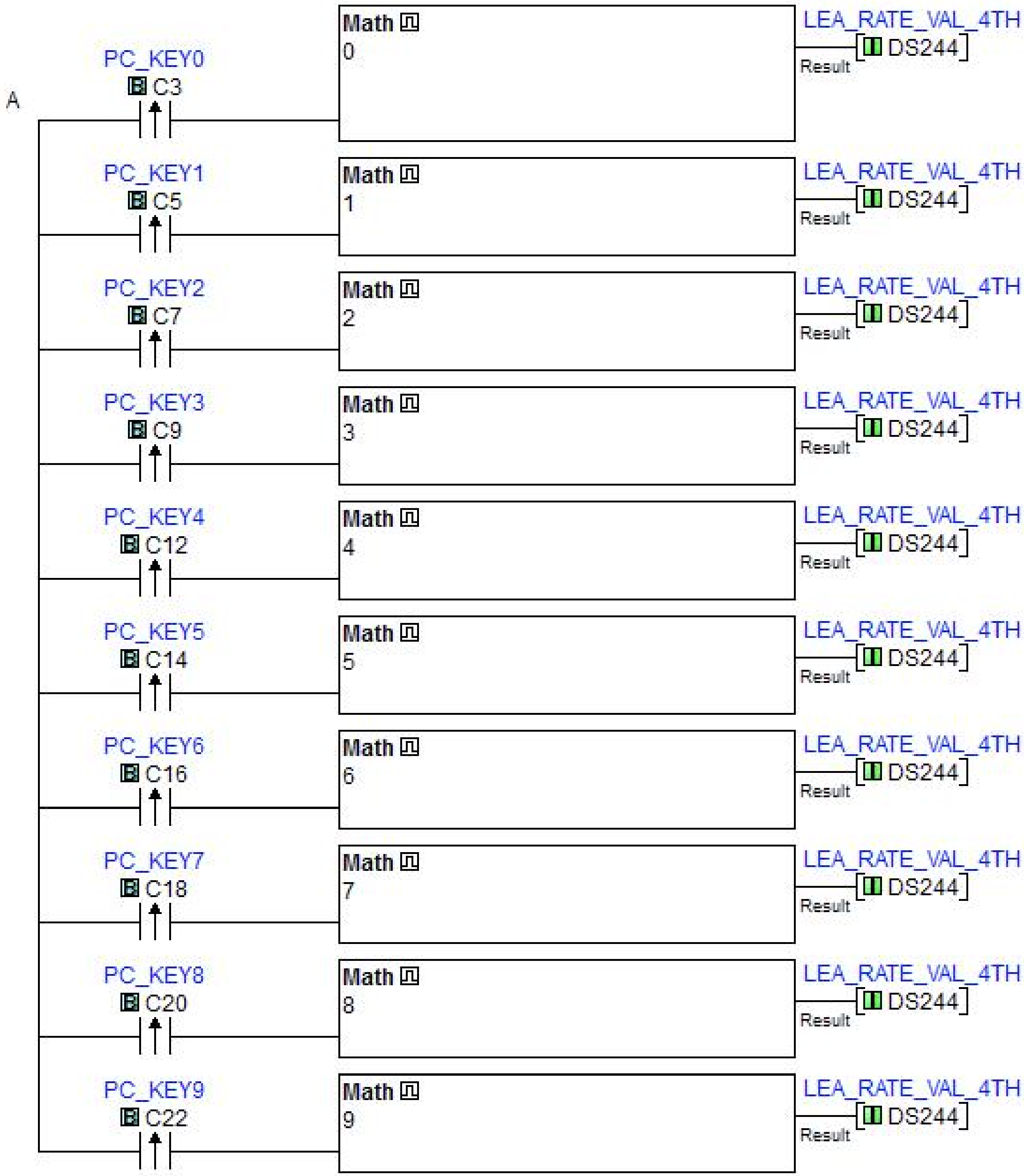
CHAN A

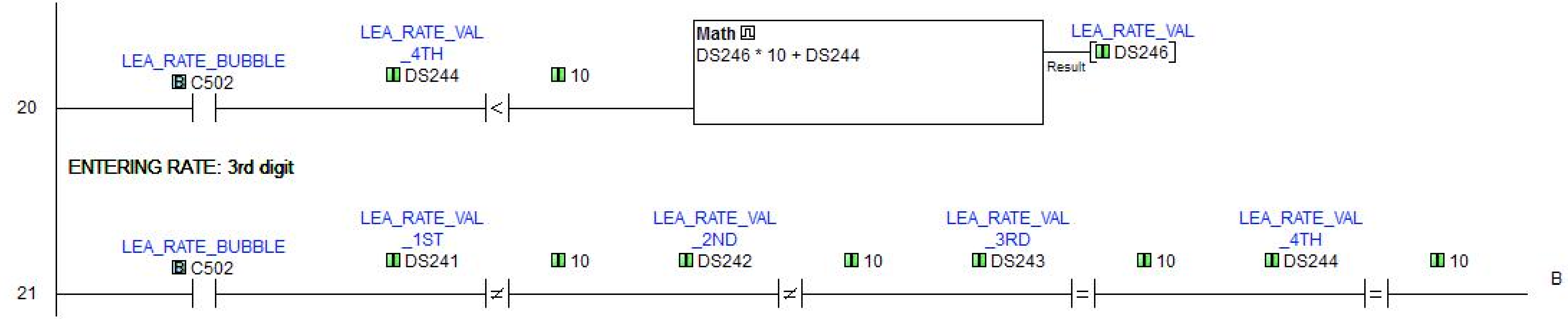


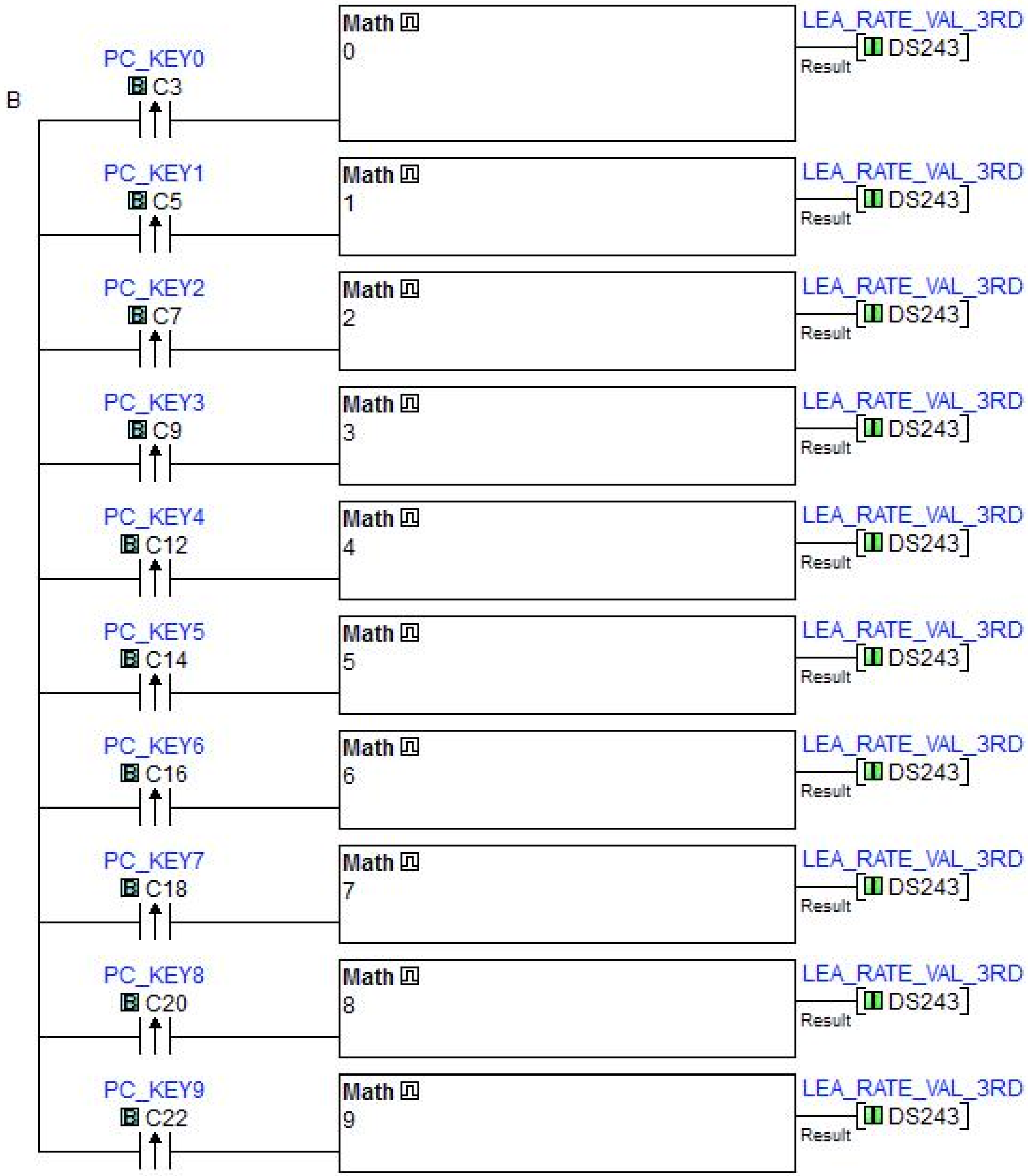

14
SELECTION MADE, NEXT PC SCREEN
PC_SCREEN
DS31
4
PC_LHS_BUTT_1
C41
PC_LHS_BUTT_2
C42
PC_LHS_BUTT_3
C43
Math
5
Result
PC_SCREEN
DS31
PC_LHS_BUTT_1
C41
RST
PC_LHS_BUTT_2
C42
RST
PC_LHS_BUTT_3
C43
RST
15
SELECTION MADE, NEXT PC SCREEN
PC_SCREEN
DS31
5
PC_LHS_BUTT_1
C41
PC_LHS_BUTT_2
C42
PC_LHS_BUTT_3
C43
PC_LHS_BUTT_4
C44
Math
6
Result
PC_SCREEN
DS31
PC_LHS_BUTT_2
C42
RST
PC_LHS_BUTT_3
C43
RST


CHANNEL SELECT BUTTON IS PRESSED ON PUMPS - BRING UP RATE AND VTBI SCREEN, SET A / B DISPLAY IN MENU
16
PUMP_CHAN_SELECT_A
C71
Math
6
Result
PC_SCREEN
DS31
Math
1
Result
LEA_PUMP_CHAN
DS232
PC_CHAN_TEXT_A
C107
SET
Math
DS247
Result
LEA_RATE_VAL
DS246
Math
DS256
Result
LEA_VTBI_VAL
DS255
17
PUMP_CHAN_SELECT_B
C81
Math
6
Result
PC_SCREEN
DS31
Math
2
Result
LEA_PUMP_CHAN
DS232
PC_CHAN_TEXT_B
C108
SET
Math
DS248
Result
LEA_RATE_VAL
DS246
Math
DS257
Result
LEA_VTBI_VAL
DS255


18
PC_SCREEN
DS31
=
6
PC_LHS_BUTT_2
C42
LEA_RATE_BUBBLE
C502
SET
ENTERING RATE: 3rd digit
19
LEA_RATE_BUBBLE
C502
LEA_RATE_VAL_1ST
DS241
≠
10
LEA_RATE_VAL_2ND
DS242
≠
10
LEA_RATE_VAL_3RD
DS243
≠
10
LEA_RATE_VAL_4TH
DS244
=
10
A


A
PC_KEY0
C3
Math
0
LEA_RATE_VAL_4TH
DS244
Result
PC_KEY1
C5
Math
1
LEA_RATE_VAL_4TH
DS244
Result
PC_KEY2
C7
Math
2
LEA_RATE_VAL_4TH
DS244
Result
PC_KEY3
C9
Math
3
LEA_RATE_VAL_4TH
DS244
Result
PC_KEY4
C12
Math
4
LEA_RATE_VAL_4TH
DS244
Result
PC_KEY5
C14
Math
5
LEA_RATE_VAL_4TH
DS244
Result
PC_KEY6
C16
Math
6
LEA_RATE_VAL_4TH
DS244
Result
PC_KEY7
C18
Math
7
LEA_RATE_VAL_4TH
DS244
Result
PC_KEY8
C20
Math
8
LEA_RATE_VAL_4TH
DS244
Result
PC_KEY9
C22
Math
9
LEA_RATE_VAL_4TH
DS244
Result

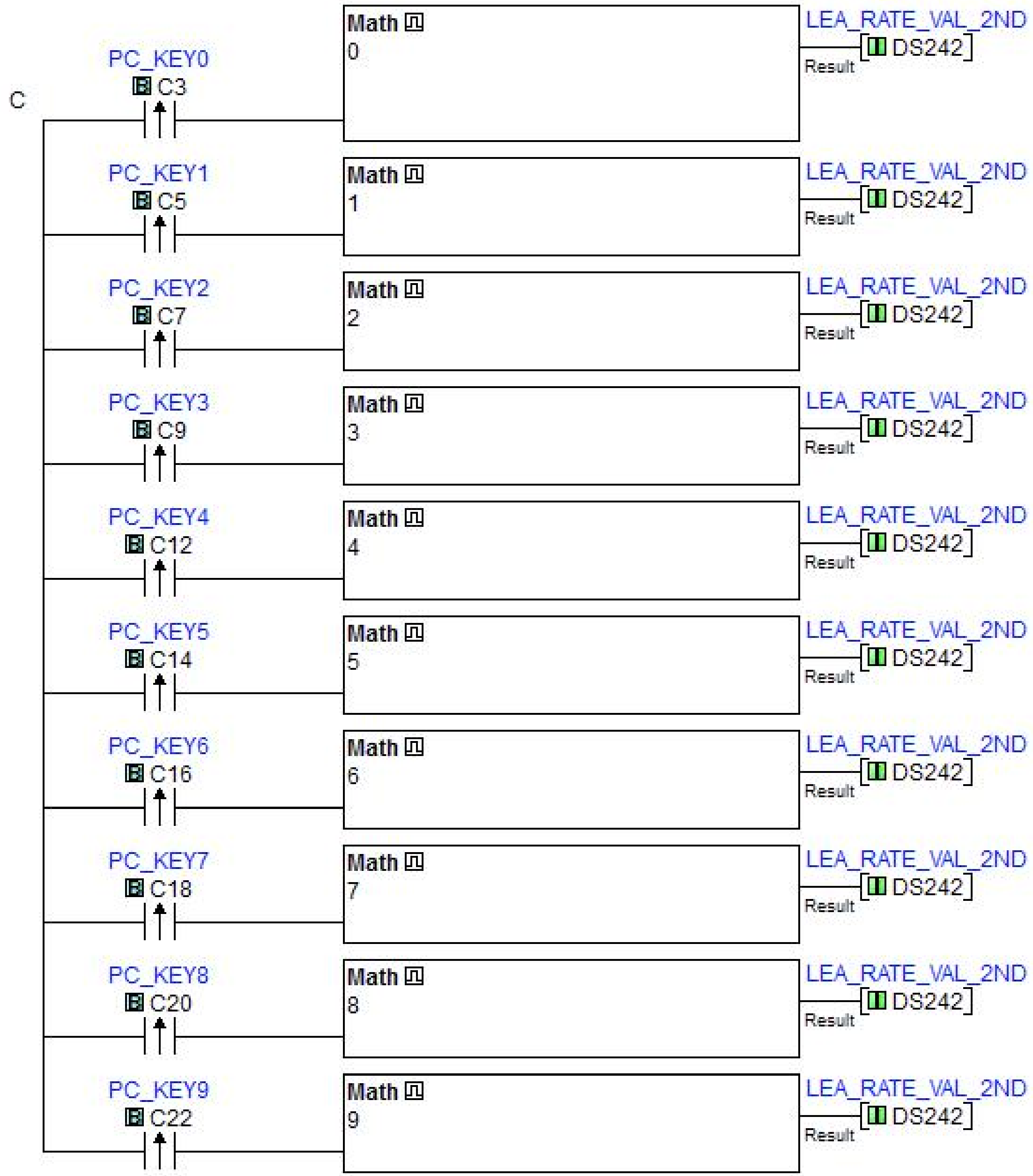

20
LEA_RATE_BUBBLE
C502
LEA_RATE_VAL
_4TH
DS244
<
10
Math
DS246 * 10 + DS244
Result
LEA_RATE_VAL
DS246
ENTERING RATE: 3rd digit
21
LEA_RATE_BUBBLE
C502
LEA_RATE_VAL
_1ST
DS241
≠
10
LEA_RATE_VAL
_2ND
DS242
≠
10
LEA_RATE_VAL
_3RD
DS243
=
10
LEA_RATE_VAL
_4TH
DS244
=
10
B

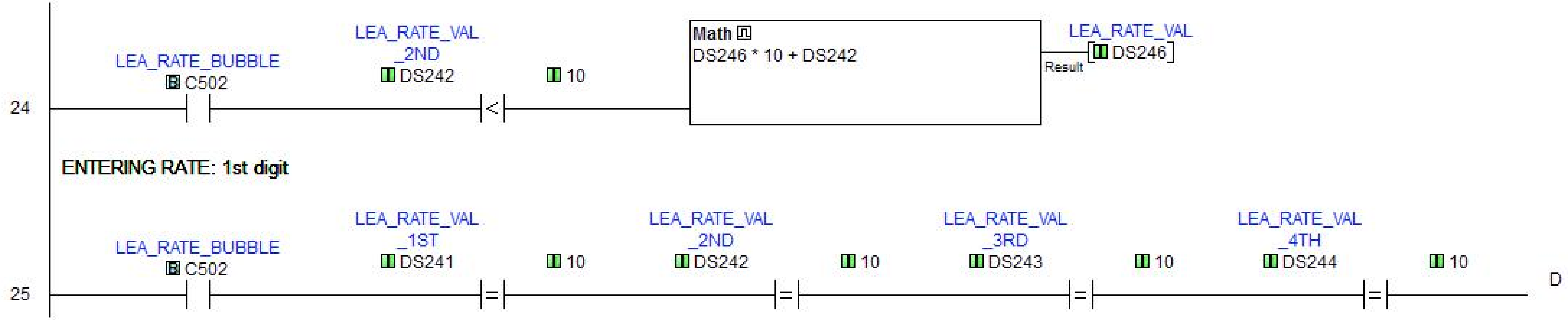

B
PC_KEY0
C3
Math
0
LEA_RATE_VAL_3RD
DS243
Result
PC_KEY1
C5
Math
1
LEA_RATE_VAL_3RD
DS243
Result
PC_KEY2
C7
Math
2
LEA_RATE_VAL_3RD
DS243
Result
PC_KEY3
C9
Math
3
LEA_RATE_VAL_3RD
DS243
Result
PC_KEY4
C12
Math
4
LEA_RATE_VAL_3RD
DS243
Result
PC_KEY5
C14
Math
5
LEA_RATE_VAL_3RD
DS243
Result
PC_KEY6
C16
Math
6
LEA_RATE_VAL_3RD
DS243
Result
PC_KEY7
C18
Math
7
LEA_RATE_VAL_3RD
DS243
Result
PC_KEY8
C20
Math
8
LEA_RATE_VAL_3RD
DS243
Result
PC_KEY9
C22
Math
9
LEA_RATE_VAL_3RD
DS243
Result

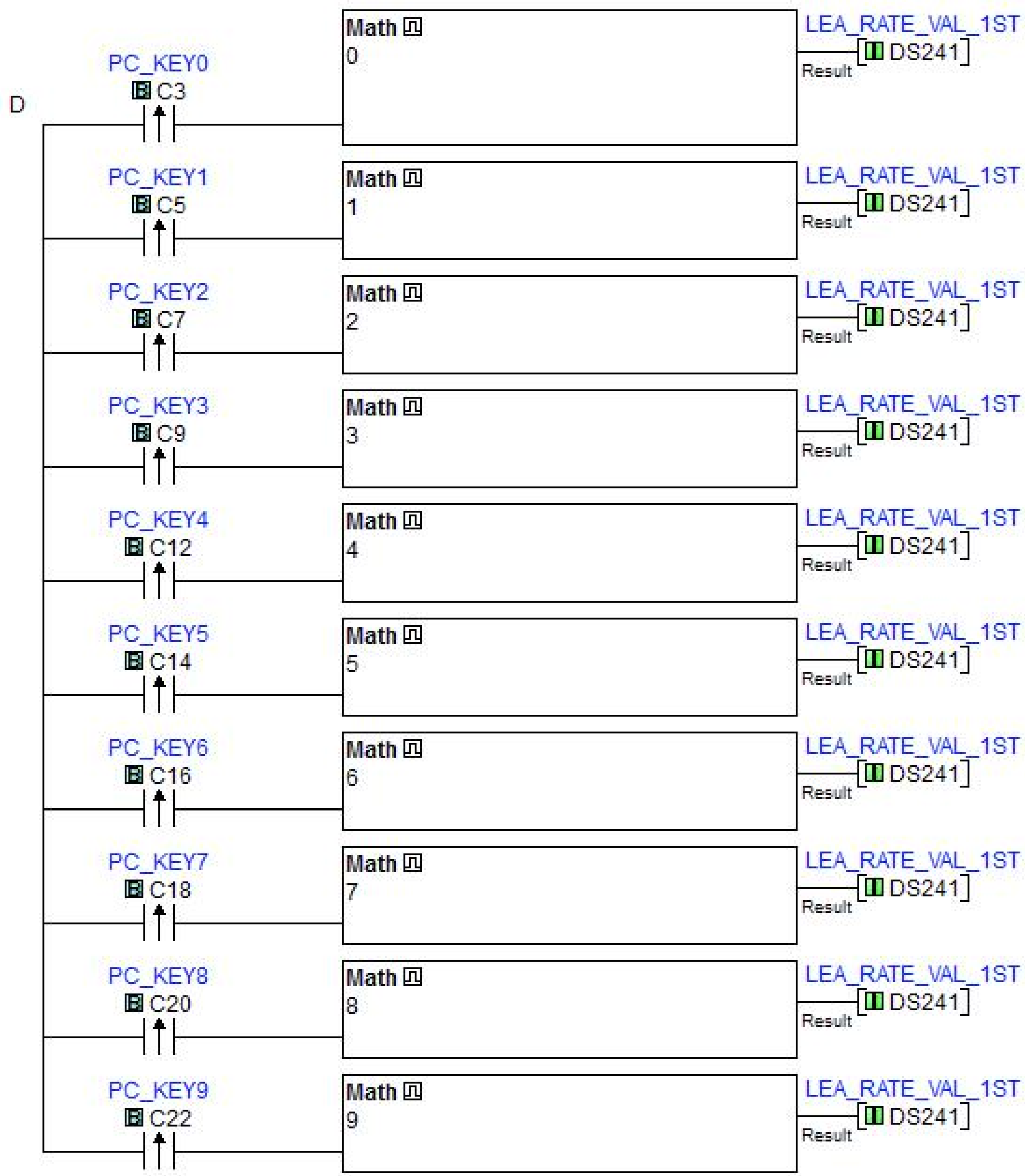
22
LEA_RATE_BUBBLE C502
LEA_RATE_VAL_3RD DS243 < 10
Math
DS246 * 10 + DS243
Result LEA_RATE_VAL [DS246]

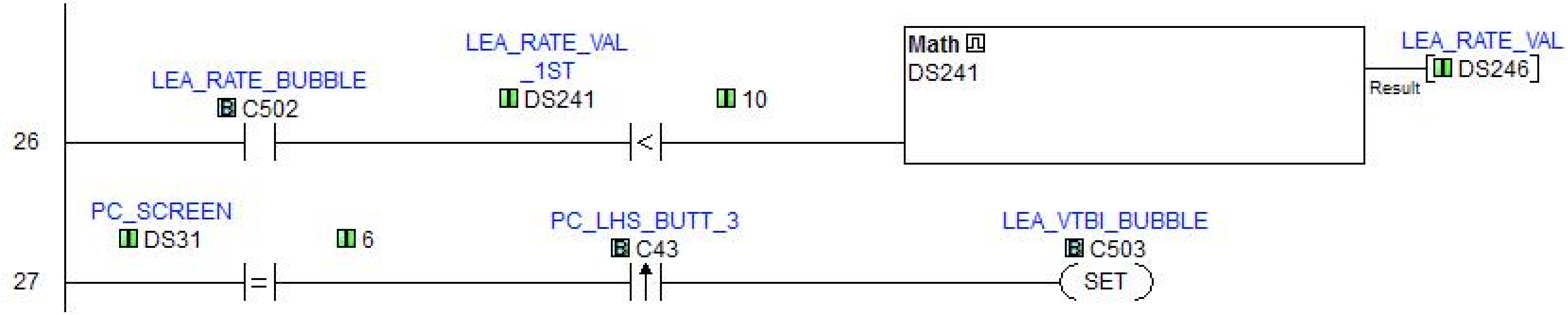
ENTERING RATE: 2nd digit

23
LEA_RATE_BUBBLE C502
LEA_RATE_VAL_1ST DS241 ≠ 10
LEA_RATE_VAL_2ND DS242 = 10
LEA_RATE_VAL_3RD DS243 = 10
LEA_RATE_VAL_4TH DS244 = 10
C

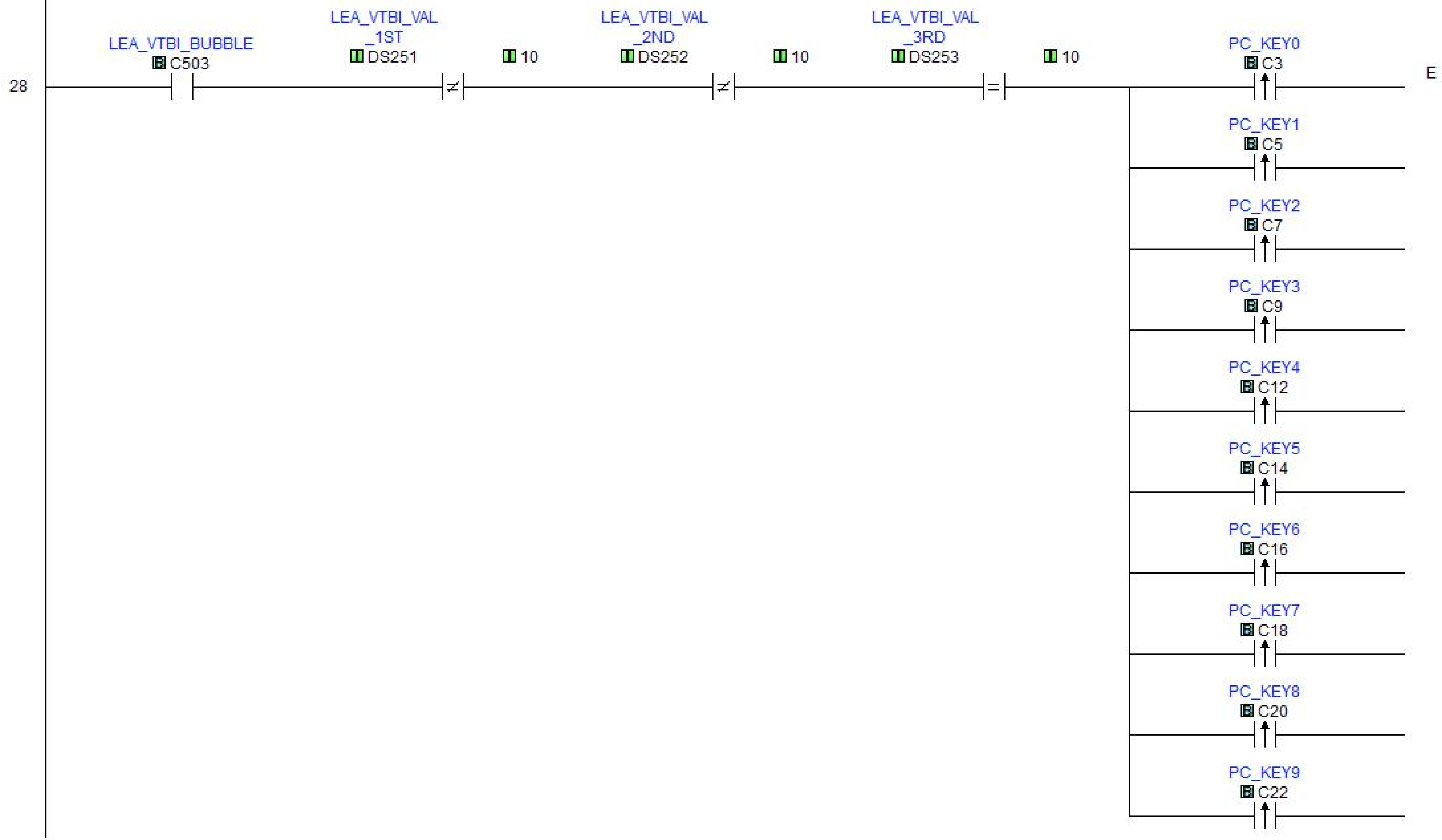

C
PC_KEY0
C3
Math
0
LEA_RATE_VAL_2ND
DS242
Result
PC_KEY1
C5
Math
1
LEA_RATE_VAL_2ND
DS242
Result
PC_KEY2
C7
Math
2
LEA_RATE_VAL_2ND
DS242
Result
PC_KEY3
C9
Math
3
LEA_RATE_VAL_2ND
DS242
Result
PC_KEY4
C12
Math
4
LEA_RATE_VAL_2ND
DS242
Result
PC_KEY5
C14
Math
5
LEA_RATE_VAL_2ND
DS242
Result
PC_KEY6
C16
Math
6
LEA_RATE_VAL_2ND
DS242
Result
PC_KEY7
C18
Math
7
LEA_RATE_VAL_2ND
DS242
Result
PC_KEY8
C20
Math
8
LEA_RATE_VAL_2ND
DS242
Result
PC_KEY9
C22
Math
9
LEA_RATE_VAL_2ND
DS242
Result


24
LEA_RATE_BUBBLE
C502
LEA_RATE_VAL
_2ND
DS242
<
10
Math
DS246 * 10 + DS242
Result
LEA_RATE_VAL
DS246
ENTERING RATE: 1st digit
25
LEA_RATE_BUBBLE
C502
LEA_RATE_VAL
_1ST
DS241
=
10
LEA_RATE_VAL
_2ND
DS242
=
10
LEA_RATE_VAL
_3RD
DS243
=
10
LEA_RATE_VAL
_4TH
DS244
=
10
D

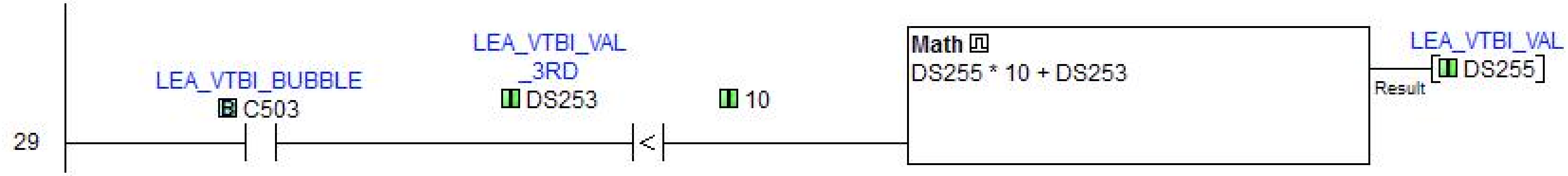

D
PC_KEY0
C3
Math
0
LEA_RATE_VAL_1ST
DS241
Result
PC_KEY1
C5
Math
1
LEA_RATE_VAL_1ST
DS241
Result
PC_KEY2
C7
Math
2
LEA_RATE_VAL_1ST
DS241
Result
PC_KEY3
C9
Math
3
LEA_RATE_VAL_1ST
DS241
Result
PC_KEY4
C12
Math
4
LEA_RATE_VAL_1ST
DS241
Result
PC_KEY5
C14
Math
5
LEA_RATE_VAL_1ST
DS241
Result
PC_KEY6
C16
Math
6
LEA_RATE_VAL_1ST
DS241
Result
PC_KEY7
C18
Math
7
LEA_RATE_VAL_1ST
DS241
Result
PC_KEY8
C20
Math
8
LEA_RATE_VAL_1ST
DS241
Result
PC_KEY9
C22
Math
9
LEA_RATE_VAL_1ST
DS241
Result


26
LEA_RATE_BUBBLE
C502
LEA_RATE_VAL
_1ST
DS241
<
10
Math
DS241
Result
LEA_RATE_VAL
DS246
27
PC_SCREEN
DS31
=
6
PC_LHS_BUTT_3
C43
LEA_VTBI_BUBBLE
C503
SET

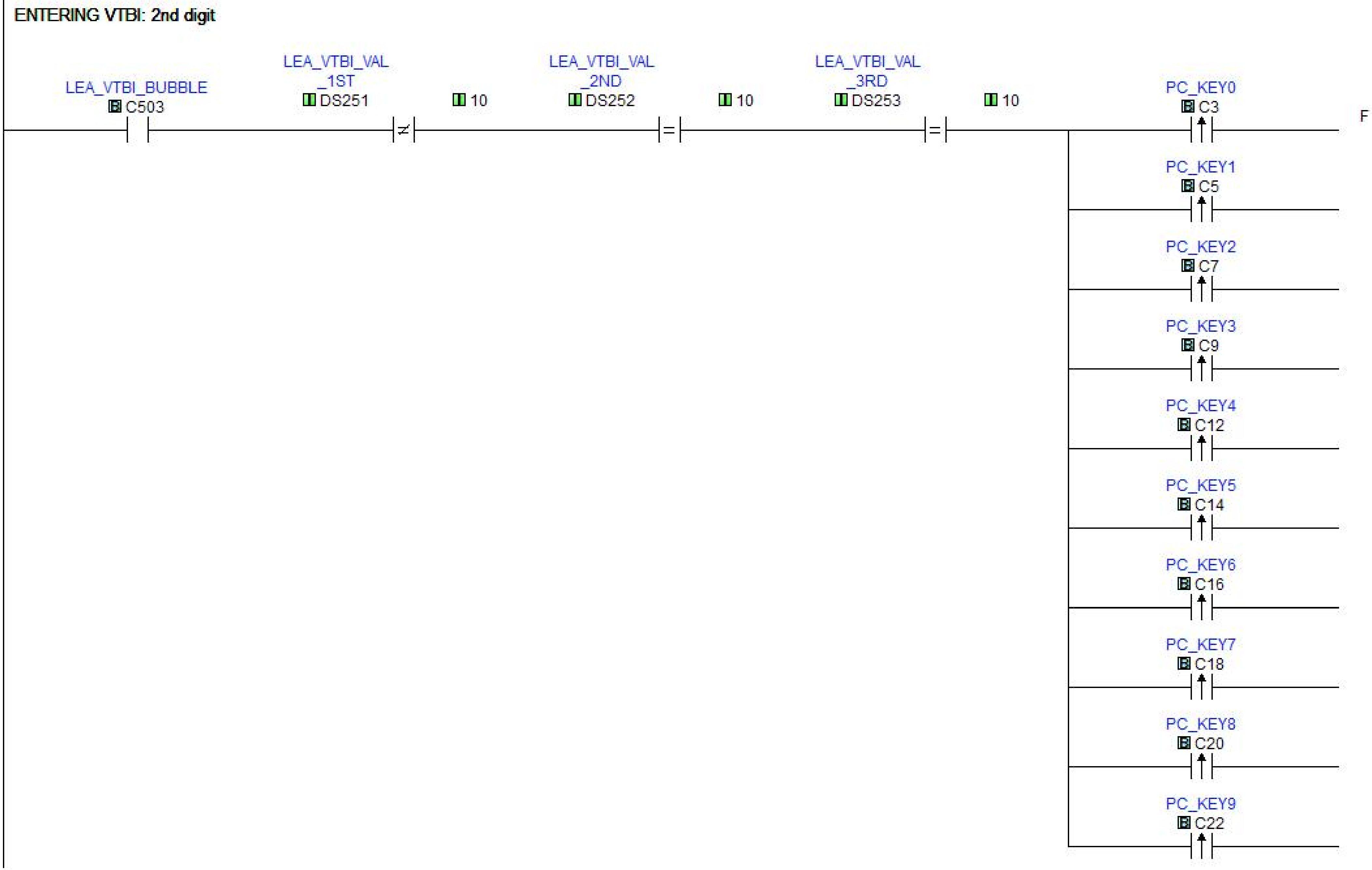
ENTERING VTBI: 3rd digit



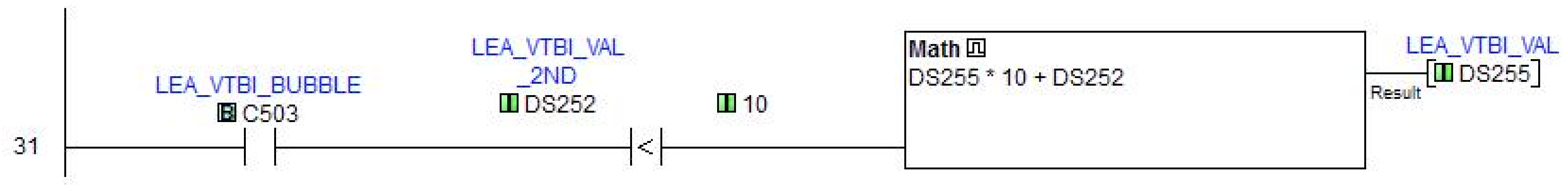

E
Math 0
LEA_VTBI_VAL_3RD
DS253
Result
Math 1
LEA_VTBI_VAL_3RD
DS253
Result
Math 2
LEA_VTBI_VAL_3RD
DS253
Result
Math 3
LEA_VTBI_VAL_3RD
DS253
Result
Math 4
LEA_VTBI_VAL_3RD
DS253
Result
Math 5
LEA_VTBI_VAL_3RD
DS253
Result
Math 6
LEA_VTBI_VAL_3RD
DS253
Result
Math 7
LEA_VTBI_VAL_3RD
DS253
Result
Math 8
LEA_VTBI_VAL_3RD
DS253
Result
Math 9
LEA_VTBI_VAL_3RD
DS253
Result


29
LEA_VTBI_BUBBLE
C503
LEA_VTBI_VAL
_3RD
DS253
<
10
Math
DS255 * 10 + DS253
Result
LEA_VTBI_VAL
DS255

30

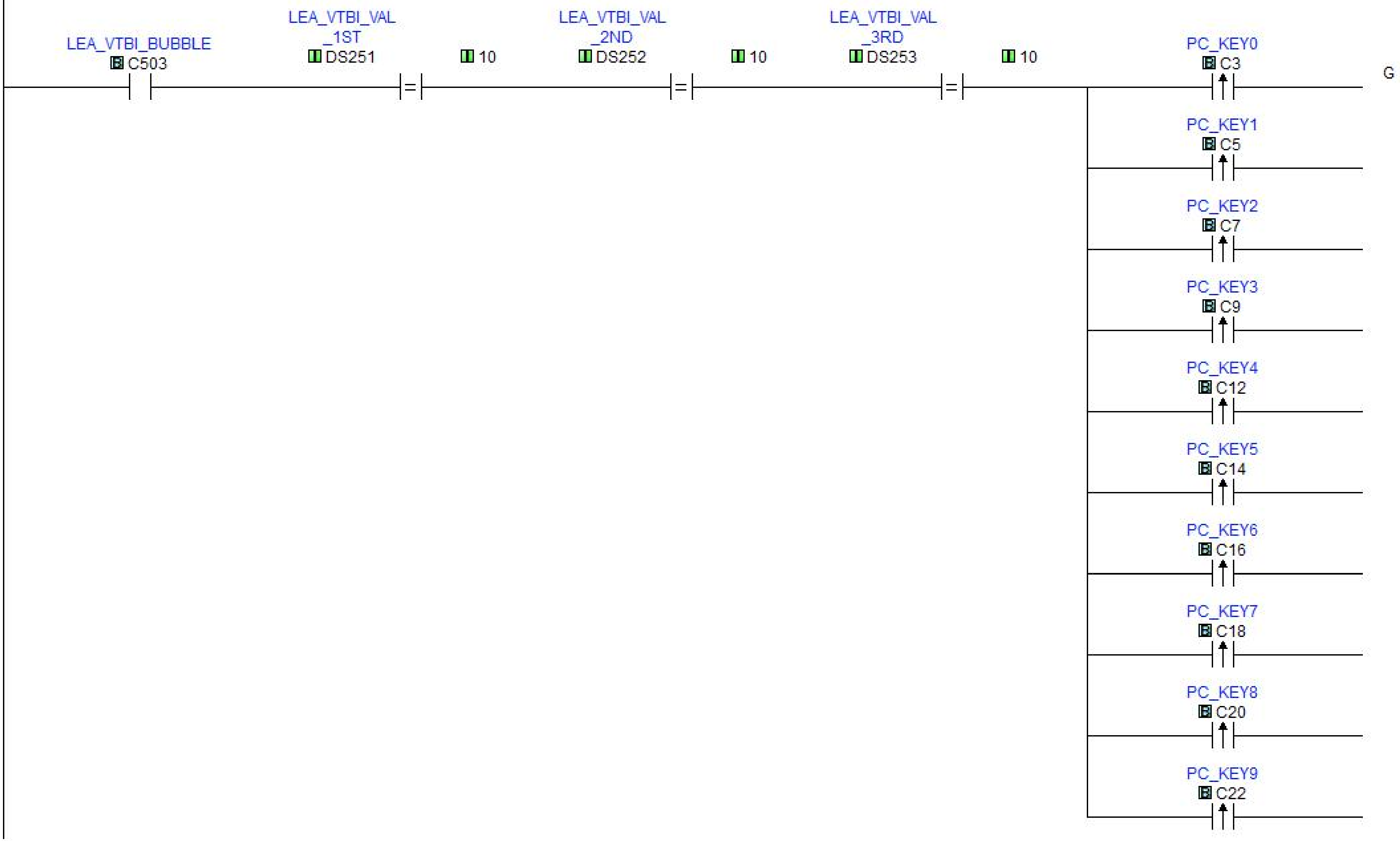

ENTERING VTBI: 2nd digit
LEA_VTBI_BUBBLE
C503
LEA_VTBI_VAL_1ST
DS251
≠
10
LEA_VTBI_VAL_2ND
DS252
=
10
LEA_VTBI_VAL_3RD
DS253
=
10
PC_KEY0
C3
F
PC_KEY1
C5
PC_KEY2
C7
PC_KEY3
C9
PC_KEY4
C12
PC_KEY5
C14
PC_KEY6
C16
PC_KEY7
C18
PC_KEY8
C20
PC_KEY9
C22


F
Math 0
Result
LEA_VTBI_VAL_2ND DS252
Math 1
Result
LEA_VTBI_VAL_2ND DS252
Math 2
Result
LEA_VTBI_VAL_2ND DS252
Math 3
Result
LEA_VTBI_VAL_2ND DS252
Math 4
Result
LEA_VTBI_VAL_2ND DS252
Math 5
Result
LEA_VTBI_VAL_2ND DS252
Math 6
Result
LEA_VTBI_VAL_2ND DS252
Math 7
Result
LEA_VTBI_VAL_2ND DS252
Math 8
Result
LEA_VTBI_VAL_2ND DS252
Math 9
Result
LEA_VTBI_VAL_2ND DS252

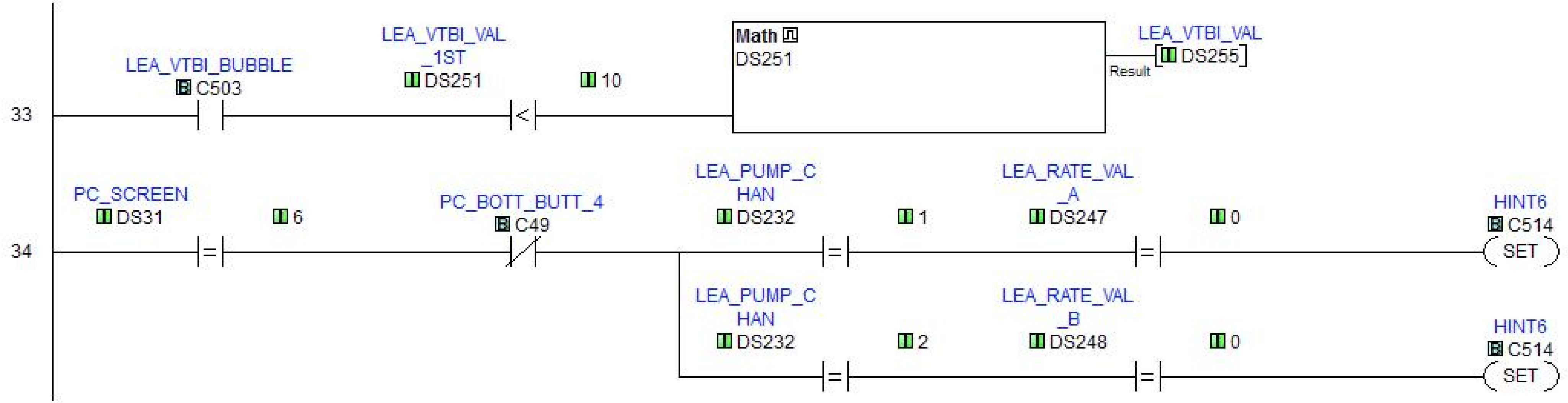

31
LEA_VTBI_BUBBLE
C503
LEA_VTBI_VAL
_2ND
DS252
<
10
Math
DS255 * 10 + DS252
Result
LEA_VTBI_VAL
DS255

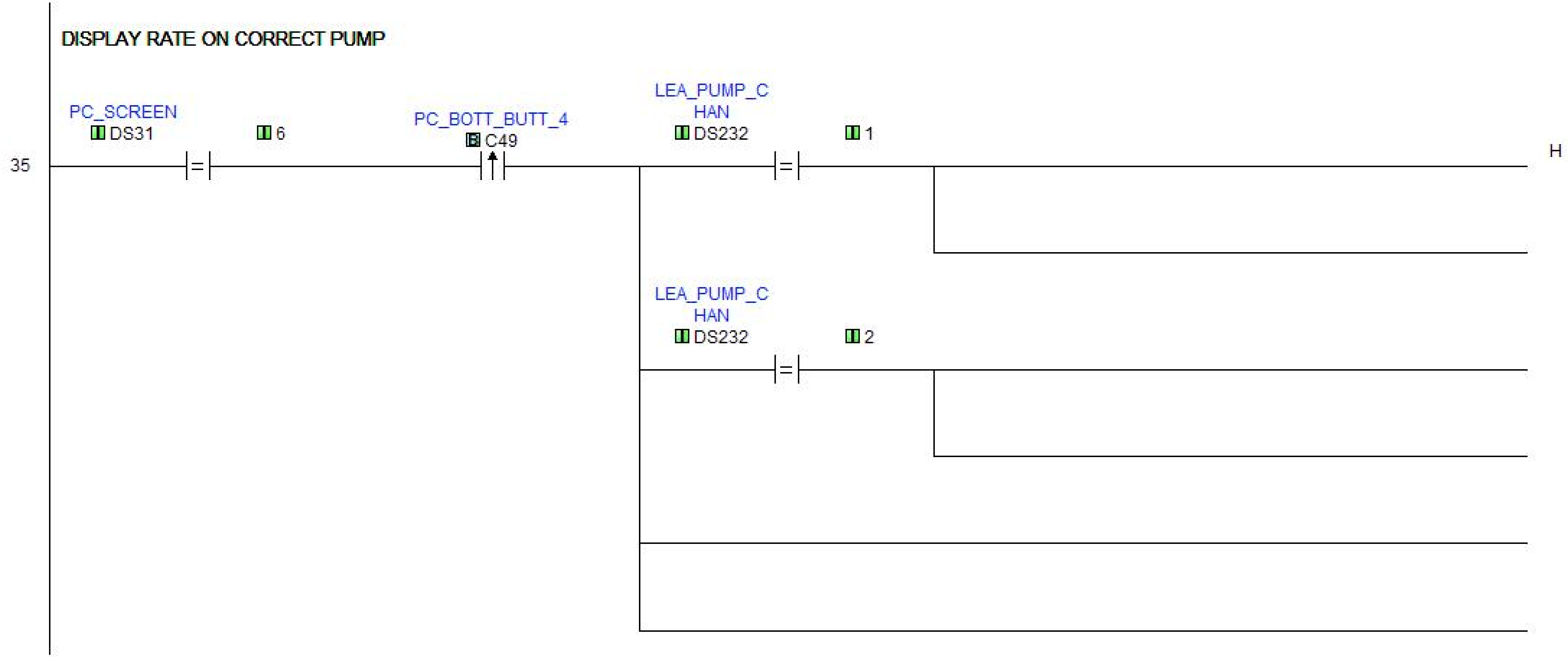
32

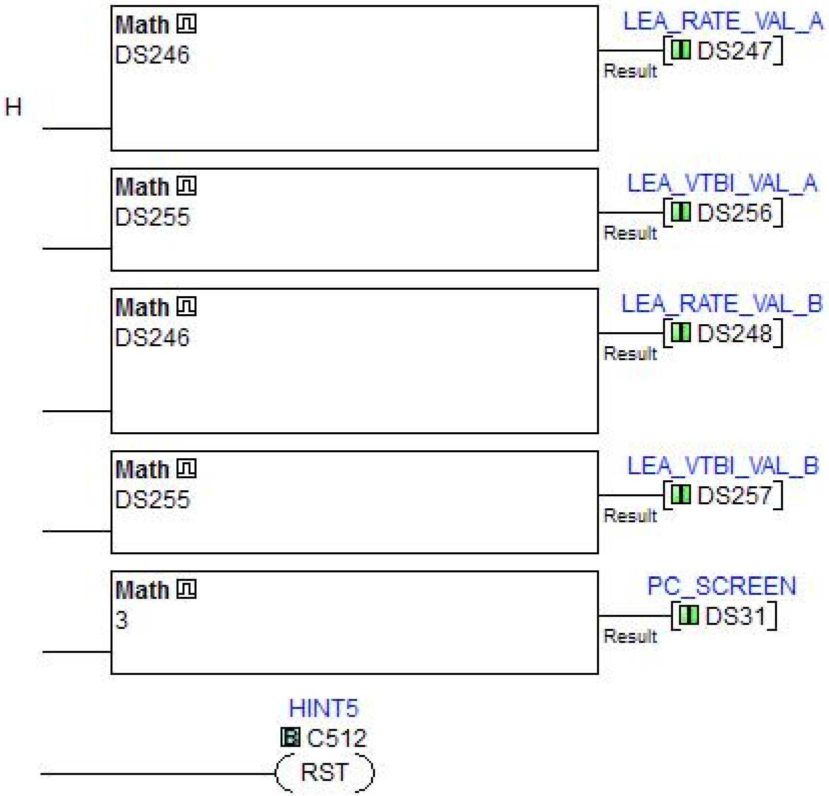
ENTERING VTBI: 2nd digit

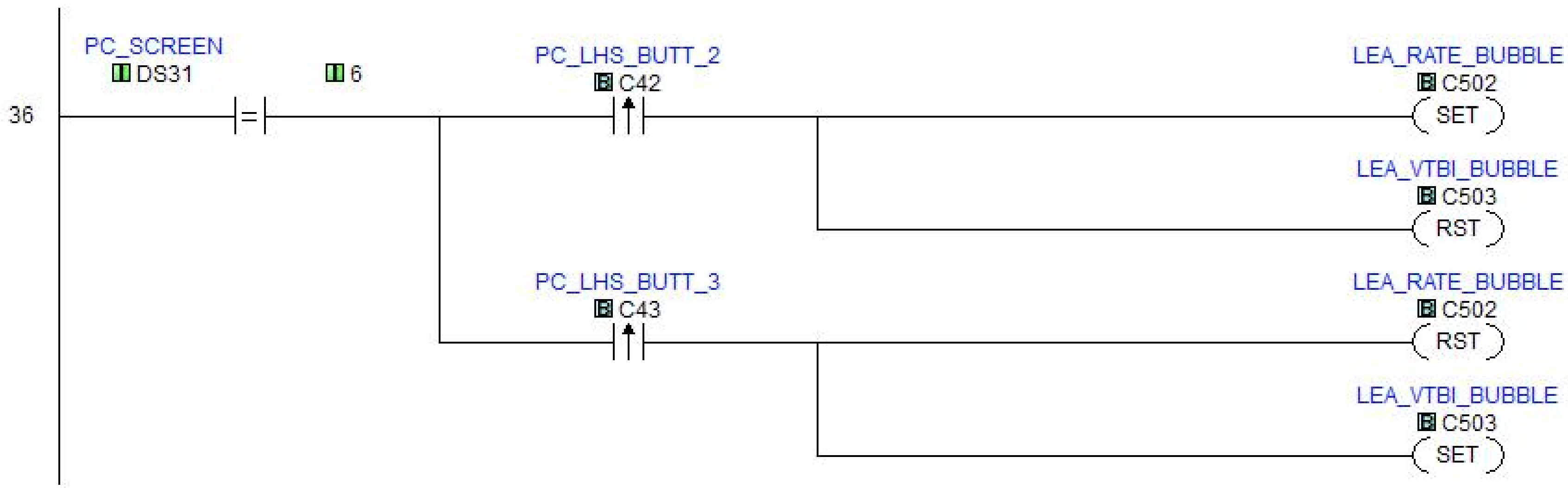


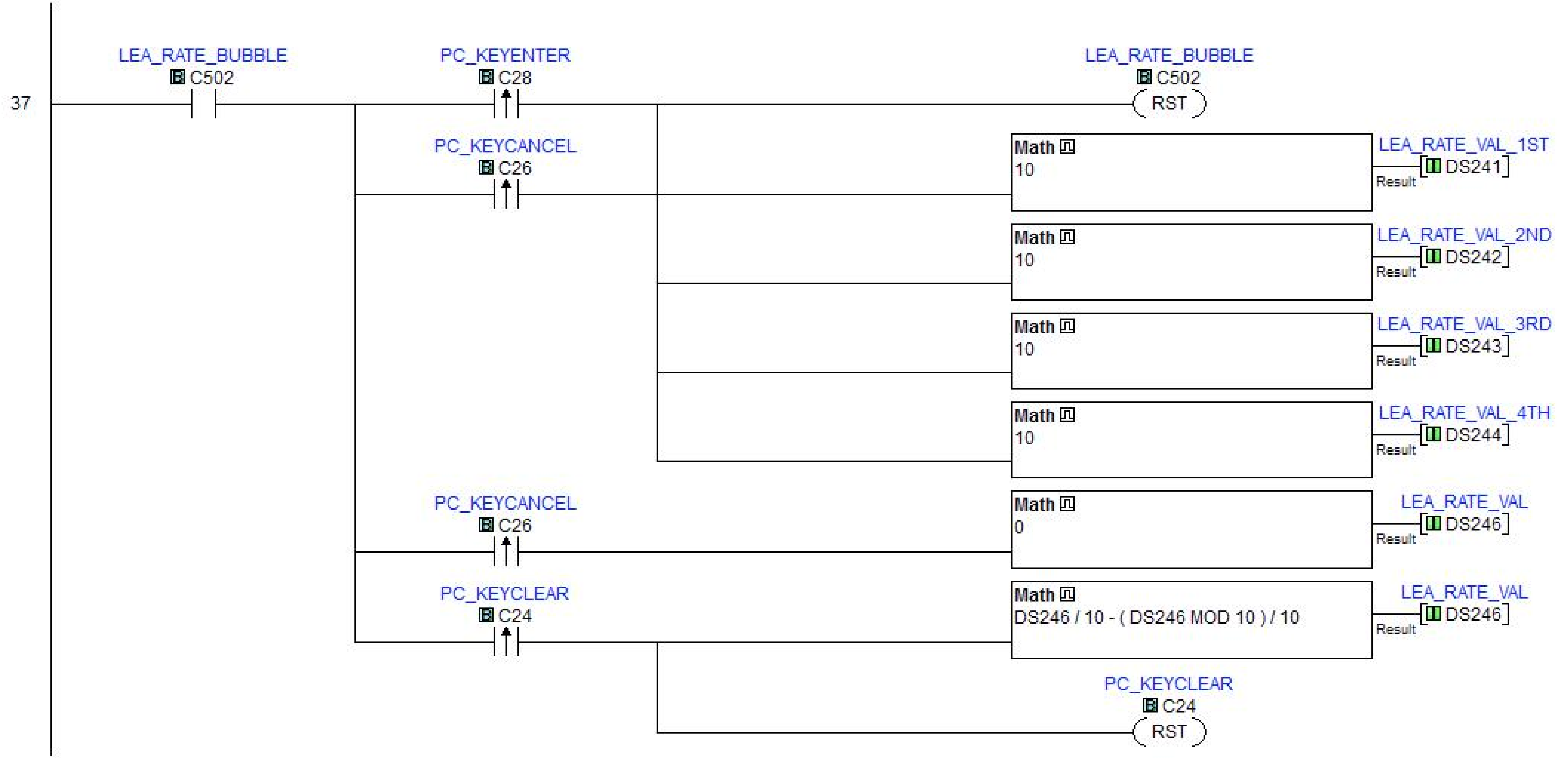

G
Math
0
LEA_VTBI_VAL_1ST
DS251
Result
Math
1
LEA_VTBI_VAL_1ST
DS251
Result
Math
2
LEA_VTBI_VAL_1ST
DS251
Result
Math
3
LEA_VTBI_VAL_1ST
DS251
Result
Math
4
LEA_VTBI_VAL_1ST
DS251
Result
Math
5
LEA_VTBI_VAL_1ST
DS251
Result
Math
6
LEA_VTBI_VAL_1ST
DS251
Result
Math
7
LEA_VTBI_VAL_1ST
DS251
Result
Math
8
LEA_VTBI_VAL_1ST
DS251
Result
Math
9
LEA_VTBI_VAL_1ST
DS251
Result

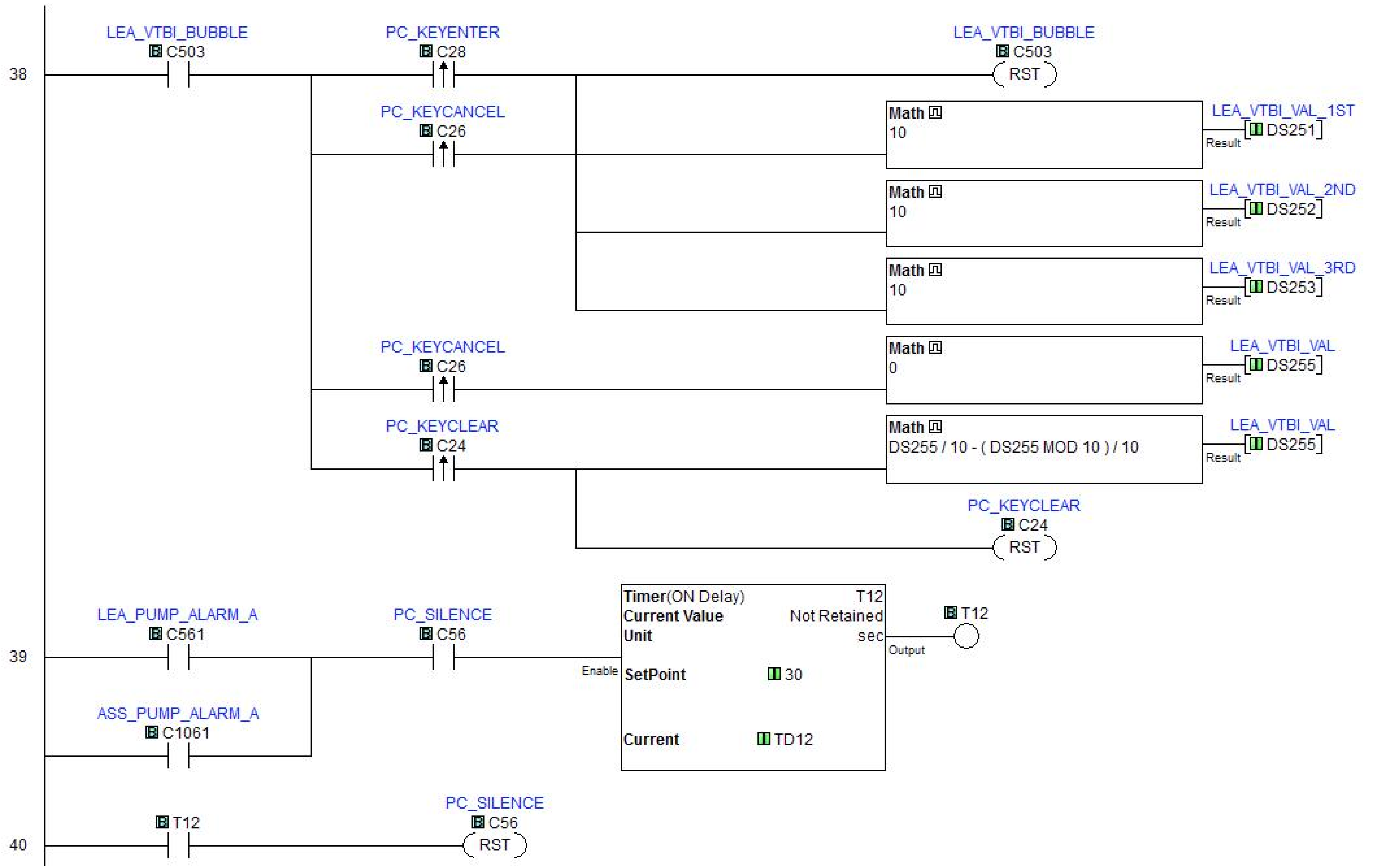

33
LEA_VTBI_BUBBLE
C503
LEA_VTBI_VAL_1ST
DS251
<
10
Math
DS251
Result
LEA_VTBI_VAL
DS255
34
PC_SCREEN
DS31
=
6
PC_BOTT_BUTT_4
C49
LEA_PUMP_CHAN
DS232
=
1
LEA_RATE_VAL_A
DS247
=
0
HINT6
C514
SET
LEA_PUMP_CHAN
DS232
=
2
LEA_RATE_VAL_B
DS248
=
0
HINT6
C514
SET


DISPLAY RATE ON CORRECT PUMP
35
PC_SCREEN
DS31
6
PC_BOTT_BUTT_4
C49
LEA_PUMP_CHAN
DS232
1
LEA_PUMP_CHAN
DS232
2
H

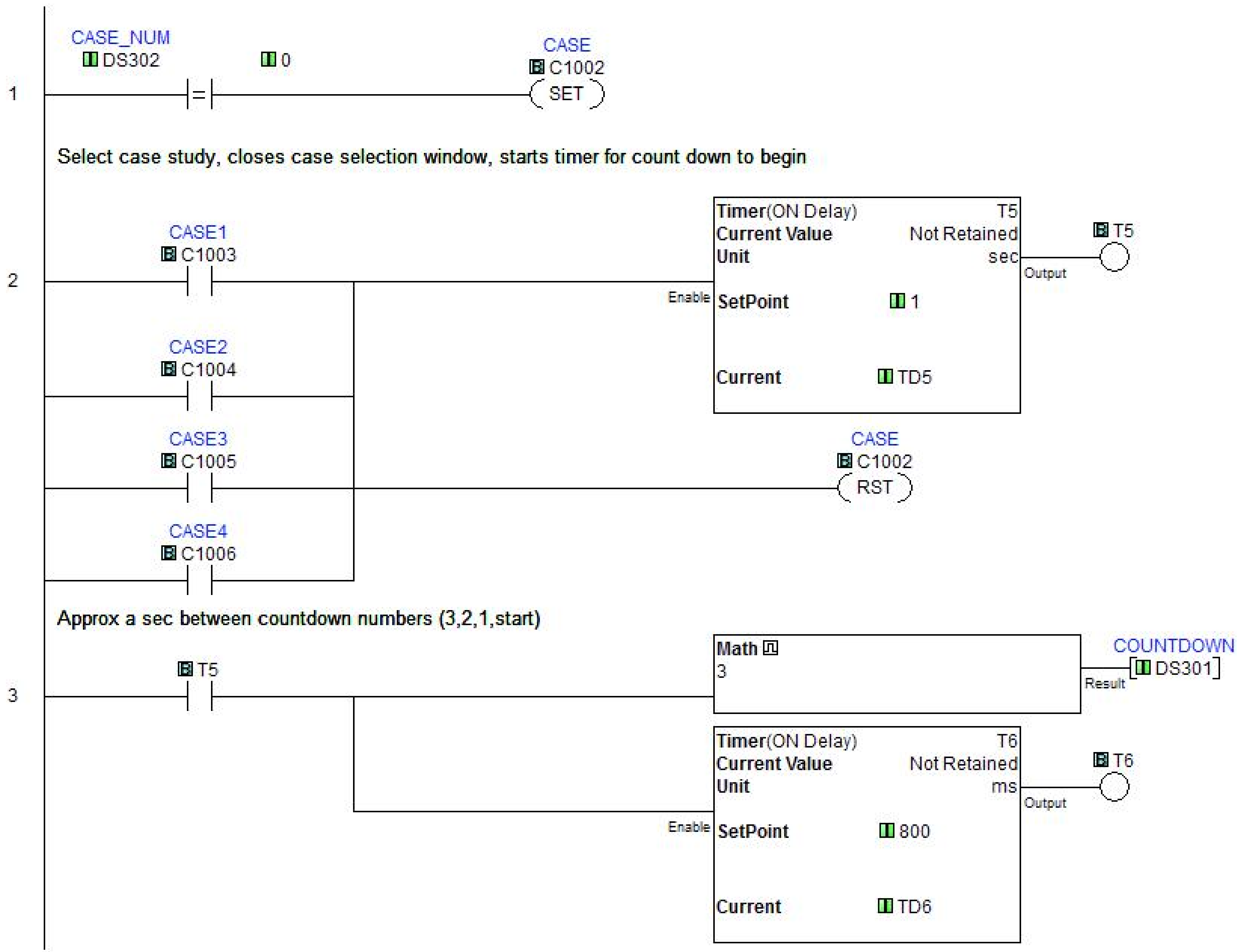

Math
DS246
LEA_RATE_VAL_A
DS247
Result
H
Math
DS255
LEA_VTBI_VAL_A
DS256
Result
Math
DS246
LEA_RATE_VAL_B
DS248
Result
Math
DS255
LEA_VTBI_VAL_B
DS257
Result
Math
3
PC_SCREEN
DS31
Result
HINT5
C512
RST

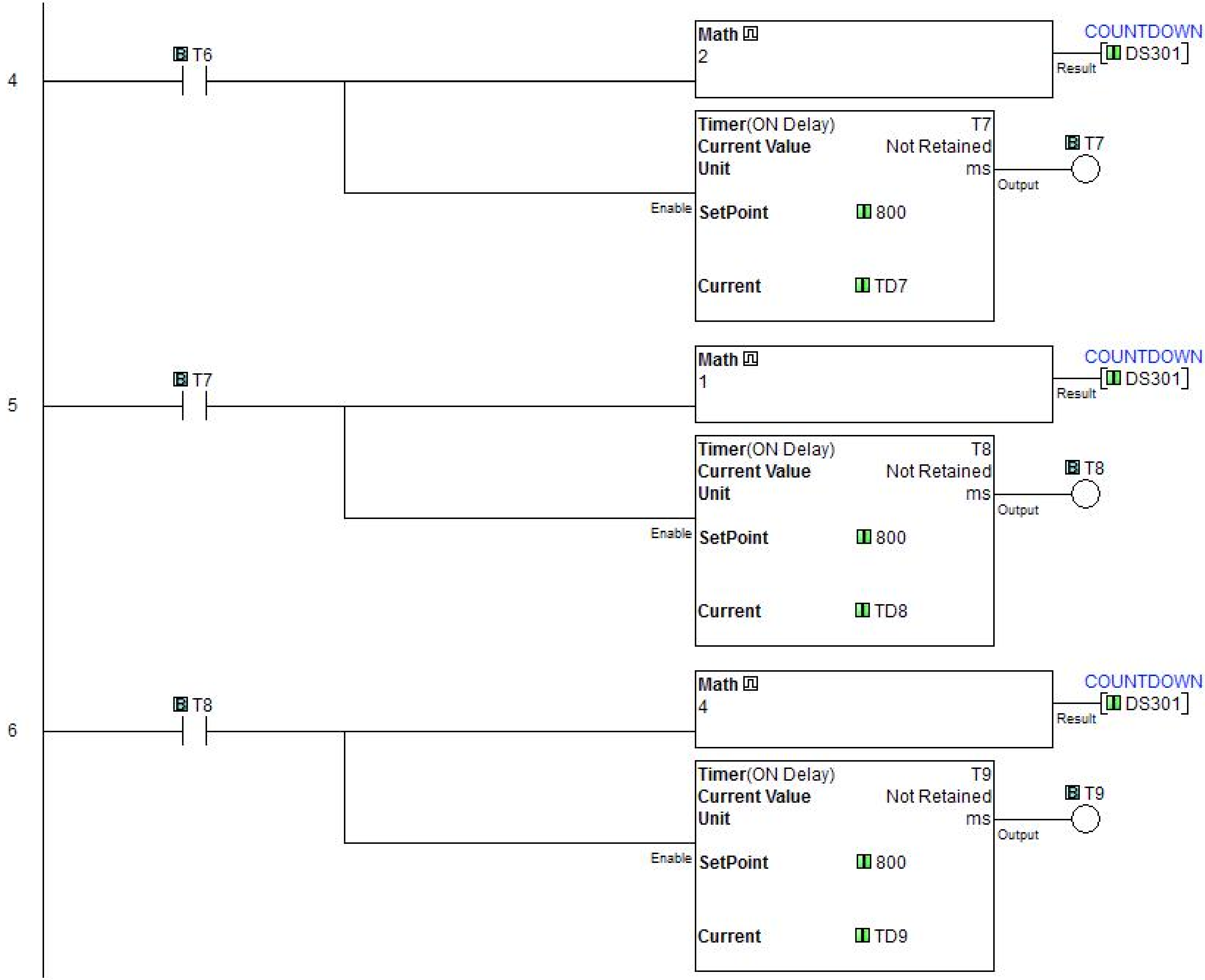

36
PC_SCREEN
DS31
=
6
PC_LHS_BUTT_2
C42
PC_LHS_BUTT_3
C43
LEA_RATE_BUBBLE
C502
SET
LEA_VTBI_BUBBLE
C503
RST
LEA_RATE_BUBBLE
C502
RST
LEA_VTBI_BUBBLE
C503
SET

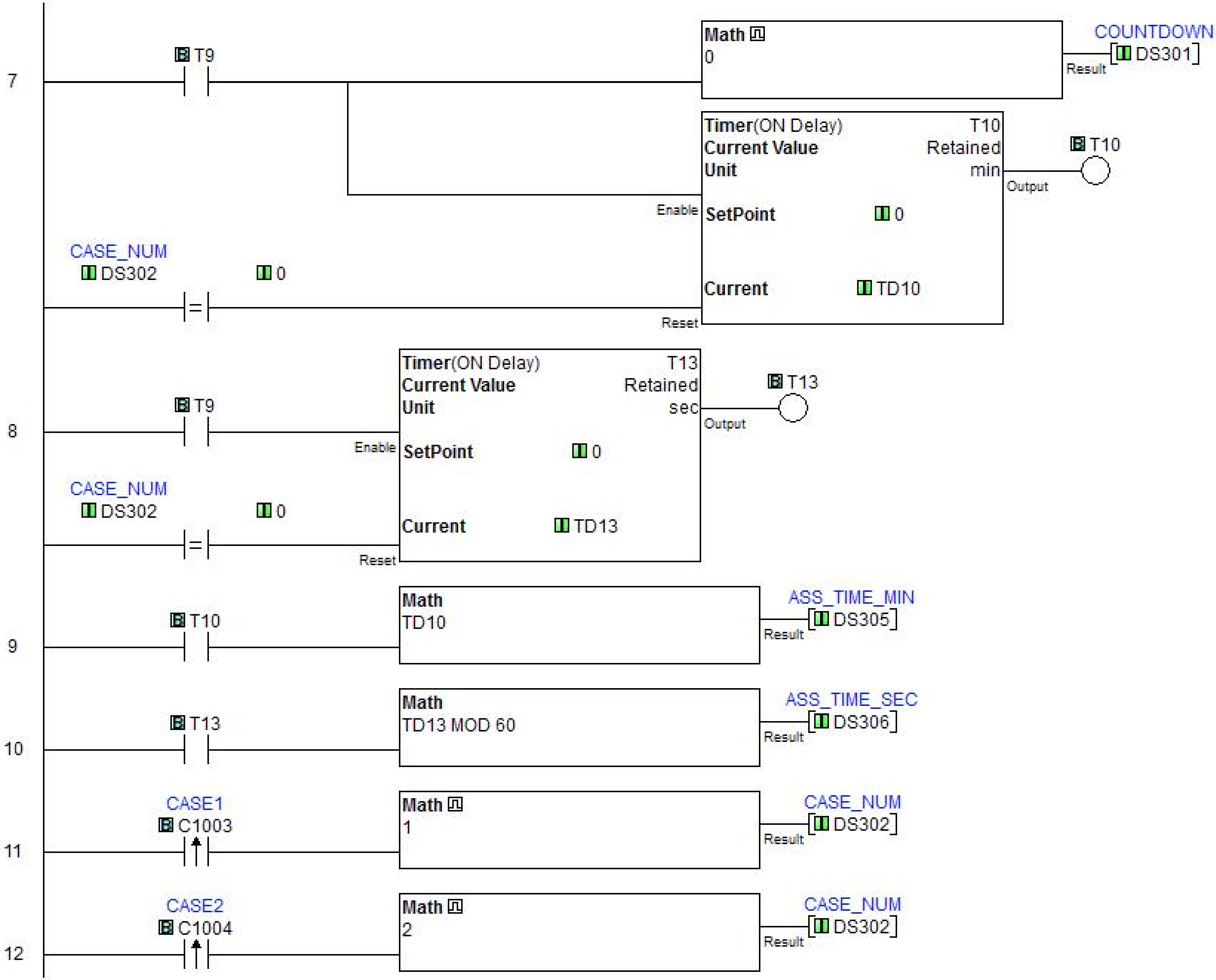

37
LEA_RATE_BUBBLE
C502
PC_KEYENTER
C28
LEA_RATE_BUBBLE
C502
RST
PC_KEYCANCEL
C26
Math
10
LEA_RATE_VAL_1ST
DS241
Result
Math
10
LEA_RATE_VAL_2ND
DS242
Result
Math
10
LEA_RATE_VAL_3RD
DS243
Result
Math
10
LEA_RATE_VAL_4TH
DS244
Result
PC_KEYCANCEL
C26
Math
0
LEA_RATE_VAL
DS246
Result
PC_KEYCLEAR
C24
Math
DS246 / 10 - (DS246 MOD 10) / 10
LEA_RATE_VAL
DS246
Result
PC_KEYCLEAR
C24
RST

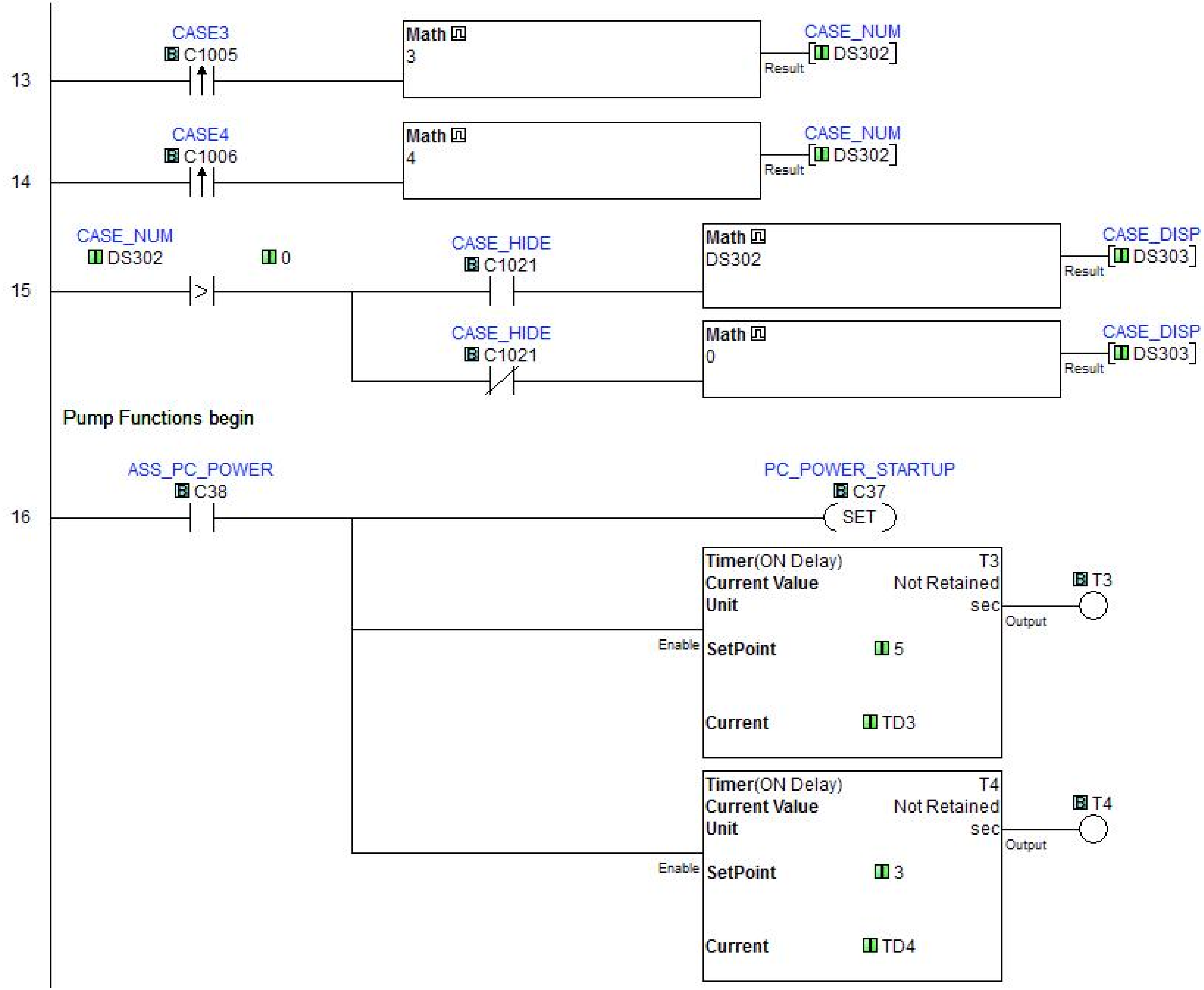

38
LEA_VTBI_BUBBLE C503
PC_KEYENTER C28
LEA_VTBI_BUBBLE C503 RST
PC_KEYCANCEL C26
Math 10
Result LEA_VTBI_VAL_1ST DS251
Math 10
Result LEA_VTBI_VAL_2ND DS252
Math 10
Result LEA_VTBI_VAL_3RD DS253
PC_KEYCANCEL C26
Math 0
Result LEA_VTBI_VAL DS255
PC_KEYCLEAR C24
Math DS255 / 10 - (DS255 MOD 10) / 10
Result LEA_VTBI_VAL DS255
PC_KEYCLEAR C24 RST
39
LEA_PUMP_ALARM_A C561
ASS_PUMP_ALARM_A C1061
PC_SILENCE C56
Enable
Timer(ON Delay) T12
Current Value Not Retained
Unit sec
SetPoint 30
Current TD12
Output
T12
40
T12
PC_SILENCE C56 RST

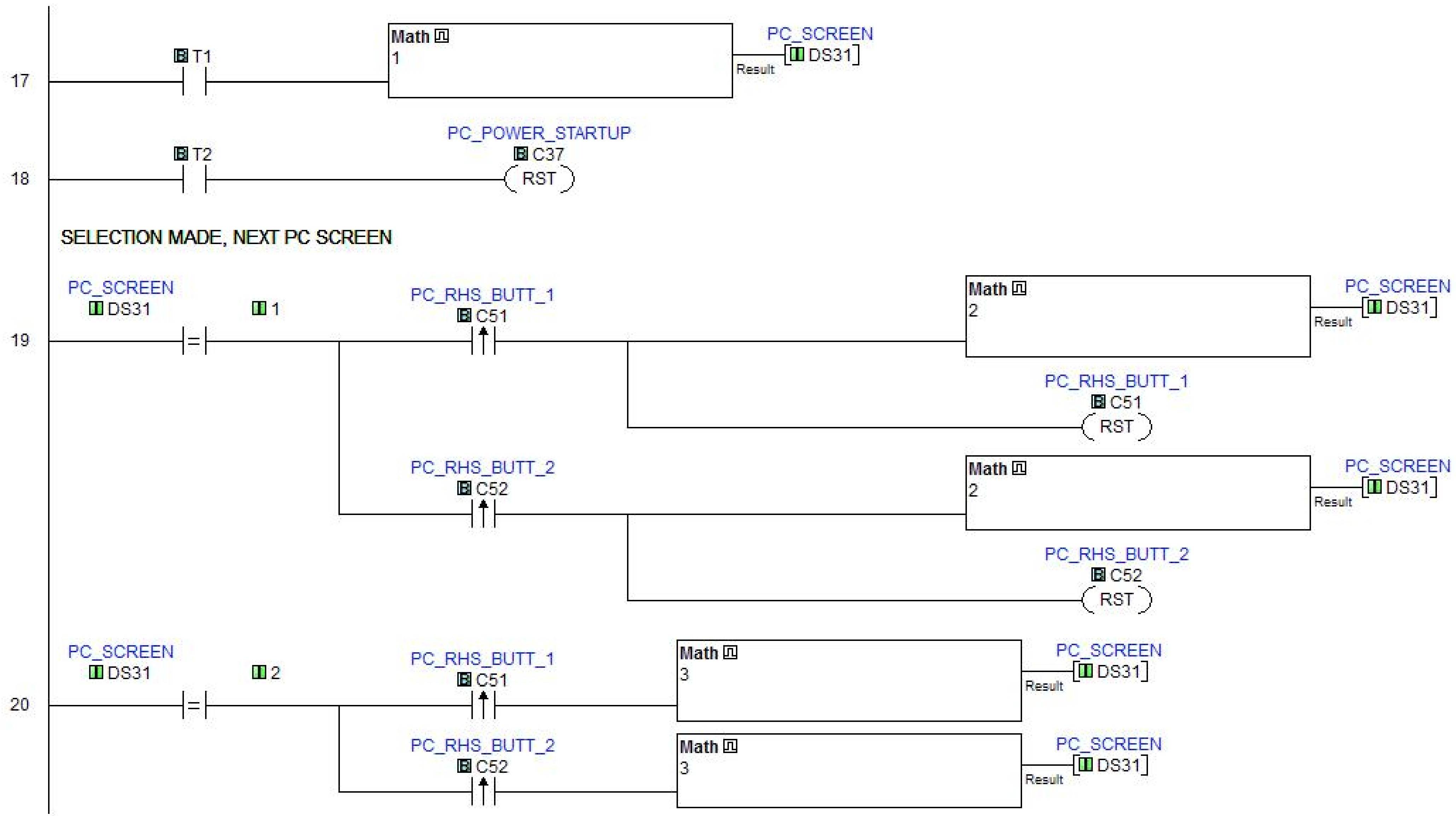

41
Return


1
CASE_NUM
DS302
0
CASE
C1002
SET
Select case study, closes case selection window, starts timer for count down to begin
2
CASE1
C1003
CASE2
C1004
CASE3
C1005
CASE4
C1006
Enable
Timer(ON Delay) T5
Current Value Not Retained
Unit sec
SetPoint 1
Current TD5
Output
T5
CASE
C1002
RST
Approx a sec between countdown numbers (3,2,1,start)
3
T5
Math
3
Result
COUNTDOWN
DS301
Enable
Timer(ON Delay) T6
Current Value Not Retained
Unit ms
SetPoint 800
Current TD6
Output
T6


4
T6
Math
2
COUNTDOWN
DS301
Result
Timer(ON Delay) T7
Current Value Not Retained
Unit ms
Enable
SetPoint 800
Current TD7
Output
T7
5
T7
Math
1
COUNTDOWN
DS301
Result
Timer(ON Delay) T8
Current Value Not Retained
Unit ms
Enable
SetPoint 800
Current TD8
Output
T8
6
T8
Math
4
COUNTDOWN
DS301
Result
Timer(ON Delay) T9
Current Value Not Retained
Unit ms
Enable
SetPoint 800
Current TD9
Output
T9

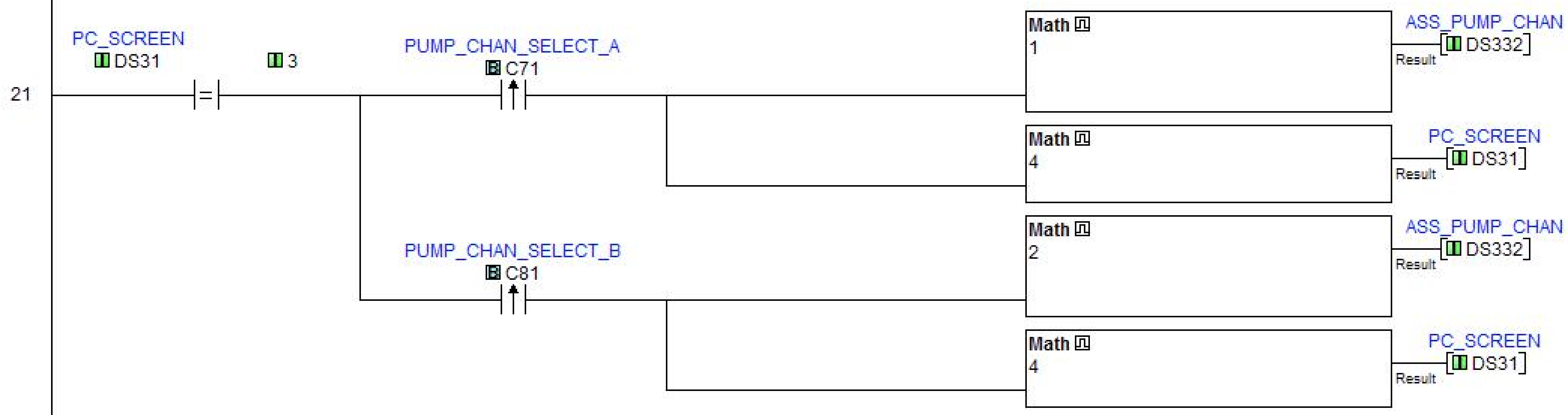

7
T9
Math
0
COUNTDOWN
DS301
Result
Timer(ON Delay) T10
Current Value Retained
Unit min
Output
T10
Enable
SetPoint 0
Current TD10
Reset
CASE_NUM
DS302
0
8
T9
Timer(ON Delay) T13
Current Value Retained
Unit sec
Output
T13
Enable
SetPoint 0
Current TD13
Reset
CASE_NUM
DS302
0
9
T10
Math
TD10
ASS_TIME_MIN
DS305
Result
10
T13
Math
TD13 MOD 60
ASS_TIME_SEC
DS306
Result
11
CASE1
C1003
Math
1
CASE_NUM
DS302
Result
12
CASE2
C1004
Math
2
CASE_NUM
DS302
Result


13
CASE3
C1005
Math
3
Result
CASE_NUM
DS302
14
CASE4
C1006
Math
4
Result
CASE_NUM
DS302
15
CASE_NUM
DS302
0
CASE_HIDE
C1021
Math
DS302
Result
CASE_DISP
DS303
CASE_HIDE
C1021
Math
0
Result
CASE_DISP
DS303
Pump Functions begin
16
ASS_PC_POWER
C38
PC_POWER_STARTUP
C37
SET
Timer(ON Delay) T3
Current Value Not Retained
Unit sec
Enable
SetPoint 5
Current TD3
Output
T3
Timer(ON Delay) T4
Current Value Not Retained
Unit sec
Enable
SetPoint 3
Current TD4
Output
T4

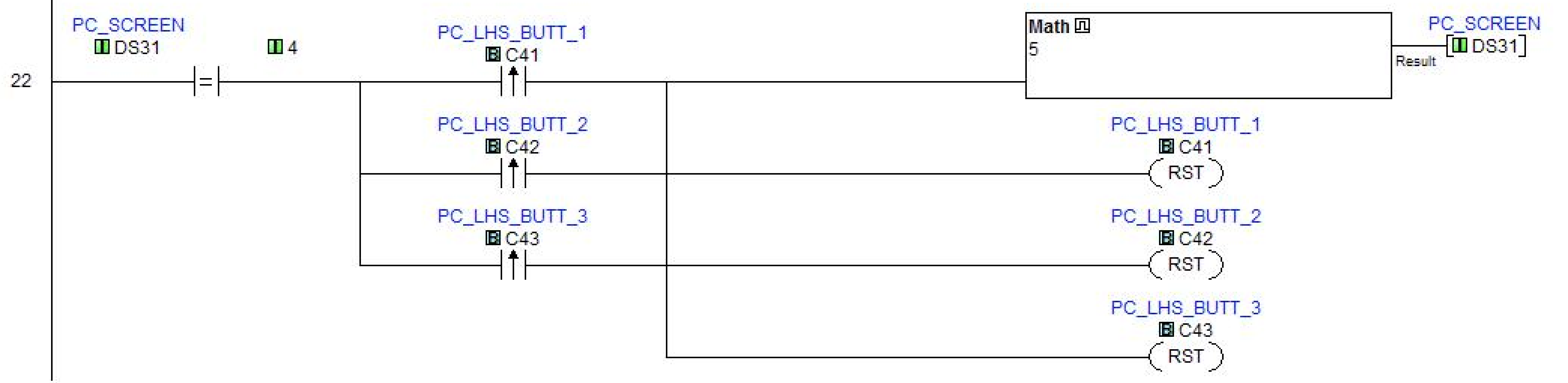

17
T1
Math
1
Result
PC_SCREEN
DS31
18
T2
PC_POWER_STARTUP
C37
RST
SELECTION MADE, NEXT PC SCREEN
19
PC_SCREEN
DS31
1
PC_RHS_BUTT_1
C51
Math
2
Result
PC_SCREEN
DS31
PC_RHS_BUTT_1
C51
RST
PC_RHS_BUTT_2
C52
Math
2
Result
PC_SCREEN
DS31
PC_RHS_BUTT_2
C52
RST
20
PC_SCREEN
DS31
2
PC_RHS_BUTT_1
C51
Math
3
Result
PC_SCREEN
DS31
PC_RHS_BUTT_2
C52
Math
3
Result
PC_SCREEN
DS31

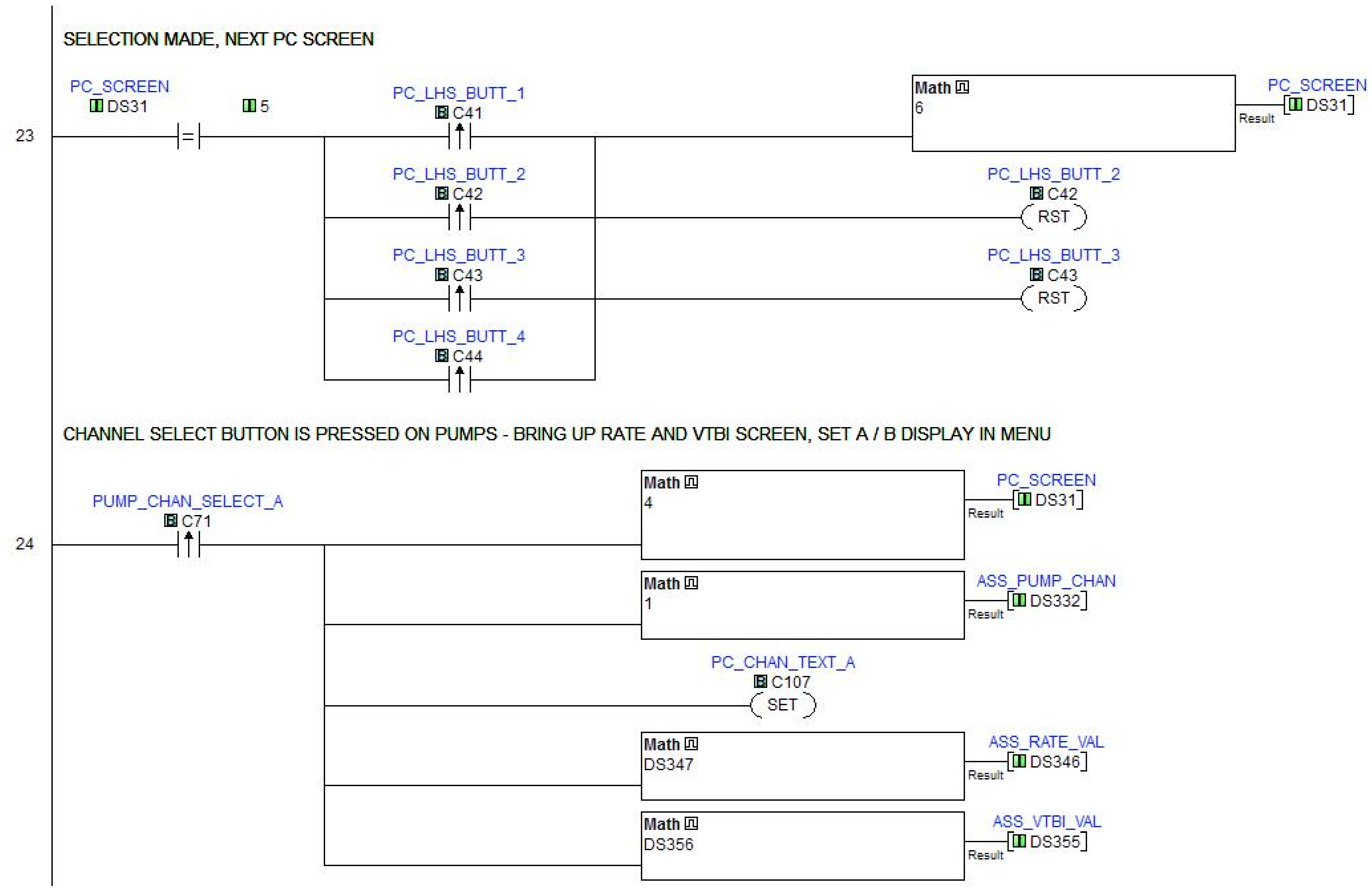
CHANNEL SELECTION SCREEN, PC BUTTONS AND PUMP BUTTONS FOR SELECTION

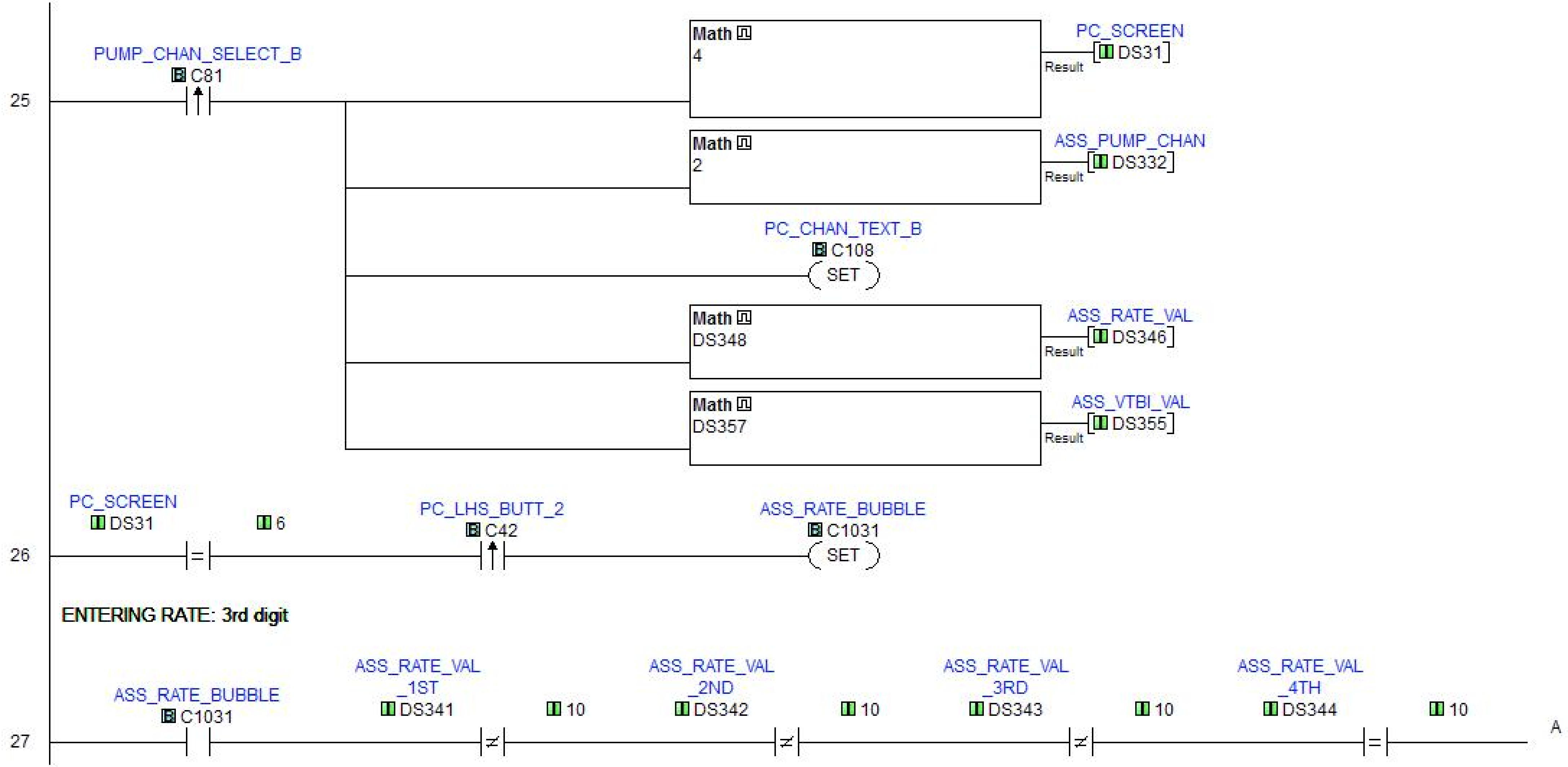
CHAN A

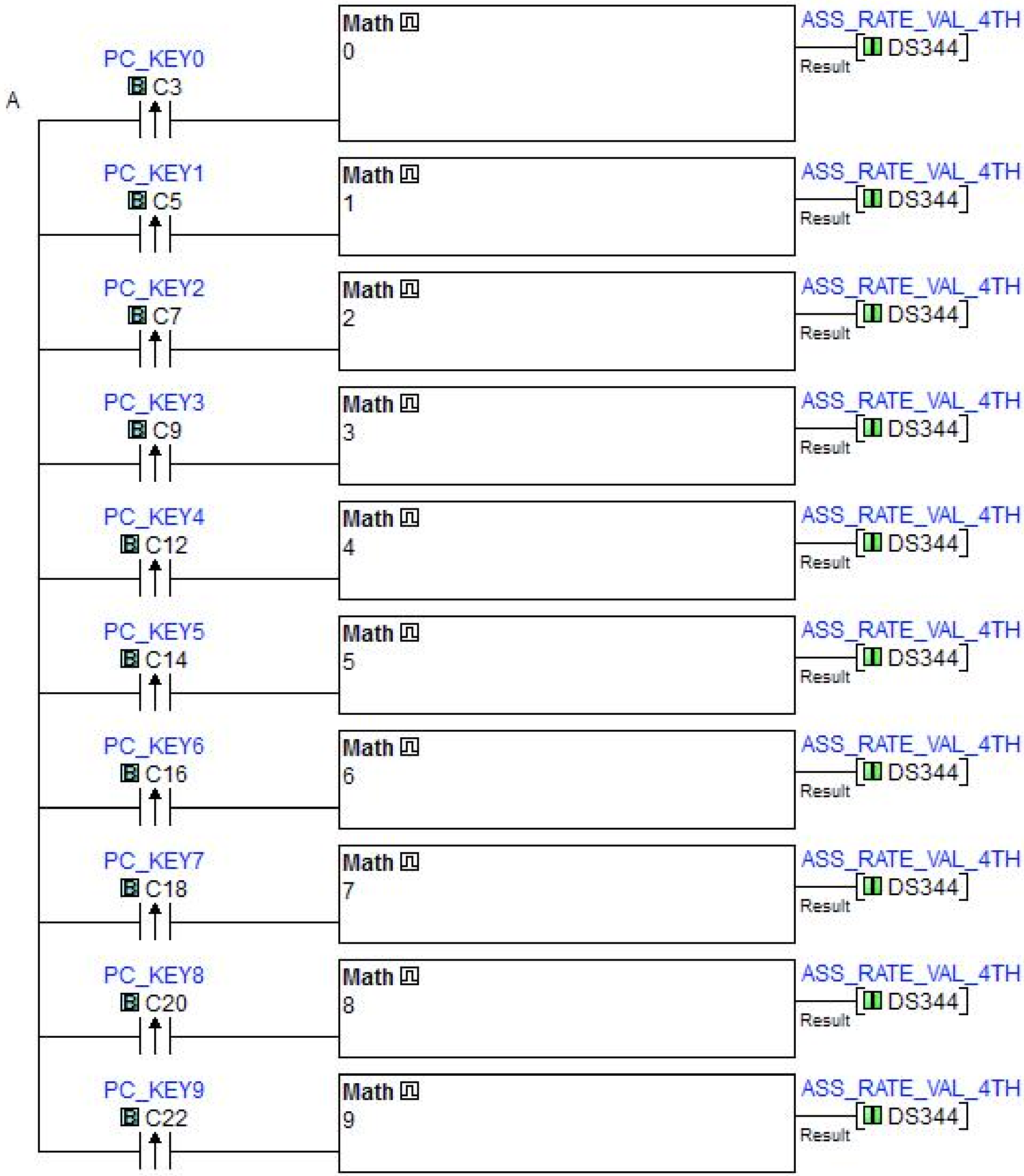


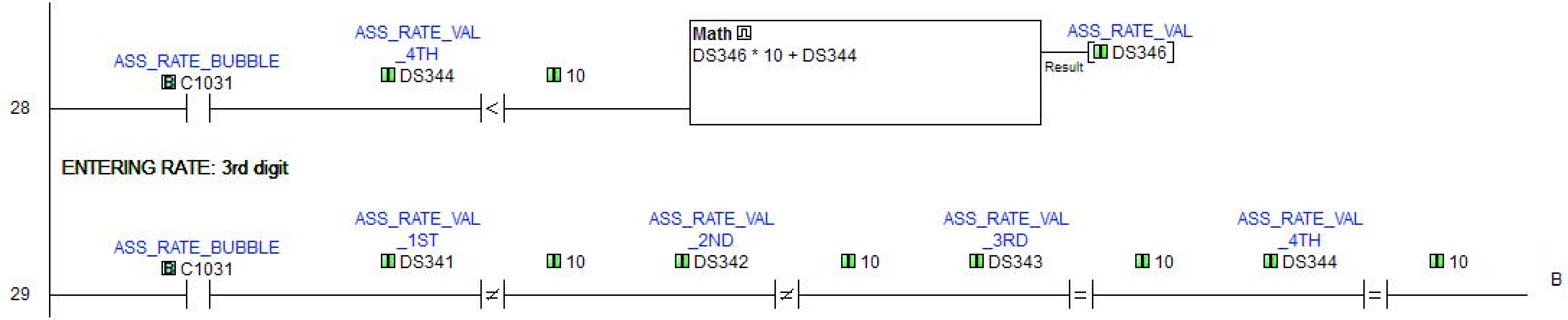
SELECTION MADE, NEXT PC SCREEN

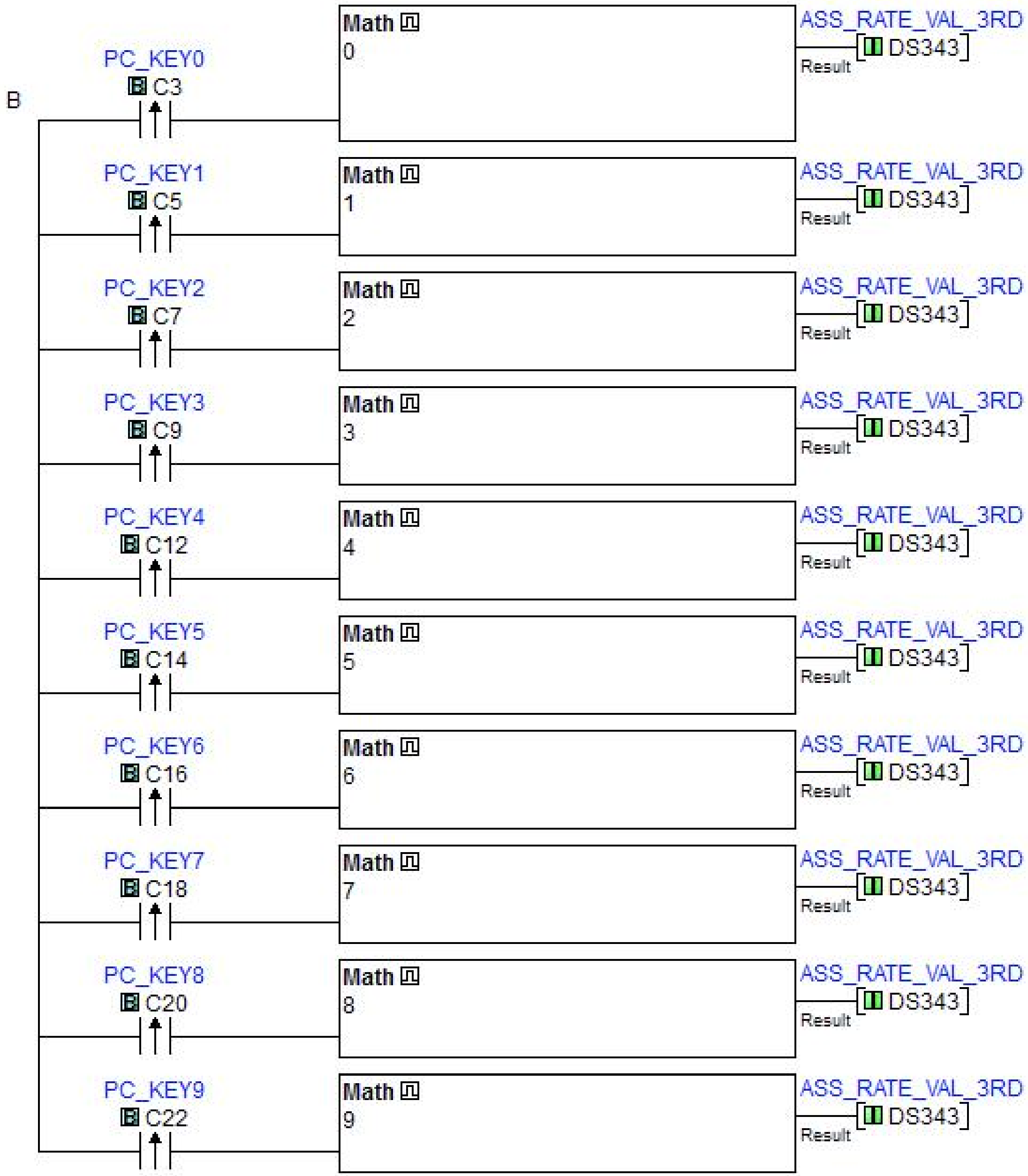


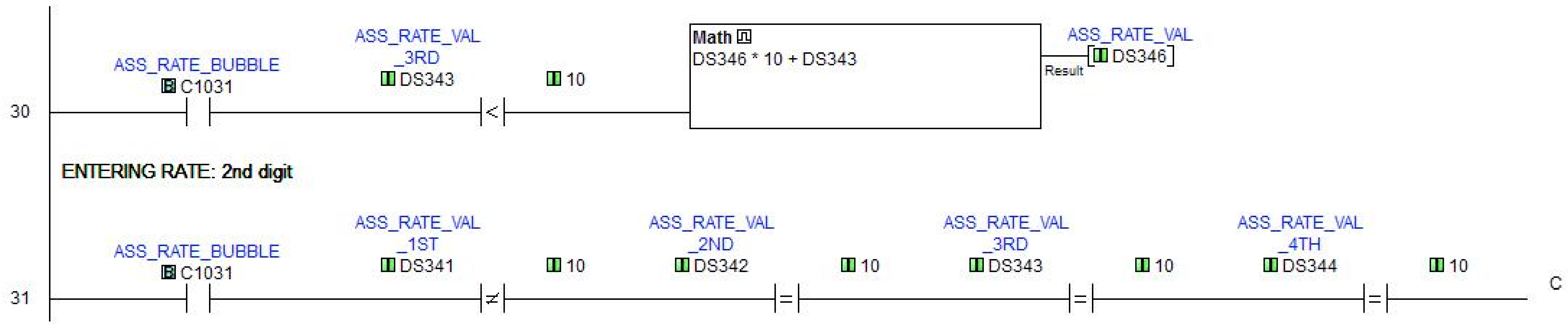

23
SELECTION MADE, NEXT PC SCREEN
PC_SCREEN
DS31
5
PC_LHS_BUTT_1
C41
PC_LHS_BUTT_2
C42
PC_LHS_BUTT_3
C43
PC_LHS_BUTT_4
C44
Math
6
Result
PC_SCREEN
DS31
PC_LHS_BUTT_2
C42
RST
PC_LHS_BUTT_3
C43
RST
24
CHANNEL SELECT BUTTON IS PRESSED ON PUMPS - BRING UP RATE AND VTBI SCREEN, SET A / B DISPLAY IN MENU
PUMP_CHAN_SELECT_A
C71
Math
4
Result
PC_SCREEN
DS31
Math
1
Result
ASS_PUMP_CHAN
DS332
PC_CHAN_TEXT_A
C107
SET
Math
DS347
Result
ASS_RATE_VAL
DS346
Math
DS356
Result
ASS_VTBI_VAL
DS355

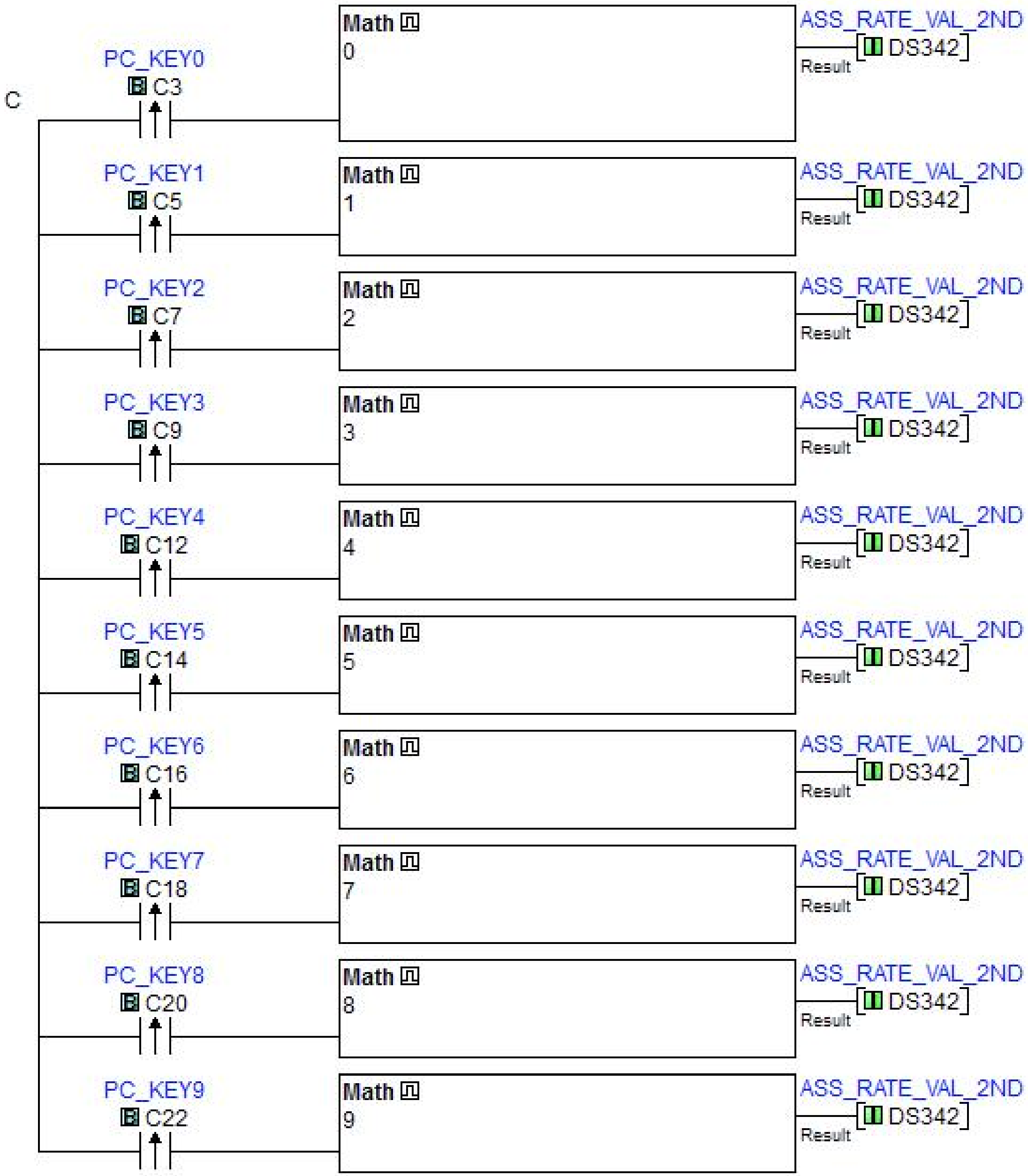

25
PUMP_CHAN_SELECT_B
C81
Math
4
Result
PC_SCREEN
DS31
Math
2
Result
ASS_PUMP_CHAN
DS332
PC_CHAN_TEXT_B
C108
SET
Math
DS348
Result
ASS_RATE_VAL
DS346
Math
DS357
Result
ASS_VTBI_VAL
DS355
26
PC_SCREEN
DS31
6
PC_LHS_BUTT_2
C42
ASS_RATE_BUBBLE
C1031
SET
ENTERING RATE: 3rd digit
27
ASS_RATE_BUBBLE
C1031
ASS_RATE_VAL
_1ST
DS341
10
ASS_RATE_VAL
_2ND
DS342
10
ASS_RATE_VAL
_3RD
DS343
10
ASS_RATE_VAL
_4TH
DS344
10
A

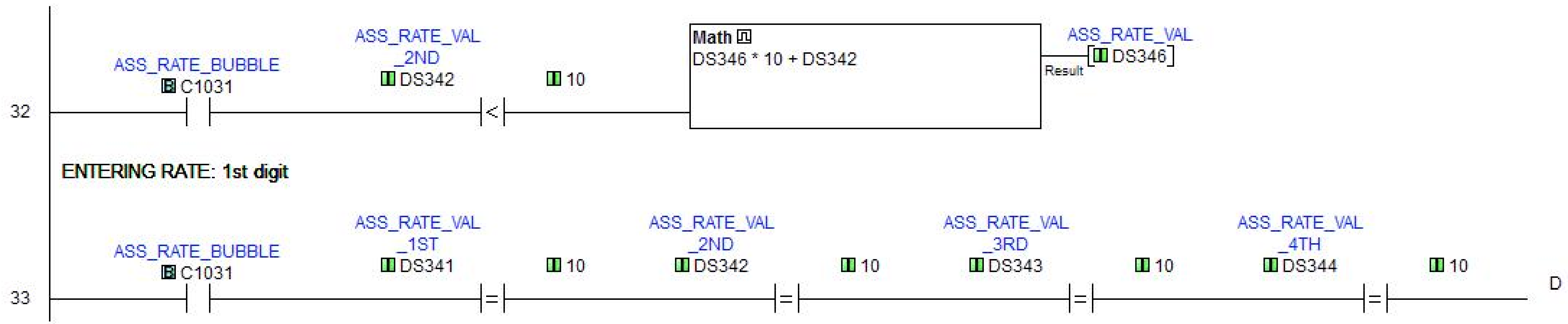

A
PC_KEY0
C3
Math
0
ASS_RATE_VAL_4TH
DS344
Result
PC_KEY1
C5
Math
1
ASS_RATE_VAL_4TH
DS344
Result
PC_KEY2
C7
Math
2
ASS_RATE_VAL_4TH
DS344
Result
PC_KEY3
C9
Math
3
ASS_RATE_VAL_4TH
DS344
Result
PC_KEY4
C12
Math
4
ASS_RATE_VAL_4TH
DS344
Result
PC_KEY5
C14
Math
5
ASS_RATE_VAL_4TH
DS344
Result
PC_KEY6
C16
Math
6
ASS_RATE_VAL_4TH
DS344
Result
PC_KEY7
C18
Math
7
ASS_RATE_VAL_4TH
DS344
Result
PC_KEY8
C20
Math
8
ASS_RATE_VAL_4TH
DS344
Result
PC_KEY9
C22
Math
9
ASS_RATE_VAL_4TH
DS344
Result

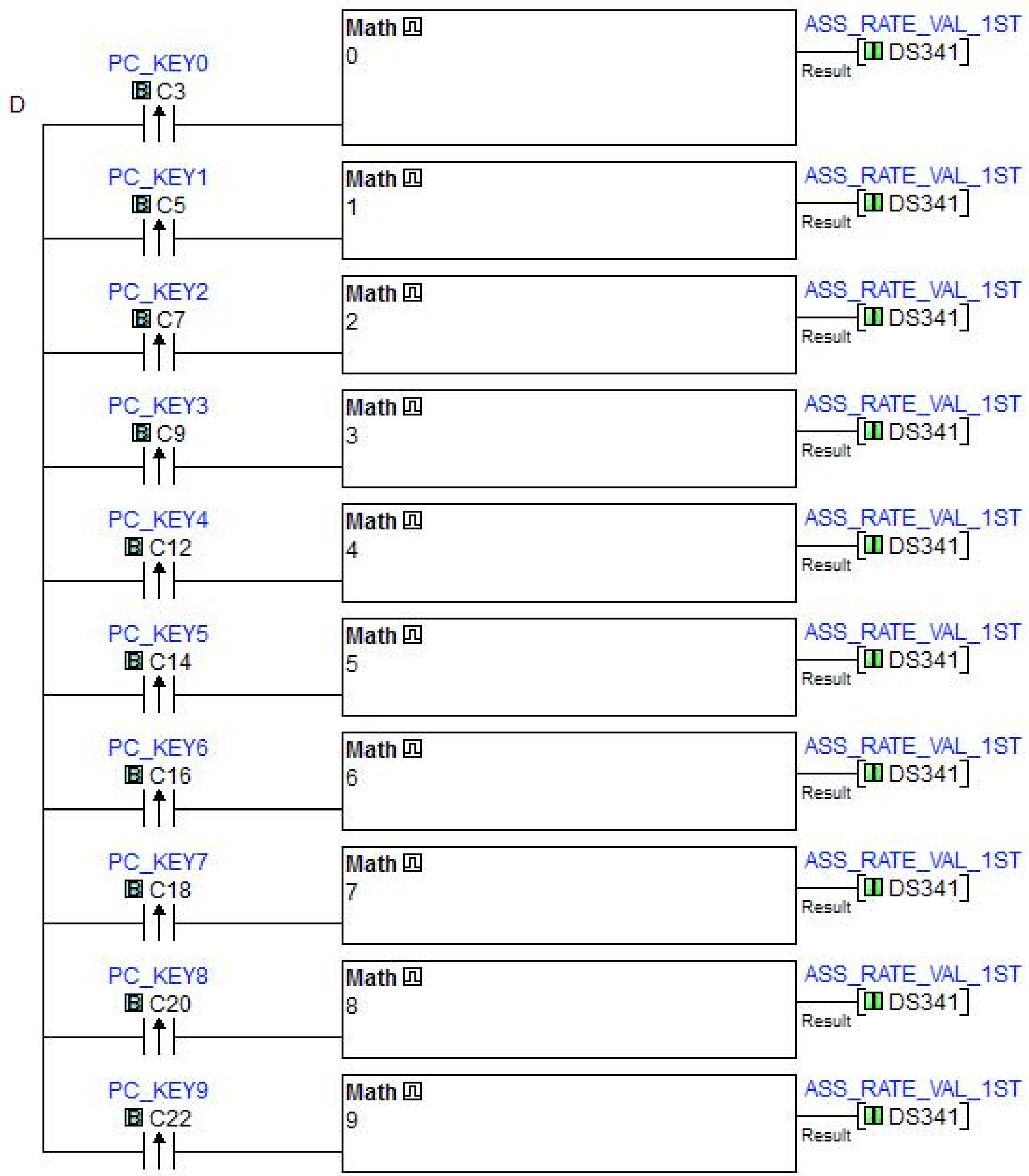

28
ASS_RATE_BUBBLE
C1031
ASS_RATE_VAL
_4TH
DS344
<
10
Math
DS346 * 10 + DS344
Result
ASS_RATE_VAL
DS346
ENTERING RATE: 3rd digit
29
ASS_RATE_BUBBLE
C1031
ASS_RATE_VAL
_1ST
DS341
≠
10
ASS_RATE_VAL
_2ND
DS342
≠
10
ASS_RATE_VAL
_3RD
DS343
=
10
ASS_RATE_VAL
_4TH
DS344
=
10
B

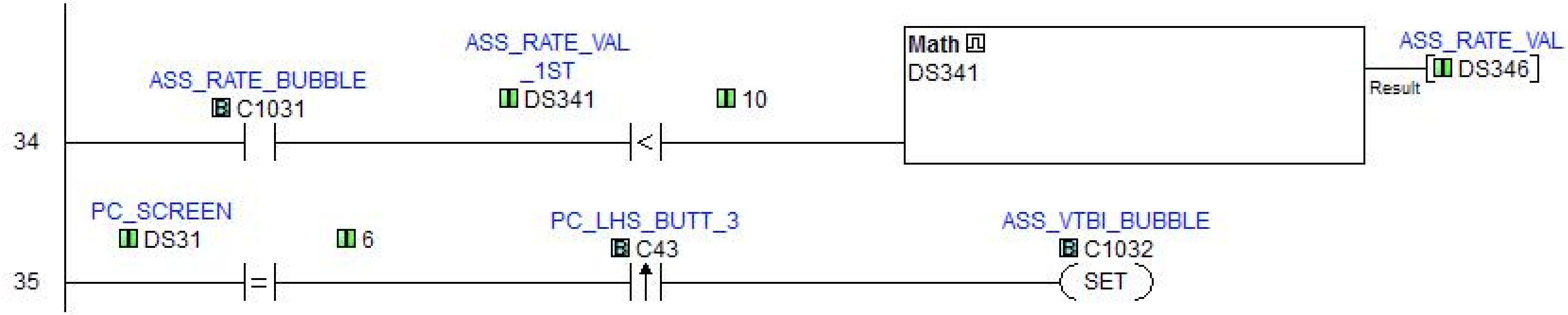

B
PC_KEY0
C3
Math
0
ASS_RATE_VAL_3RD
DS343
Result
PC_KEY1
C5
Math
1
ASS_RATE_VAL_3RD
DS343
Result
PC_KEY2
C7
Math
2
ASS_RATE_VAL_3RD
DS343
Result
PC_KEY3
C9
Math
3
ASS_RATE_VAL_3RD
DS343
Result
PC_KEY4
C12
Math
4
ASS_RATE_VAL_3RD
DS343
Result
PC_KEY5
C14
Math
5
ASS_RATE_VAL_3RD
DS343
Result
PC_KEY6
C16
Math
6
ASS_RATE_VAL_3RD
DS343
Result
PC_KEY7
C18
Math
7
ASS_RATE_VAL_3RD
DS343
Result
PC_KEY8
C20
Math
8
ASS_RATE_VAL_3RD
DS343
Result
PC_KEY9
C22
Math
9
ASS_RATE_VAL_3RD
DS343
Result

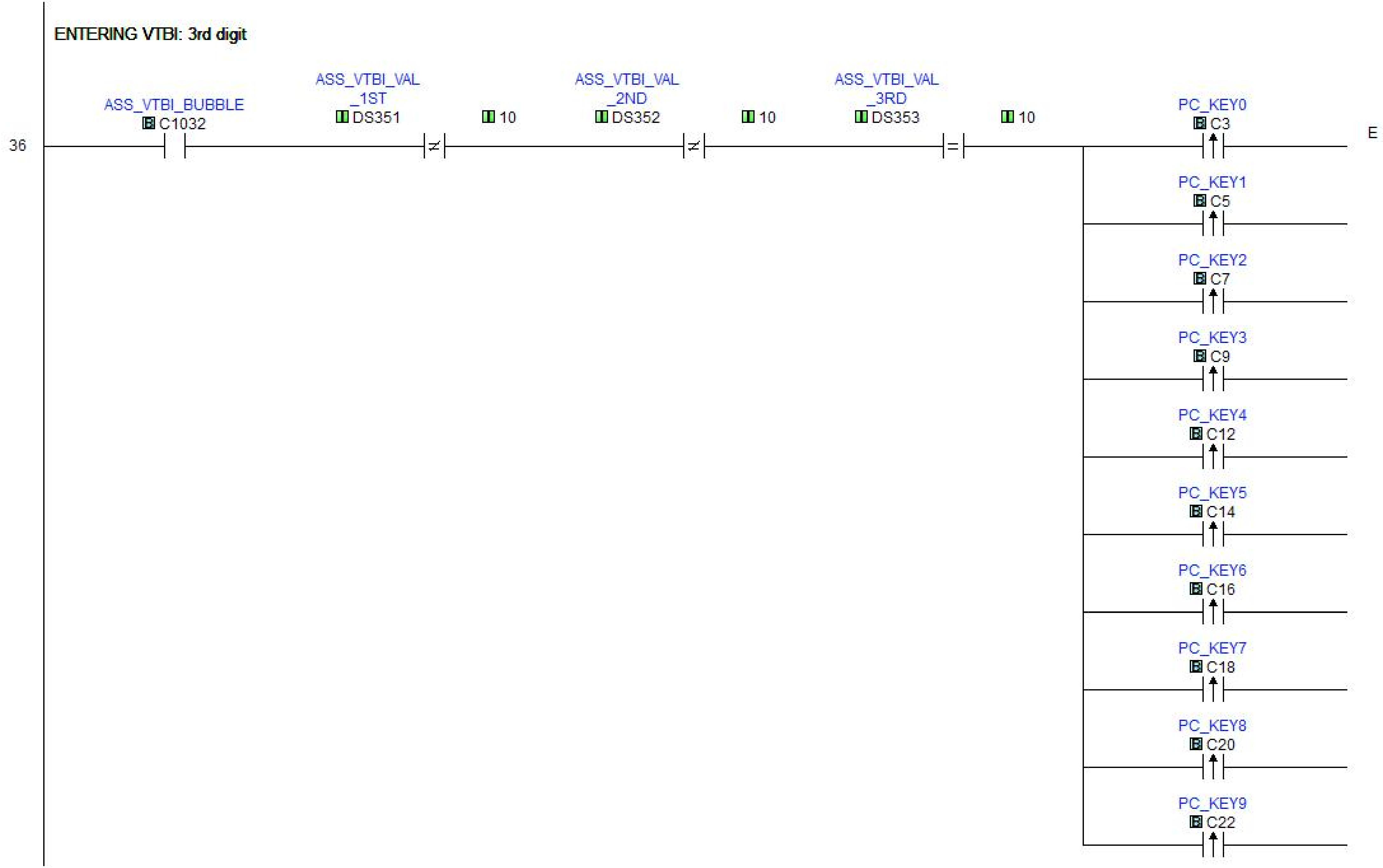

30
ASS_RATE_BUBBLE
C1031
ASS_RATE_VAL
_3RD
DS343
<
10
Math
DS346 * 10 + DS343
Result
ASS_RATE_VAL
DS346
ENTERING RATE: 2nd digit
31
ASS_RATE_BUBBLE
C1031
ASS_RATE_VAL
_1ST
DS341
≠
10
ASS_RATE_VAL
_2ND
DS342
=
10
ASS_RATE_VAL
_3RD
DS343
=
10
ASS_RATE_VAL
_4TH
DS344
=
10
C

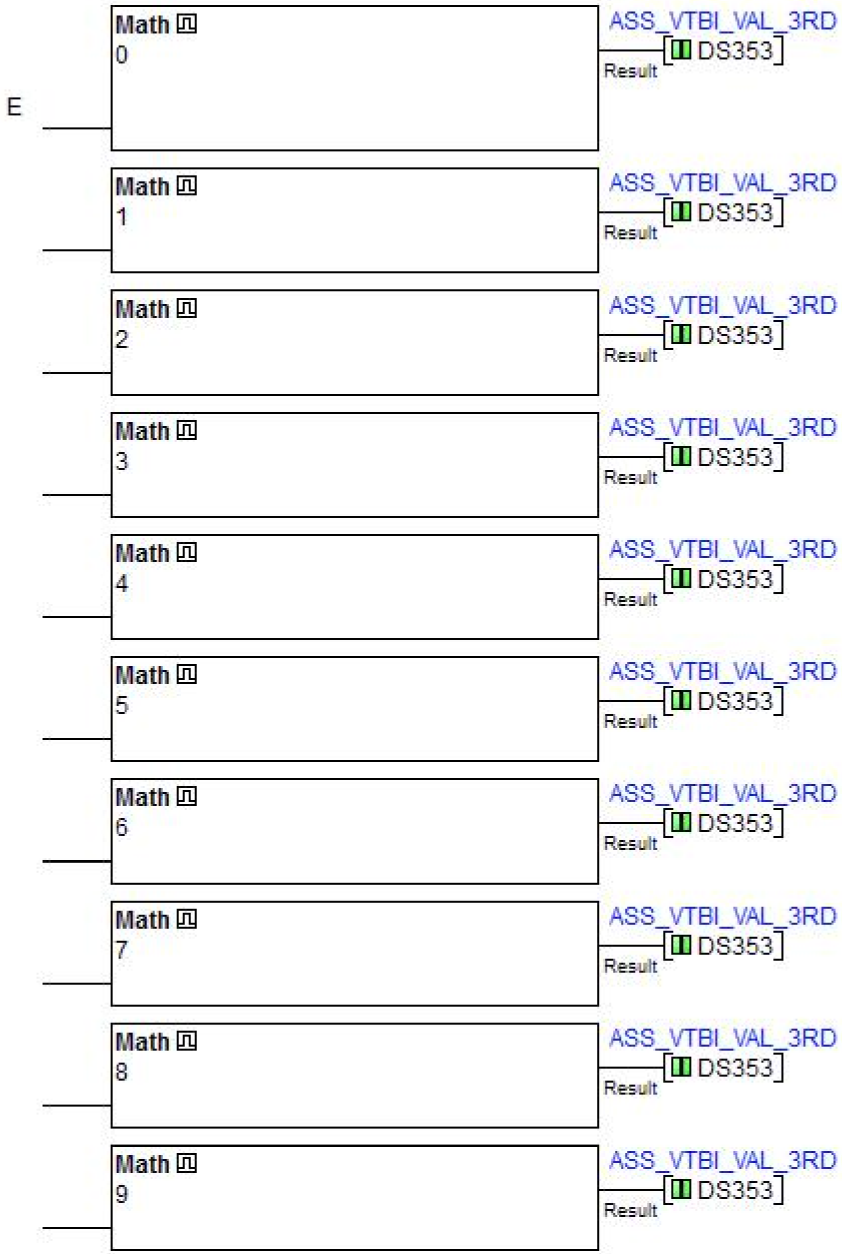

C
PC_KEY0
C3
Math
0
ASS_RATE_VAL_2ND
DS342
Result
PC_KEY1
C5
Math
1
ASS_RATE_VAL_2ND
DS342
Result
PC_KEY2
C7
Math
2
ASS_RATE_VAL_2ND
DS342
Result
PC_KEY3
C9
Math
3
ASS_RATE_VAL_2ND
DS342
Result
PC_KEY4
C12
Math
4
ASS_RATE_VAL_2ND
DS342
Result
PC_KEY5
C14
Math
5
ASS_RATE_VAL_2ND
DS342
Result
PC_KEY6
C16
Math
6
ASS_RATE_VAL_2ND
DS342
Result
PC_KEY7
C18
Math
7
ASS_RATE_VAL_2ND
DS342
Result
PC_KEY8
C20
Math
8
ASS_RATE_VAL_2ND
DS342
Result
PC_KEY9
C22
Math
9
ASS_RATE_VAL_2ND
DS342
Result

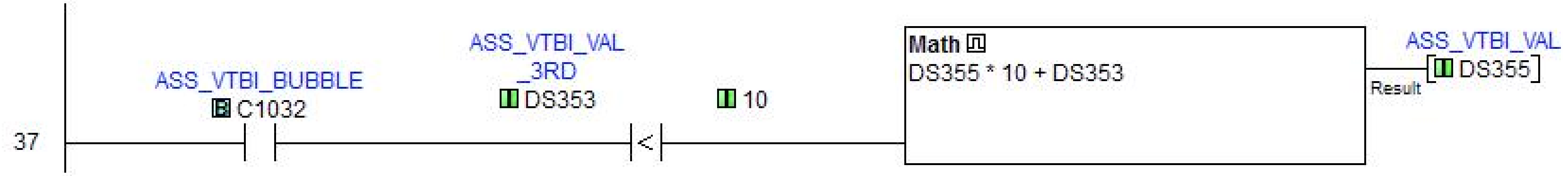

32
ASS_RATE_BUBBLE
C1031
ASS_RATE_VAL
_2ND
DS342
<
10
Math
DS346 * 10 + DS342
Result
ASS_RATE_VAL
DS346
ENTERING RATE: 1st digit
33
ASS_RATE_BUBBLE
C1031
ASS_RATE_VAL
_1ST
DS341
=
10
ASS_RATE_VAL
_2ND
DS342
=
10
ASS_RATE_VAL
_3RD
DS343
=
10
ASS_RATE_VAL
_4TH
DS344
=
10
D


D
PC_KEY0
C3
Math
0
ASS_RATE_VAL_1ST
DS341
Result
PC_KEY1
C5
Math
1
ASS_RATE_VAL_1ST
DS341
Result
PC_KEY2
C7
Math
2
ASS_RATE_VAL_1ST
DS341
Result
PC_KEY3
C9
Math
3
ASS_RATE_VAL_1ST
DS341
Result
PC_KEY4
C12
Math
4
ASS_RATE_VAL_1ST
DS341
Result
PC_KEY5
C14
Math
5
ASS_RATE_VAL_1ST
DS341
Result
PC_KEY6
C16
Math
6
ASS_RATE_VAL_1ST
DS341
Result
PC_KEY7
C18
Math
7
ASS_RATE_VAL_1ST
DS341
Result
PC_KEY8
C20
Math
8
ASS_RATE_VAL_1ST
DS341
Result
PC_KEY9
C22
Math
9
ASS_RATE_VAL_1ST
DS341
Result

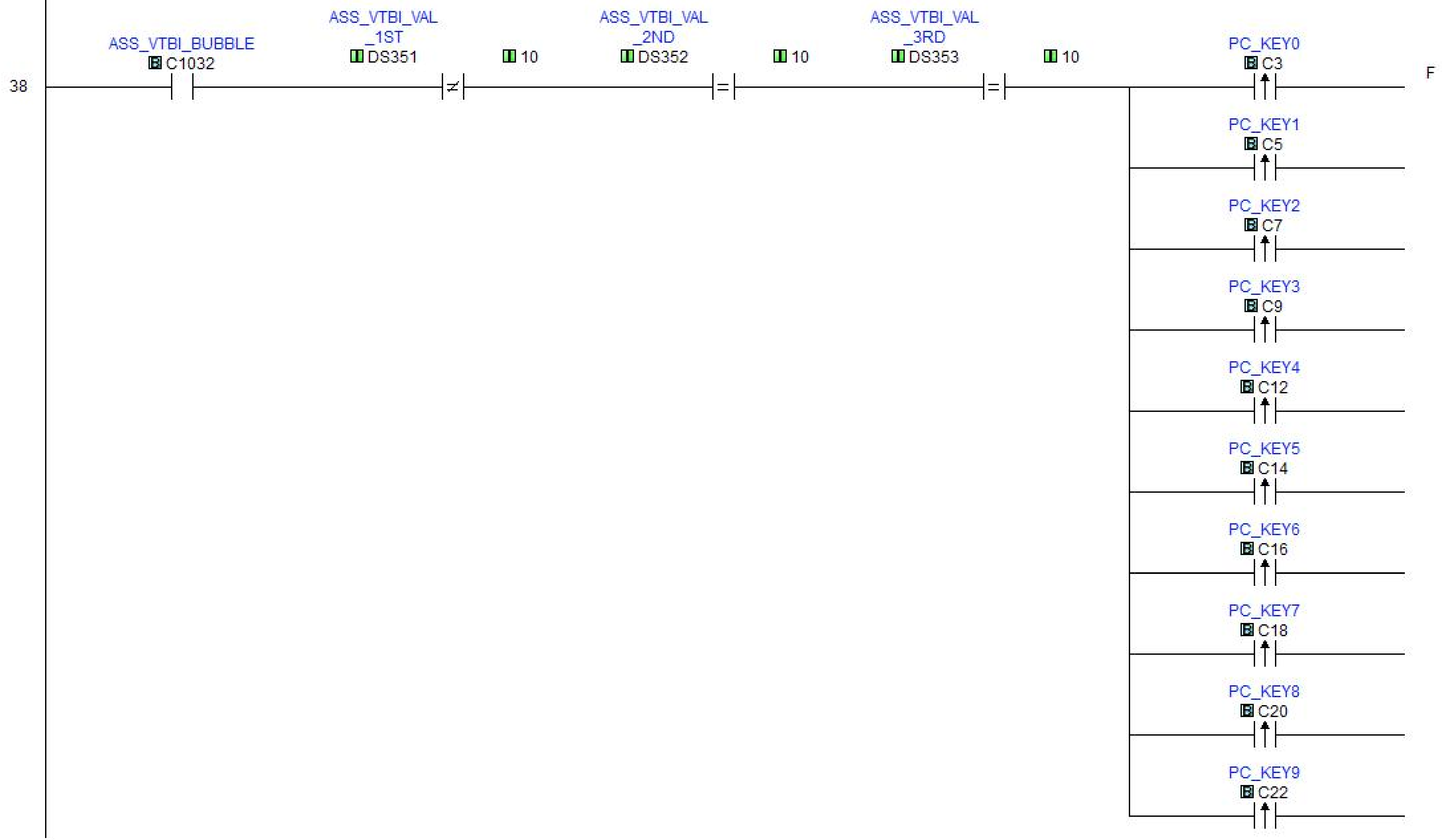

34
ASS_RATE_BUBBLE
C1031
ASS_RATE_VAL
_1ST
DS341
<
10
Math
DS341
ASS_RATE_VAL
DS346
Result
35
PC_SCREEN
DS31
=
6
PC_LHS_BUTT_3
C43
ASS_VTBI_BUBBLE
C1032
SET

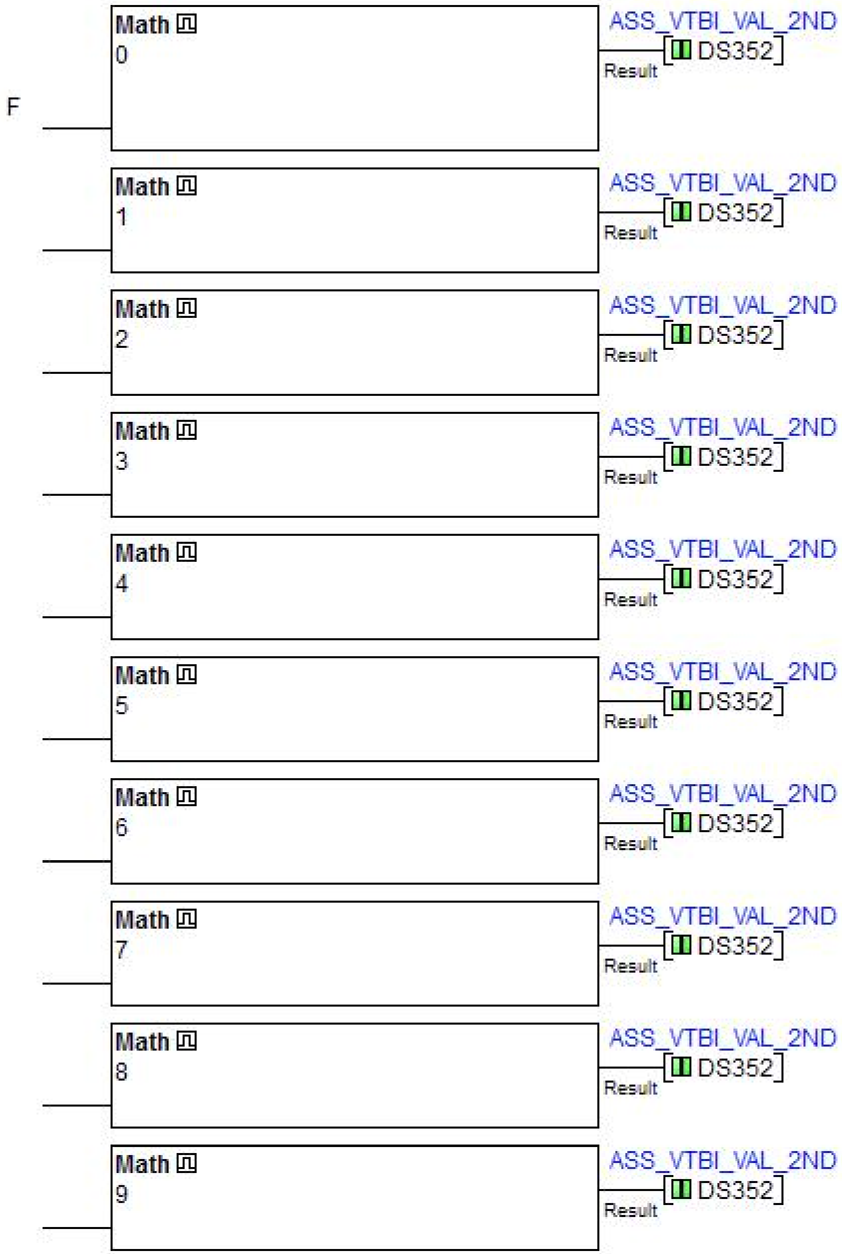

ENTERING VTBI: 3rd digit
36
ASS_VTBI_BUBBLE
C1032
ASS_VTBI_VAL
_1ST
DS351
10
ASS_VTBI_VAL
_2ND
DS352
10
ASS_VTBI_VAL
_3RD
DS353
10
PC_KEY0
C3
PC_KEY1
C5
PC_KEY2
C7
PC_KEY3
C9
PC_KEY4
C12
PC_KEY5
C14
PC_KEY6
C16
PC_KEY7
C18
PC_KEY8
C20
PC_KEY9
C22
E

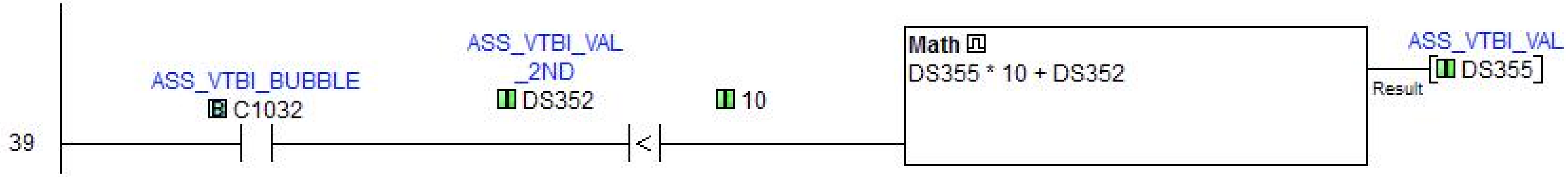

E
Math 0
ASS_VTBI_VAL_3RD
DS353
Result
Math 1
ASS_VTBI_VAL_3RD
DS353
Result
Math 2
ASS_VTBI_VAL_3RD
DS353
Result
Math 3
ASS_VTBI_VAL_3RD
DS353
Result
Math 4
ASS_VTBI_VAL_3RD
DS353
Result
Math 5
ASS_VTBI_VAL_3RD
DS353
Result
Math 6
ASS_VTBI_VAL_3RD
DS353
Result
Math 7
ASS_VTBI_VAL_3RD
DS353
Result
Math 8
ASS_VTBI_VAL_3RD
DS353
Result
Math 9
ASS_VTBI_VAL_3RD
DS353
Result


37
ASS_VTBI_BUBBLE
C1032
ASS_VTBI_VAL
_3RD
DS353
<
10
Math
DS355 * 10 + DS353
Result
ASS_VTBI_VAL
DS355

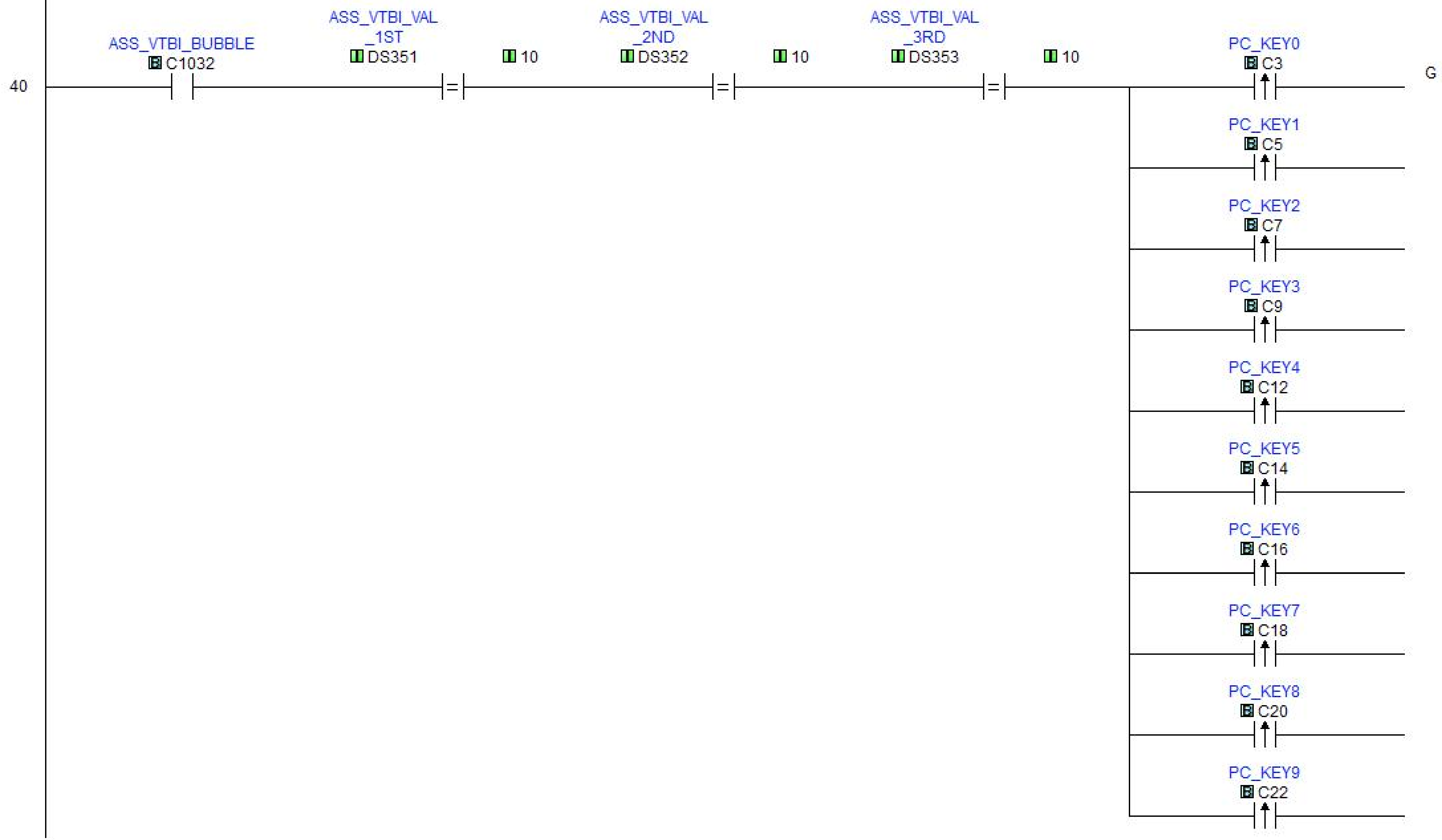
ENTERING VTBI: 2nd digit



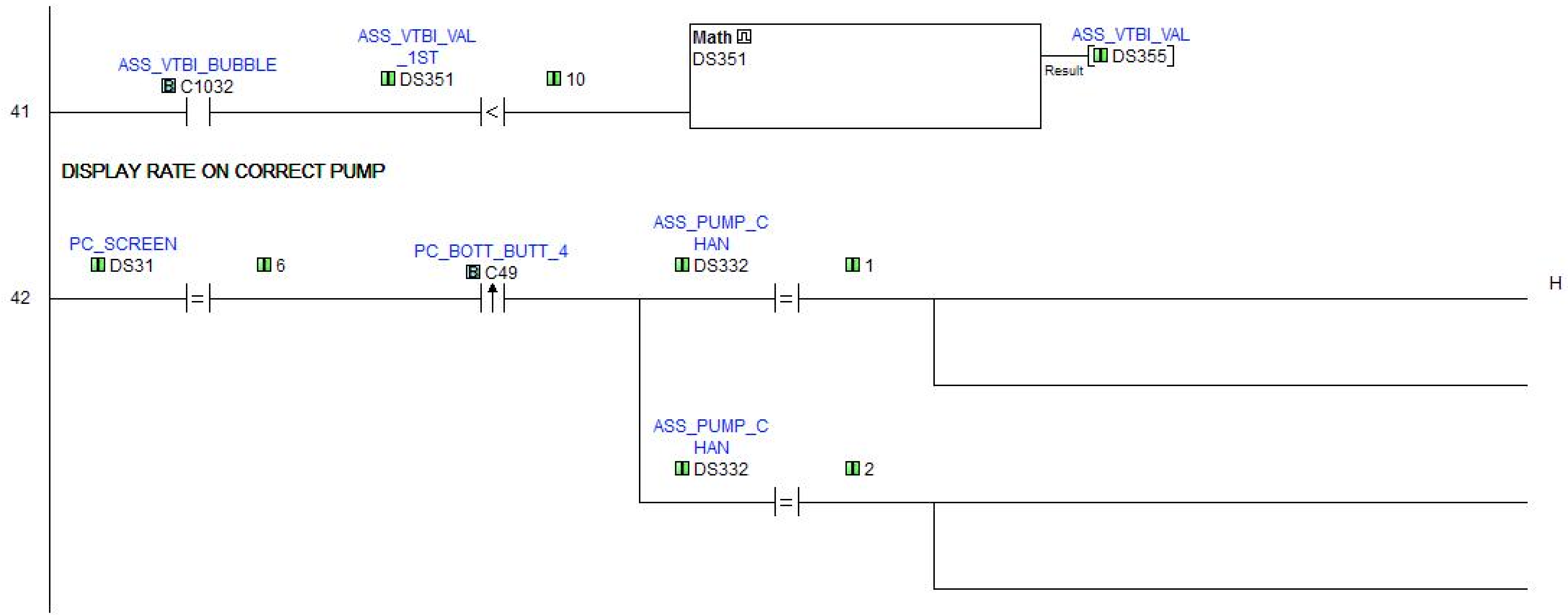

F
Math
0
Result
ASS_VTBI_VAL_2ND
DS352
Math
1
Result
ASS_VTBI_VAL_2ND
DS352
Math
2
Result
ASS_VTBI_VAL_2ND
DS352
Math
3
Result
ASS_VTBI_VAL_2ND
DS352
Math
4
Result
ASS_VTBI_VAL_2ND
DS352
Math
5
Result
ASS_VTBI_VAL_2ND
DS352
Math
6
Result
ASS_VTBI_VAL_2ND
DS352
Math
7
Result
ASS_VTBI_VAL_2ND
DS352
Math
8
Result
ASS_VTBI_VAL_2ND
DS352
Math
9
Result
ASS_VTBI_VAL_2ND
DS352

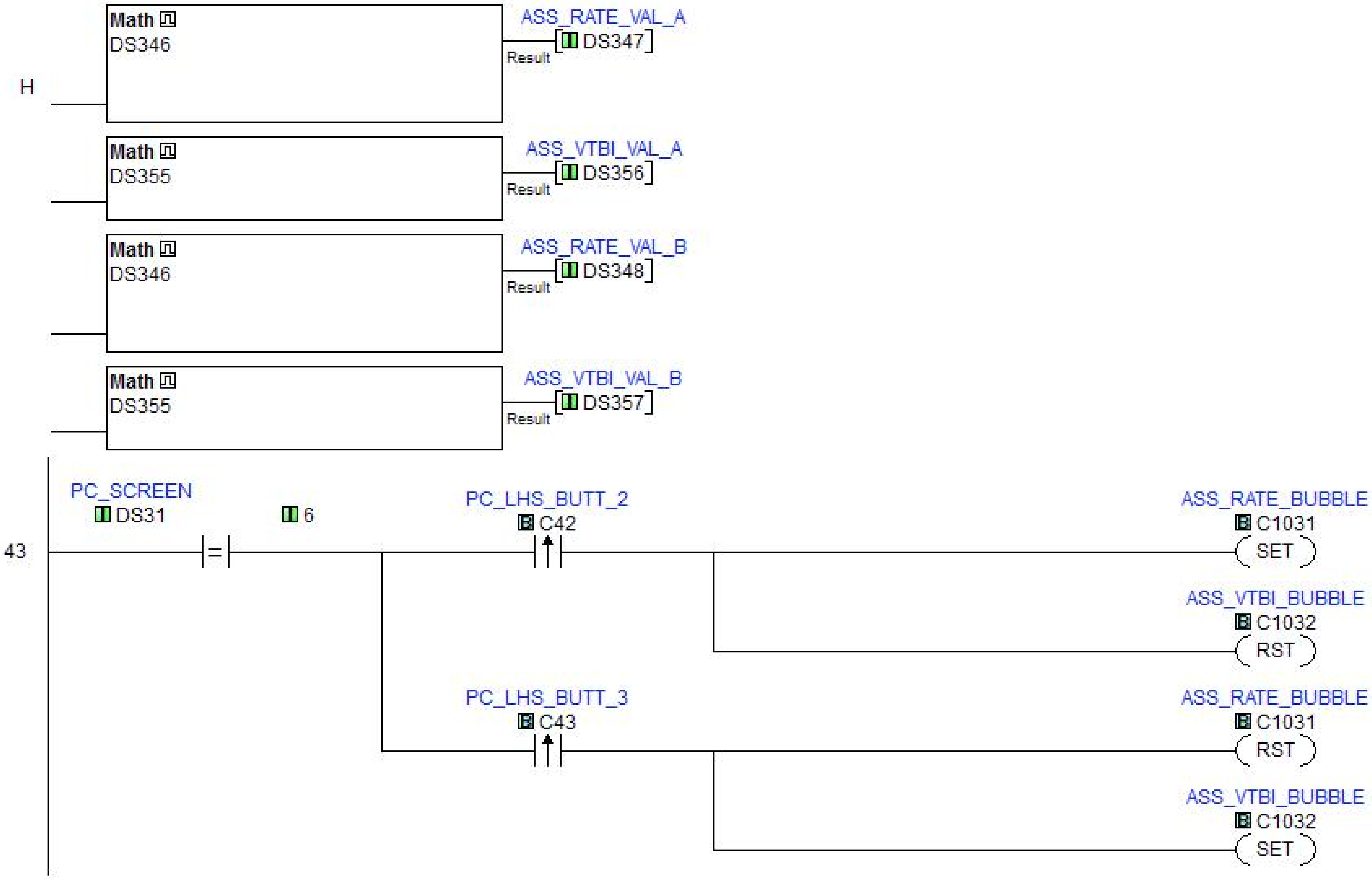

39
ASS_VTBI_BUBBLE
C1032
ASS_VTBI_VAL
_2ND
DS352
<
10
Math
DS355 * 10 + DS352
Result
ASS_VTBI_VAL
DS355

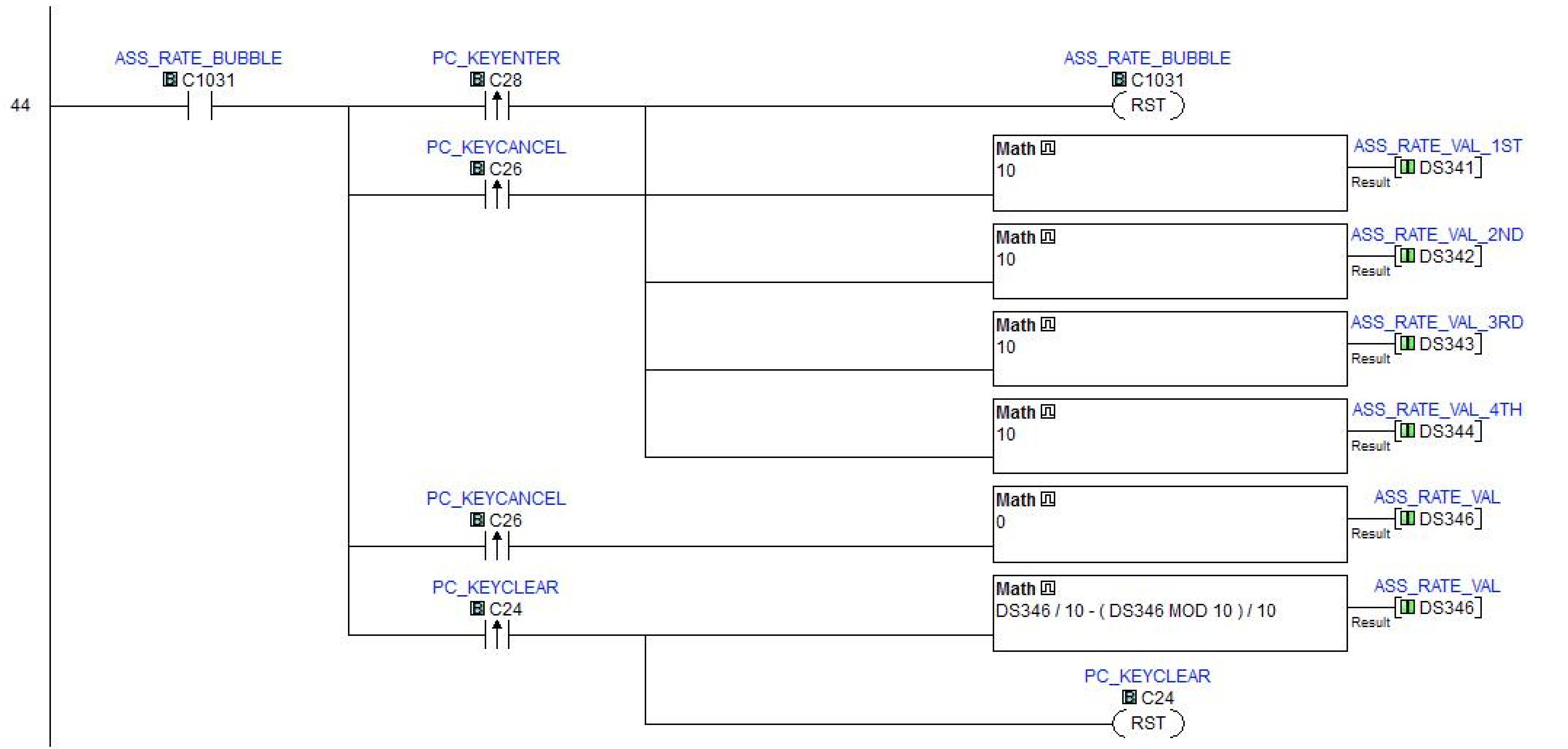
ENTERING VTBI: 2nd digit

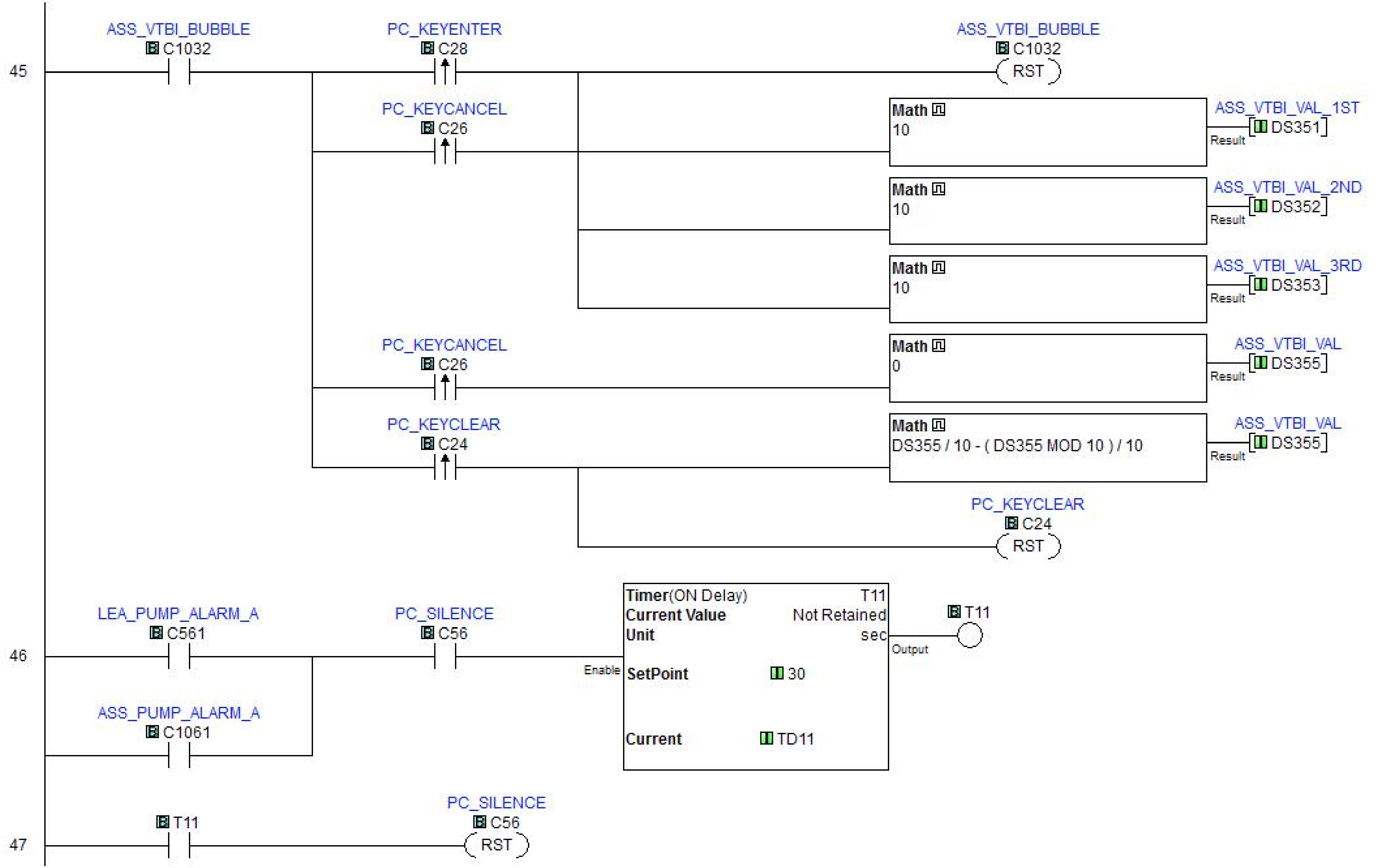



G
Math
0
ASS_VTBI_VAL_1ST
DS351
Result
Math
1
ASS_VTBI_VAL_1ST
DS351
Result
Math
2
ASS_VTBI_VAL_1ST
DS351
Result
Math
3
ASS_VTBI_VAL_1ST
DS351
Result
Math
4
ASS_VTBI_VAL_1ST
DS351
Result
Math
5
ASS_VTBI_VAL_1ST
DS351
Result
Math
6
ASS_VTBI_VAL_1ST
DS351
Result
Math
7
ASS_VTBI_VAL_1ST
DS351
Result
Math
8
ASS_VTBI_VAL_1ST
DS351
Result
Math
9
ASS_VTBI_VAL_1ST
DS351
Result

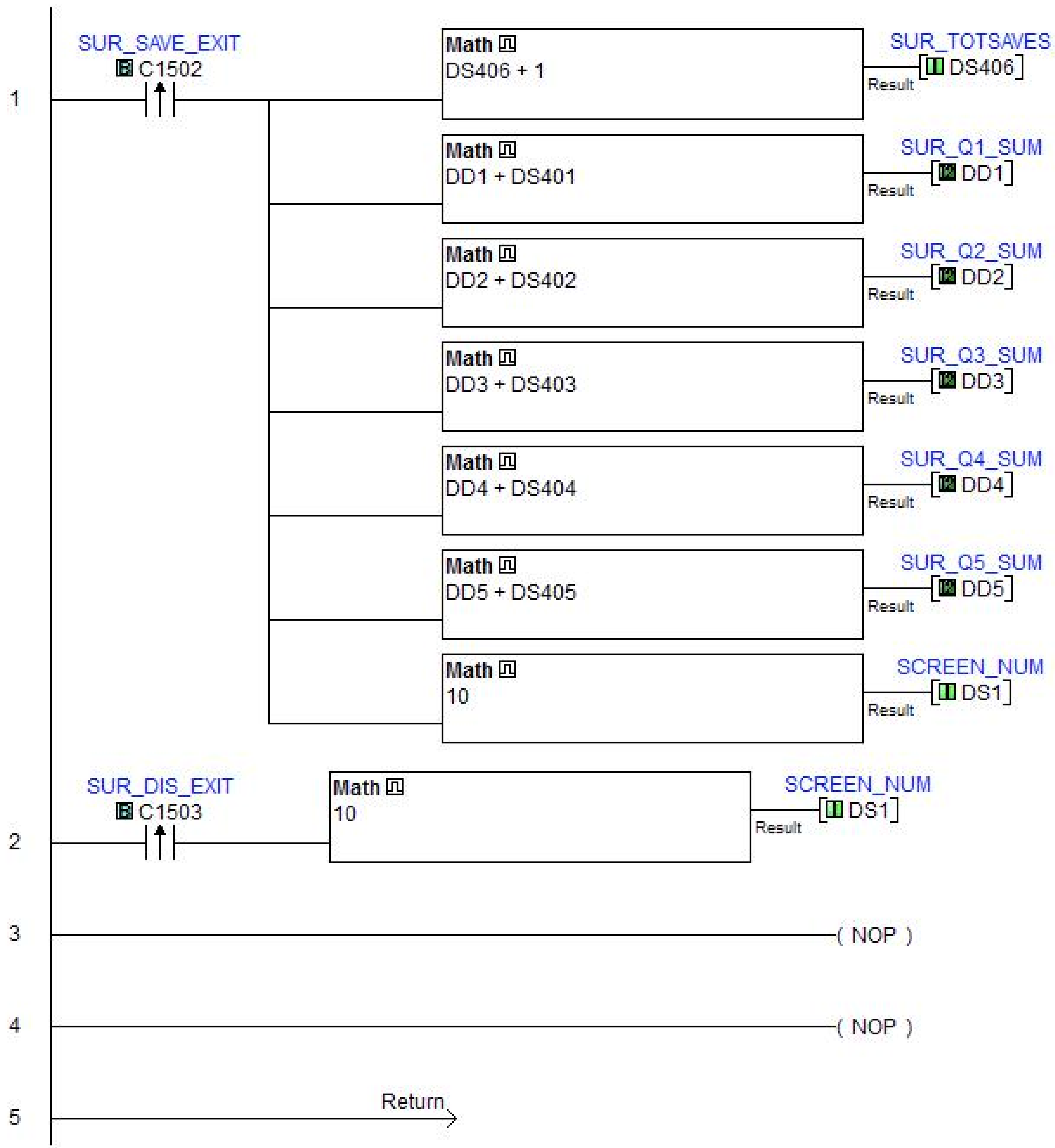

41
ASS_VTBI_BUBBLE
C1032
ASS_VTBI_VAL _1ST
DS351
<
10
Math
DS351
Result
ASS_VTBI_VAL
DS355
DISPLAY RATE ON CORRECT PUMP
42
PC_SCREEN
DS31
=
6
PC_BOTT_BUTT_4
C49
ASS_PUMP_C HAN
DS332
=
1
H
ASS_PUMP_C HAN
DS332
=
2


H
Math
DS346
ASS_RATE_VAL_A
DS347
Result
Math
DS355
ASS_VTBI_VAL_A
DS356
Result
Math
DS346
ASS_RATE_VAL_B
DS348
Result
Math
DS355
ASS_VTBI_VAL_B
DS357
Result
43
PC_SCREEN
DS31
=
6
PC_LHS_BUTT_2
C42
ASS_RATE_BUBBLE
C1031
SET
ASS_VTBI_BUBBLE
C1032
RST
PC_LHS_BUTT_3
C43
ASS_RATE_BUBBLE
C1031
RST
ASS_VTBI_BUBBLE
C1032
SET


44
ASS_RATE_BUBBLE
C1031
PC_KEYENTER
C28
ASS_RATE_BUBBLE
C1031
RST
PC_KEYCANCEL
C26
Math
10
ASS_RATE_VAL_1ST
DS341
Result
Math
10
ASS_RATE_VAL_2ND
DS342
Result
Math
10
ASS_RATE_VAL_3RD
DS343
Result
Math
10
ASS_RATE_VAL_4TH
DS344
Result
PC_KEYCANCEL
C26
Math
0
ASS_RATE_VAL
DS346
Result
PC_KEYCLEAR
C24
Math
DS346 / 10 - (DS346 MOD 10) / 10
ASS_RATE_VAL
DS346
Result
PC_KEYCLEAR
C24
RST


45
ASS_VTBI_BUBBLE
C1032
PC_KEYENTER
C28
ASS_VTBI_BUBBLE
C1032
RST
PC_KEYCANCEL
C26
Math
10
ASS_VTBI_VAL_1ST
DS351
Result
Math
10
ASS_VTBI_VAL_2ND
DS352
Result
Math
10
ASS_VTBI_VAL_3RD
DS353
Result
PC_KEYCANCEL
C26
Math
0
ASS_VTBI_VAL
DS355
Result
PC_KEYCLEAR
C24
Math
DS355 / 10 - (DS355 MOD 10) / 10
ASS_VTBI_VAL
DS355
Result
PC_KEYCLEAR
C24
RST
46
LEA_PUMP_ALARM_A
C561
ASS_PUMP_ALARM_A
C1061
PC_SILENCE
C56
Enable
Timer(ON Delay) T11
Current Value Not Retained
Unit sec
SetPoint 30
Current TD11
Output
T11
47
T11
PC_SILENCE
C56
RST


48
Return


1
SUR_SAVE_EXIT
C1502
Math
DS406 + 1
Result
SUR_TOTSAVES
DS406
Math
DD1 + DS401
Result
SUR_Q1_SUM
DD1
Math
DD2 + DS402
Result
SUR_Q2_SUM
DD2
Math
DD3 + DS403
Result
SUR_Q3_SUM
DD3
Math
DD4 + DS404
Result
SUR_Q4_SUM
DD4
Math
DD5 + DS405
Result
SUR_Q5_SUM
DD5
Math
10
Result
SCREEN_NUM
DS1
2
SUR_DIS_EXIT
C1503
Math
10
Result
SCREEN_NUM
DS1
3
(NOP)
4
(NOP)
5
Return