January 19, 2009

Mr. Patrick Leung
School of Engineering Science
Simon Fraser University
8888 University Drive
Burnaby, BC. V5A 1S6

Re: ENSC 440/305 Project Proposal for an Electric Guitar Multi-Effects Device

Dear Professor Leung,

The attached document, *Project Proposal for an Electric Guitar Multi-Effects Device*, details our project for ENSC 440/305. The product allows electric guitar musicians to use a variety of specialized live audio effects for the electric guitar, along with the unprecedented ability to have electronic control over the sequence in which the effects are processed.

This document provides an overview of our proposed product and its features, as well as details regarding potential sources of funding, projected budget and project timeline. We also discuss the new possibilities obtainable to musicians by using our product to create more specialized sounds.

In Tune Innovations consists of four engineers, each in fourth-year: Kyle Balston, Tom Schultz, Scott Witzel and Michael Vogel. If there are any questions you have about our project, feel free to contact us at **mav1@sfu.ca**.

Sincerely,

In Tune Innovations: Kyle Balston, Tom Schultz, Scott Witzel, Michael Vogel

In Tune Innovations

Proposal for an

Electric Guitar Multi-Effects Device

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Submitted to: Patrick Leung: ENSC 440
Steve Whitmore: ENSC 305
School of Engineering Science
Simon Fraser University

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Executive Summary

To musicians, only two things really matter:

- SOUND, and
- The ability to create that sound

Making music is a universal hobby that continually evolves as technology advances. Since being first commercially available in the 1950s, the electric guitar has been the definitive musical instrument for both professional and aspiring musicians because of the wide range of sounds possible through electronic manipulation.

Altering the sound of the electric guitar creates what is called an "effect." Guitar effects (sometimes called guitar FX) are commonly packaged into hardware units known as pedals (because a footswitch controls their activations). Popular effects include distortion, echo and reverb. Each pedal typically controls one effect.

Most guitarists use a small assortment of individual pedals and sequence them together in a daisy chain to create a "signature sound." The order of this daisy chain can result in a dramatically different resultant sound and tone.

In Tune Innovations is developing a multi-effect device that will also give the user electronic control over the sequence of effects in the multi-effect chain. This emulates the daisy-chain approach used by musicians when using multiple guitar effects, and allows users to change the sequence on the fly without re-routing patch cables. Such a feature has never been introduced by commercial multi-effect devices. Quick electronic control over the internal daisy chain means that musicians will now be able to easily experiment creatively with the effects sequence in order to create more specialized sounds. This proposal provides an overview of In Tune's multi-effect device.

In Tune Innovations will spend the 13 week period ending in the first week of April 2009 to undertake the research and development required to create a working prototype of the multi-effect system. The budget is currently projected to be approximately $850.00, funded by different sources.

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1 Introduction

A finely-tuned assortment of guitar effects creates what is usually typified as a musical group's signature "sound": Delay effects characterize the sound of rock band U2, reverb is prominent in the works of Elvis Presley and other rockabilly artists, and heavy metal is lifeless without distortion. The list goes on.

Most guitarists use a series of footswitch-activated effect pedals daisy chained together. The order of this chain affects the resultant sound and tone. For example, placing a distortion effect in the daisy chain before an echo creates a more smooth distortion/echoing effect, whereas in the opposite sequence a more succinct and rigid echo results. Neither sequence is better than the other – it depends on what the musician is trying to achieve.

Standalone multi-effect units are becoming available to consumers who wish to relieve themselves of the clutter created by the array of effect pedals and patch cables (which can be very cumbersome, especially on stage). However, there is one major flaw with these devices: the user has no control over the daisy chain sequence of the effects because it is fixed internally by the manufacturer!

Even with a set of daisy chained pedals, it is time consuming for a musician to test all permutations of the patch cable sequence to figure out what sounds best. In Tune Innovation's plans to implement electronic control over the internal daisy chain in its multi-effect device, allowing the user simple control over the sequence. The result is that musicians will now be able to creatively experiment with the sequence in real time. Additionally, In Tune's new effects unit will be easily programmable, so that the user can cycle through a combination of effects, without having to change a single cable, or turn a single knob!

This device has diverse applications in almost any form of electronic music – including keyboard and vocal effects.

The proposal in this document provides an overview of our multi-effect box, highlighting our intended means of implementation as well as the budget, financing and timeline required to complete this project.

2 System Overview

In Tune Innovations is proposing an electric guitar multi-effect device - a self contained unit of built in guitar effects. Hardware and software will electronically control the internal daisy-chain of multiple effects. Consider a musician performing on stage with three effect pedals: tremolo, distortion and delay (think of tremolo as volume swells). Initially, the musician can choose to have all effects are turned off, resulting in an unprocessed clean guitar signal (~500 mV) being passed to the amplifier. Each effect can be independently turned on or off – however, when two or more effects are turned on, the order of processing is fixed by sequence in which they are connected by the manufacturer. This process is shown in Figure 1 below:

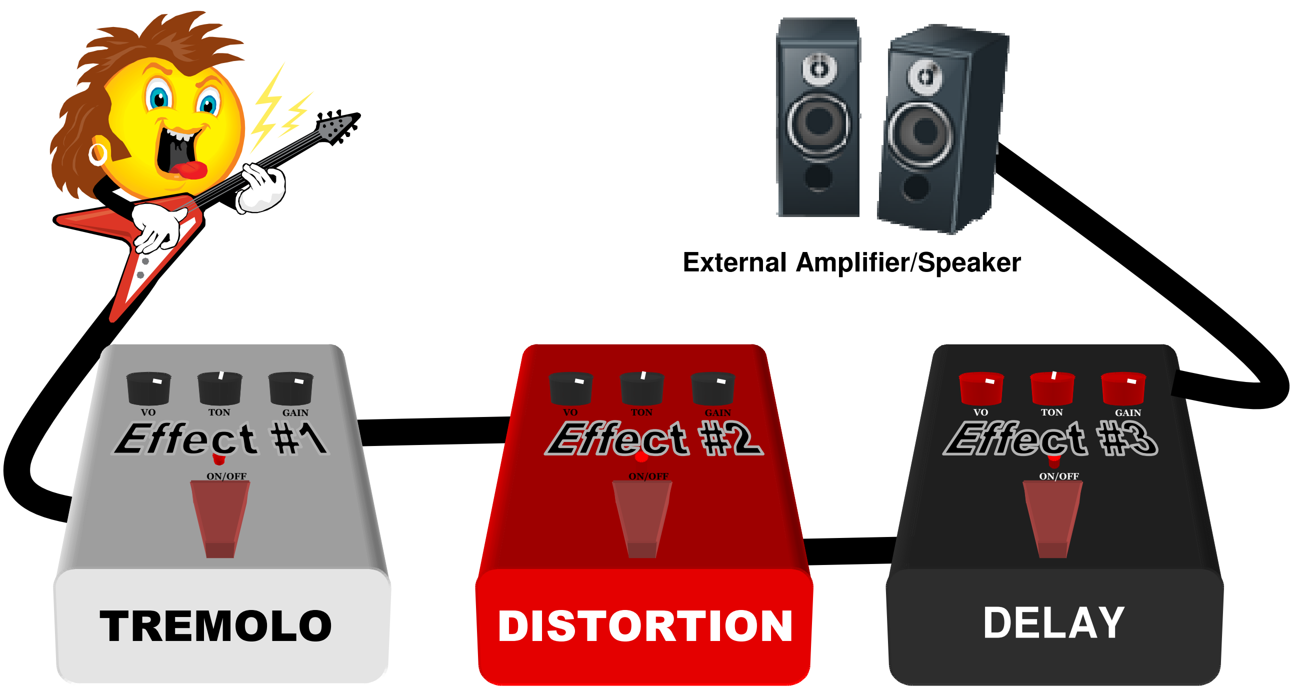

Figure 1: Diagram of Guitar-FX Processing

For the case of all three effects in use, tremolo is first applied to the guitar's clean signal, followed by distortion applied to tremolo's output, followed by delay applied to the resultant signal of the previous two pedals. The final signal is then amplified and heard over speaker.

In Tune's first prototype is proposed to contain three effects designed by the team. Control over each effect's sound can be further tuned by the user. As mentioned, the user will have simple control over the electronic "chaining" of these effects. Beyond the chaining/sequencing aspect, we are interested in including a pre-amp and signal equalization stage for the user (a fourth effect which controls bass, mid-range and high frequency ranges). As well, several hidden controls are proposed to be included in order to improve system performance. For example, hum and noise are frustrating audio problems experienced by electric guitarists; noise gating and hum removal will be implemented to produce a clearer sound.

A high level overview is shown in Figure 2:

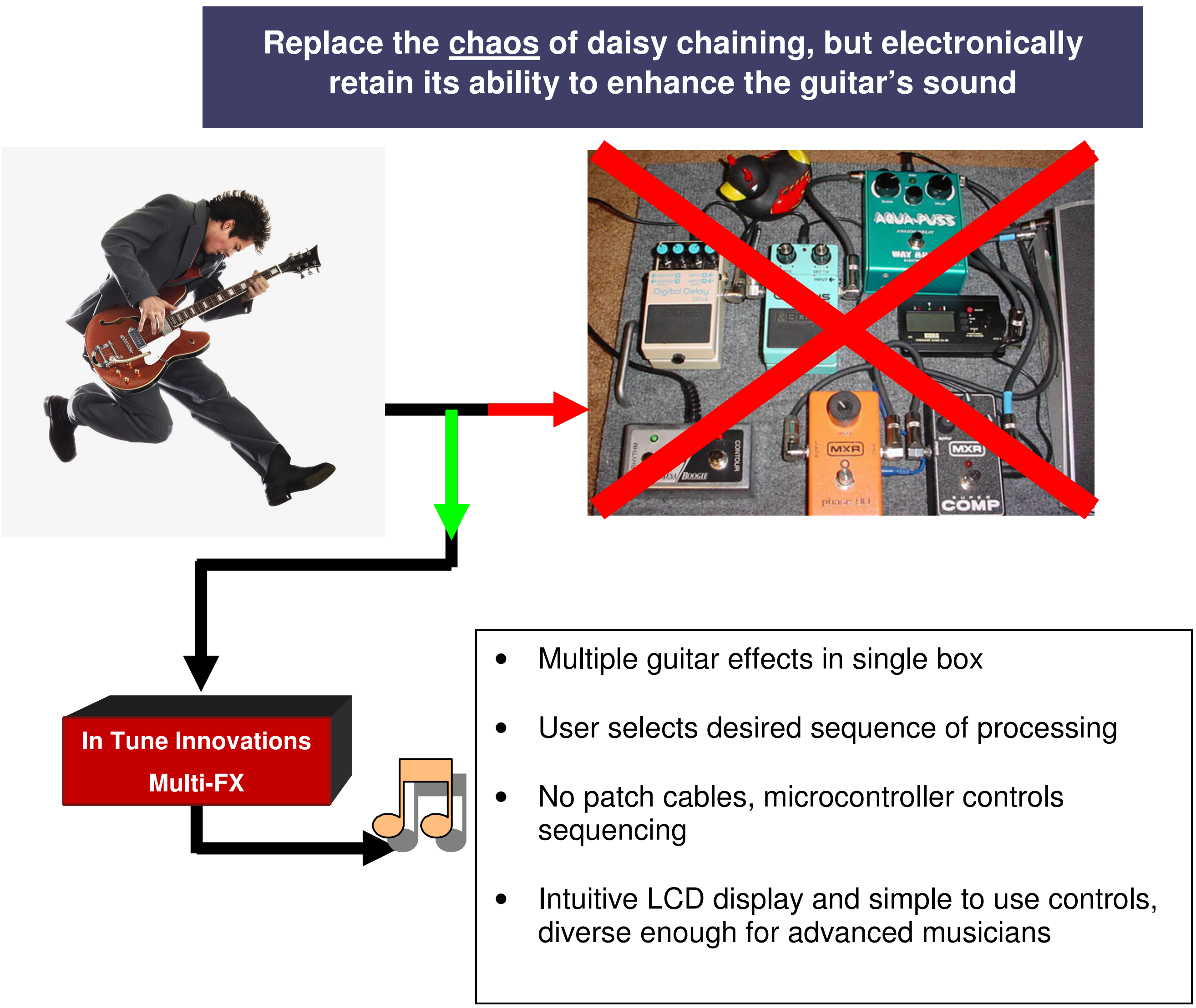

Figure 2: High Level Overview of In Tune's Multi-Effect Device

3 Possible Design Solutions

Some type of sequencing is required for routing the guitar signal between each guitar effect. Several options are possible for implementing this function; however, they are not equally practical. Options include use of mechanical switches, electronic relays, BJT/FET switching, or digital control. In our opinion, digital control (logic circuitry + microcontroller) is the only practical method, because a software environment allows for better control the system behaviour (especially when controlled in conjunction with the user interface).

For the individual guitar effects, there is debate in the music industry as to whether analogue or digital implementation is preferred. To musicians, the sound produced is what matters most. After consulting with musicians and a local guitar instructor, as well as after reading product reviews of various guitar effect pedals, our conclusion is that in analogue effects are aurally superior to digital effects. Musicians will commonly refer to the “muddiness” of digital effect pedals. This is a result of the limitations of RAM capacity and sampling rate - neither of which are issues analogue design. In our experience, even 192 kHz sampling is not enough to satisfactorily represent the authentic sound of electric guitar. There is a trade off, however: The implementation of analogue effect circuits is generally much more complex and time consuming than its digital counterpart. This is not enough reason, in our opinion, to move away from analogue effect circuitry. With a product such as ours, inferior sound quality means an inferior product.

3.1 Effect Sequencing / Microcontroller

A PIC microcontroller will control the user interface and effect path routing. It is also responsible for controlling the LCD, which is intended as the main user interface. To improve usability, a set of 7-segment displays (also controlled by the PIC) is proposed to be included to display the current effect sequence selected by the user.

3.2 Guitar Effects and Other Circuitry

Each effect circuit can be implemented as an independent block which will then integrate with the routing control system. We propose designing three effects for our first prototype; the exact effects we implement are tentatively set at some sort of delay, distortion, tremolo (and possibly compression). It is important to note that these are only “umbrella” terms. That is, there is no definitive sound in existence for each effect – it is up to the interpretation of each manufacturer and musician. Much time will be allotted for design the effects. Relatively “simple” effects typically contain 60 circuit components at minimum.

The task of designing and debugging effects circuits is very involved because what constitutes the "ideal" sound can be subjective. This is why implementing specific user control over each effect is important; the user will have the ability to fine tune the sound behaviour of each effect. We will also be consulting several musicians to ensure high quality results.

In addition to the three effects planned for sequencing, a pre-amp stage is proposed to be included in order to first amplify the guitar signal to line-level (allowing for better signal conditioning/processing). A signal equalizer is also proposed; this function gives the user control over a variety of filters which can boost or attenuate the signal volume according to frequency range.

3.3 Summary of Proposed Solution

- **PIC Microcontroller controls:**
    - LCD screen and pushbutton interface
    - Changing the routing of guitar signal through each effect
    - 7-segment LED displays indicating current effect sequence
    - Allowing for cases where not all effects are needed to be turned on
    - User programmable set of effect sequences for live performance

- **Guitar Effects:**
    - 3 effects, each turned on/off by footswitches
    - Independent user control allowing for fine-tuning of each effect's sound
    - Pre-amp stage is included to boost signal to line level / allows for cleaning signal processing
    - Equalizer is included to give user extra control over sound in various frequency bands
    - Noise gate / Power supply Hum removal circuitry as needed
    - True bypass control to avoid unnecessary signal degradation when effects are turned off

4 Information Sources

Electric guitars have a cult like following. As such, there is a wide range of information online on web pages and forum discussions.

It is important to be in contact with musicians to provide us with feedback on our design throughout the project. They can also help us to maximize the product's usability as well as to identify important features to include. We are in regular contact with two electric guitarists; their collective experience includes working in retail sales of multi-effect pedals similar to ours as well as instruction of electric guitar and piano.

For system integration and circuit design issues, the faculty of SFU Engineering is an excellent resource. Members of our team have made contacts with past professors, and any insight they can provide will no doubt be of invaluable assistance. Mike Sjoerdsma has been approached in the past for technical and project documentation writing assistance, and has indicated the willingness to assist on our current project as well.

5 Budget and Funding

5.1 Budget

Table 1 below outlines our tentative budget for the Multi-Effect Device. The preliminary planning has already been done and the needed microcontroller peripherals are listed below. The miscellaneous costs below include any duty and shipping costs that may be needed.

Table 1: Anticipated Budget for Multi-Effect Device

Name	Quantity	Unit Cost	Total Cost
PIC Ready Board	2	$31.00	$62.00
Picflash2 Programmer	1	$115.00	$115.00
7 Segment Display	1	$29.00	$29.00
Keypad 4x4	2	$12.00	$24.00
16x2 LCD	2	$10.00	$20.00
LCD adapter	2	$8.00	$16.00
Potentiometer	6	$3.68	$22.08
Digital Potentiometer	5	$2.33	$11.65
Analog Multiplexor	6	$5.50	$33.00
Stomp Switch	2	$10.00	$20.00
Effect components (Analogue)	1	$50.00	$50.00
Vector board	1	$40.00	$40.00
Power supply	2	$10.00	$20.00
Casing, knobs, connectors	1	$60.00	$60.00
Miscellaneous costs	1	$150.00	$150.00

Total Cost	USD	CAD
	672.73	**840.91**

5.2 Funding

As is expected the initial costs required for development are much higher than its expected product costs. To help cover these prototyping costs we have applied to the Engineering Science Student Endowment Fund (ESSEF). The rest of the funding will be provided by our team members.

6 Project Timeline

13 weeks is a very quick time frame to design and construct a prototype a multi-effect device. The modular aspect of our design assists in meeting the time constraint as many components can be worked on and tested in parallel. As such, we feel that the timelines allocated, as seen in the Figure 3 Gantt chart, are achievable.

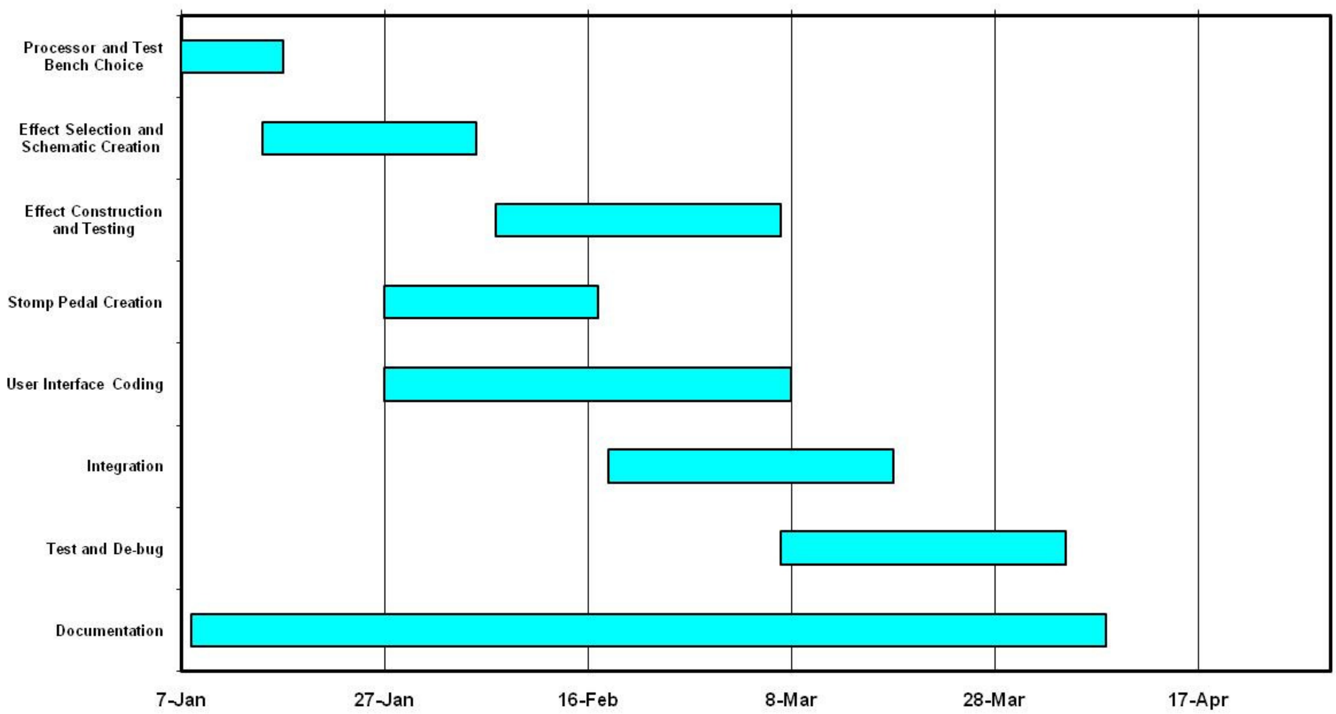

Figure 3: Gantt Chart Showing Anticipated Development and Production Dates

Figure 4 documents the timeline for the anticipated completion dates for the major steps. The dates are evenly spread out through the 13 weeks with at least 2 weeks between the completion dates, so it is anticipated that there will be no problems in achieving these deadlines.

Timeline of Deadlines and Due Dates

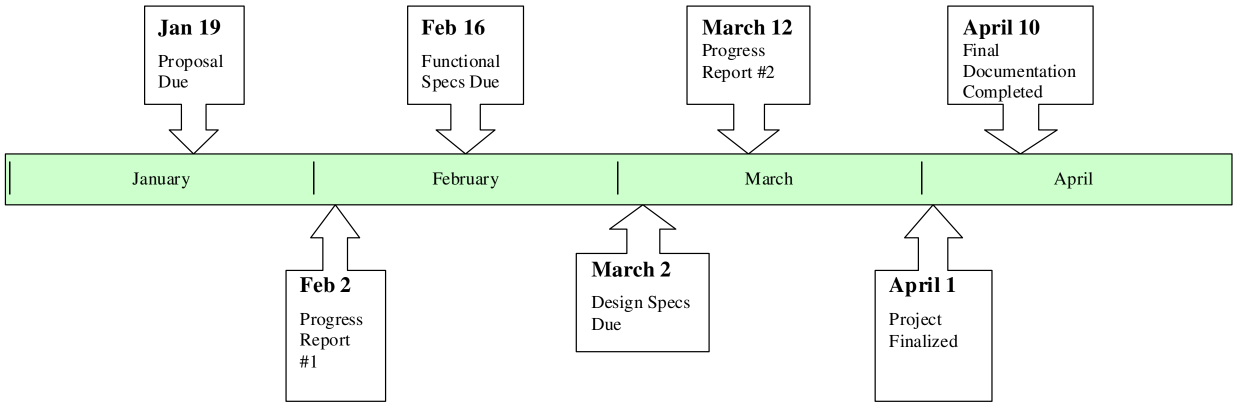

Figure 4: Timeline For Major Deadlines and Due Dates

7 Team Organization

Michael Vogel – Chief Executive Officer (CEO)

I am a fourth-year Systems Engineering student at Simon Fraser University. I have two previous co-op experiences in both software and hardware, respectively. During my most recent work term I designed a motorized lens controller system to be embedded into gigabit Ethernet cameras. From this experience, I learned about the process of using digital circuitry to control an analogue system (in this case, using a set of motors to control lens focus, iris and zoom). I am also an avid musician, proficient in guitar, piano and drums.

Kyle Balston – Chief Financial Officer (CFO)

I am a fourth-year Computer Engineering student at Simon Fraser University. To date I have completed three co-op terms involving both computer software and hardware. I have also taken courses involving real time operating systems, microcontrollers and FPGAs. I believe this experience will translate well to the digital design of our product. I also have good communication and teamwork skills.

Thomas Schultz – Vice President of Research and Development (VP R&D)

I am a fourth-year Systems Engineering student at Simon Fraser University having completed two co-op work terms at OMNEX Control Systems. I have skills and experience in both hardware and software development stemming from both my co-op work terms and the courses I have taken while attending SFU. Specifically, from my work term experiences, I specialize in hardware prototyping and testing as well as hardware and software interfacing. I also have experience in signal processing.

Scott Witzel – Vice President of Operations (VP Operations)

I am a fourth-year Systems Engineering student at Simon Fraser University. My previous co-op terms have involved prototyping, testing and optimizing pre-production products. From this experience I gained great insight into prototype development. Additionally, I have become comfortable with working under strict timelines. The strengths and skills that I bring to this team is the ability to remain on schedule with production goals as well as understanding the steps required for commercialization.

8 Conclusion

With the ever increasing complexity of today's technology the necessity for a flexible easy to use system is only increasing. In Tune Innovations is dedicated to bringing such systems to the music industry.

Manually switching the daisy chain is a hassle (and nearly impossible in a live performance environment). Many guitarists shy away from multi-effect units because the sequencing of effects is fixed without user control. Whether it is a single effect or multiple effects, musicians want exclusive control over the sound they are creating. With In Tune's product, musicians will now have the ability to change the effect sequence mid-song, enhancing the ability to create even more personalized sounds in a live environment.

By following the Gannt and milestone charts in the project timeline section and the costs associated with the project, In Tune has demonstrated that the multi effect guitar device can be completed on time and within the budget.

9 References

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Figure 2 (Left): Lizzy Daymont. *Seattle Area Bassist*
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