Raspberry Pi Based Glove for Gaming with Haptic Feedback Functionality

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***Abstract*—**The continuous changes in computing technologies necessitates creating new means for interacting with digital devices. These methods leverage one or more human senses to enable users to control interfaces. This paper explores the idea of using the sense of touch for human-computer interaction by means of vibrations in the context of gaming. We present a plug-in glove for Raspberry Pi that provides haptic feedback depending on an in-game event. The glove is portable and does not need external power supply for operation. Eight coin-type vibrational motors are employed along for producing the required effect. The General Purpose Input Output pins of Raspberry Pi are used to trigger the vibrations. Four voltage to current converters using dual operational amplifier IC LM358 are used to increase the current supply given to motors. The strength of these vibrations varies in accordance with the game's state at that time by using pulse width modulation.

***Keywords*—**Haptic feedback, gaming glove, vibrational motors, gaming accessory, operational amplifier applications,

I. INTRODUCTION

Gaming industry today is worth a 100 billion in U.S. dollars. This growth began in the 1970s with games like Pong and Space invaders were sold. Although approximately 20,000 arcade units were sold, its popularity increased and by the 1980s, almost 20 times the arcade gaming units were sold, earning Taito, revenues in billions. This led to an increase in the number of major competitors in gaming industry where companies like Namco, Bandai and Nintendo started coming up with their own versions of arcade games and this led to the boom of arcade gaming centers across countries like United States and Japan.

An alternative approach taken by some of these corporations was to develop gaming devices that can be plugged in to televisions in homes, thus eliminating the need of going to arcade gaming centers. Though this was initiated by Sanders associates, releasing their first home gaming console, it was Nintendo's entertainment system released in the mid-1980s that really attracted people's attention towards these tv plug in gaming systems. The gaming industry became more competitive with other famous corporations came into the picture. Sony came up with the first version of the play station series, The PlayStation in the mid-1990s which was an instant hit. Owing to its success, it released the Playstaion 2 which is the console that has sold the highest units to date, around 155 million units. Parallelly, Microsoft also joined the industry coming out with its X box series, its first model, the Xbox1 releasing in 2001. These gaming consoles made the switch in its gaming cartridges. The initial gaming consoles had their games installed on a fabricated semiconductor chip, enclosed in a ceramic plastic outer coating for protection, something that Nintendo incorporates into its consideration while designing their gaming platforms up to date. Video game developers started to install their games on compact discs and selling them and this approach was taken up by other gaming platform developers. One significant advantage that it provided is the increase in storage capacity and as a result, the same gaming program could be made to perform other functions. One of the unique functionalities included by Sony and Microsoft in the controllers of their gaming consoles was the haptic feedback in the controllers. Since the palm was to be placed at a fixed position in the controllers, vibrational motors were attached at strategic places to create the vibrations required, pertaining to an event occurring in the game. Although there was only one strong vibrational element, the concept can be to multiple technological gadgets today. Haptic feedback is something that is found in all modern-day consumer gadgets. The version that gives a feedback after every letter while typing on Qwerty keypad is common. The future of gaming is focused on how to give a more realistic gaming experience. While improvements in the software itself will definitely have the necessary effect, we can also create the same effect with accessories to be worn while gaming. While it is difficult to integrate such accessories with gaming consoles already well established, games will be developed to run on new platforms like raspberry pi, which are open source and more affordable. There are various concepts of other gaming accessories like a visualization helmet which creates the necessary simulation environment for the game. They create a realistic environment and provide a more real gaming experience by sound and visual effects. There are other technological inventions like virtual reality which are also booming with its increase in demand. The uniqueness in the idea is what attracts heavy investments and soon, these gaming accessories won't be used as an optional and an additional plug-in component but play an integral part of a gaming console.

II. SYSTEM MODEL

The basic functionality of the glove is to give an output corresponding to the events in the game. The game will run on raspberry pi and based on the different events in the game, vibrations will occur in different parts of the glove. As the Raspberry Pi is in use, and is a must to operate a game, the glove designed should be such that the its power supply requirement and General Purpose Input Output (GPIO) pins occupancy is satisfied. Only then can it be made a portable gaming accessory. The output of the project, is to be given by vibrational motors in the form of vibrations. For this we need to give the supply to the vibrational motors from the Raspberry Pi. The best way to

do this is by assigning each and every vibrational motor, its own respective one or more GPIO pin. For this project, we have to assign two GPIO pins for each and every vibrational motor. The purpose of this to have a sufficiently large range of vibration. The supply from the GPIO pins cannot be given directly to the vibrational motors. This is because the supply if undergone some variation in its constituents but overall producing the same power will have a larger impact on the effect that it creates. Having the same supply but with a smaller voltage and a larger current increases the strength of vibration to nearly twice that of a supply without any modification.

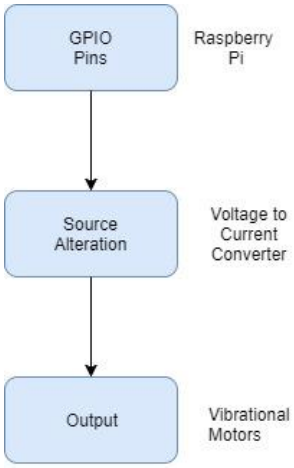

Fig 1: System Model

The modified supply is acquired by the vibrational motors which vibrate on excitation. The vibration of the motors stays constant beyond a certain range and the altered supply successfully achieves the maximum strength of vibration.

III. WORKING

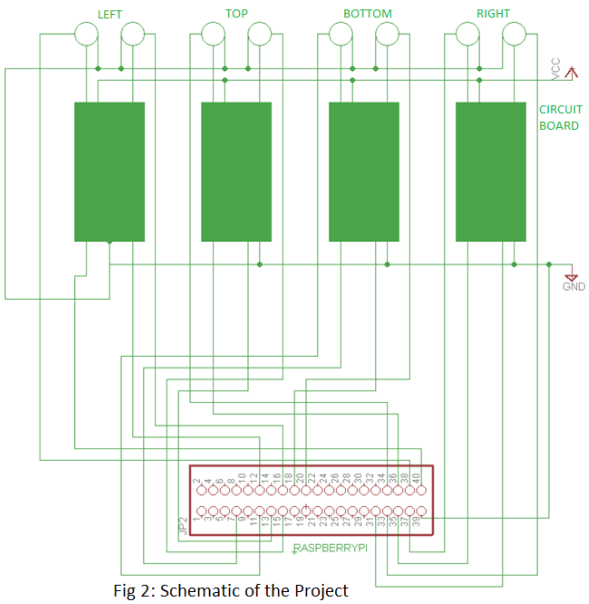

Fig 2: Schematic of the Project

The schematic of the project gives us an idea of the different components used in the system.

3.1) The Raspberry Pi

The Raspberry Pi 3 has 40 GPIO pins, since we have decided to use 2 GPIO pins of raspberry pi for each vibrational motor, we will need 16 GPIO pins of raspberry pi in total. This matches the requirement as even the first version of raspberry pi, The raspberry pi 1 has 17 GPIO pins while in Raspberry pi 3, there are 26 GPIO pins out of 40 Pins provided. The rest are used for the purpose of power supply. It is better to mark the two pins separately or to hold the two pins, being given to a single circuit board together with a tape as it could get confusing because of the large number of wires used.

It is important to deal with the issue of power supply for the entire project. As seen in fig 2 one common ground for the entire circuit has been selected and for simplification purpose, Pin 39 of the GPIO pins of raspberry pi has been selected as the central Ground of the Raspberry pi as it is located the corner. The grounding network needs to be systematic as we need to have a ground for all 4 circuit boards and all 8 the vibrational motors. We can solder male to female servo connectors on the circuit board for making all the ground connections. All the ground connections from different components can be brought here and one connection can be given to pin 39 of Raspberry pi. Checking must be carefully done as there is a possibility of malfunction in the case of a single loose connection.

For power supply to the circuit boards, two 5 voltage power supply output pins of the raspberry pi can be used. Since we need to give a positive power supply to all the Integrated Circuits(ICs), we can split the two power supplies into 4 circuit boards where the same pin gives supply to two ICs. Since a single 5 voltage pin gives a very high current supply, one pins can be simultaneously be given to 4 ICs but for the safer side, the 2 pins that are available are used. The output of the 4 ICs is capped by the power supply. The IC that we have used is LM358 which can be given a supply voltage between 3.3 and 32. 5 volts matches the requirement and hence we make use of the 5 voltage supply pins of the Raspberry pi over the 3.3 voltage one to be on the safer side. Another reason for using the 5-volt pin over the 3.3-volt pins is because of the higher current capacity of the supply of 5-volt pin over 3.3-volt pin.

3.2) Circuit Board

The circuit board is the next part of the project. It is represented in Fig.2 by a green box as there are many components in it. The basic functionality of this unit is to increase the current supply given to the vibrational motors.

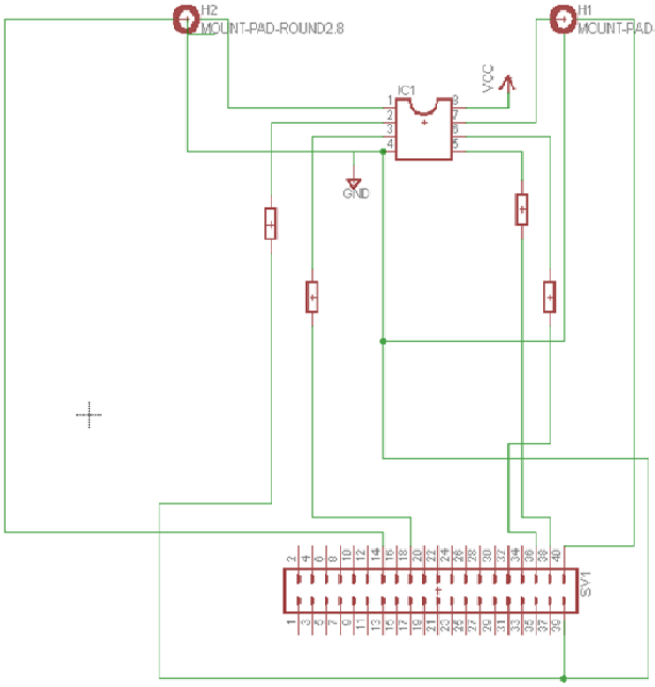

Fig 3: Schematic of circuit board

The implemented circuit uses LM358, a dual operational amplifier IC. The current to voltage conversion to be done can be done in various ways but the simplest, most efficient and easily implementable way is to do it is using an operational amplifier. Since we have 8 vibrational motors and we need only one of the two inputs to the vibrational motors as the one that is varied in proportion to the incremental changes in voltage, we need to implement 8 voltage to current converters. If we use single operational amplifier ICs like IC 741, then we would need 8 circuit boards. No amount of compacting can fit it into a glove and this will make the glove heavy and not portable which does not help our purpose. Instead a dual OpAmp IC like IC LM358 is used which has two operational amplifiers, integrated in a single 8 pin IC, we can minimize the number of circuit boards from 8 to 4 which on compactization, can be integrated in the glove itself. Of the 8 pins, two are for power supply, which are given from the GPIO pins of Arduino. The remaining 6 pins are for two operational amplifiers, 3 for each. Two of these are inputs and the third on is the output which is given to the vibrational motor. Operational amplifier does the job of comparing its two inputs and producing an output proportional to the difference between the two inputs. As we need maximum difference between the two inputs, one of the inputs is given to the ground and is hence at 0V. the comparison of other input with this would provide maximum amplification.

Fig3 represents the schematic of only one circuit board connection with its input from raspberry pi and its corresponding output being given to its respective vibrational motors. The grounding connections have to be made properly as without it, the whole circuit will malfunction. One circuit board has 5 grounding connections to be made. There are 20 grounding connections to be made in total and hence multiple wire connections required will make it confusing. Male to female servo connectors soldered on each and every circuit board can simplify these connections to make it easier to understand. The resistors of the right value, 1 Ohm and 5 Ohm resistors are needed to be used in the appropriate places. Reversing the place of usage of these resistors will give a very low proportional output current with respect to voltage.

3.3) Vibrational Motors

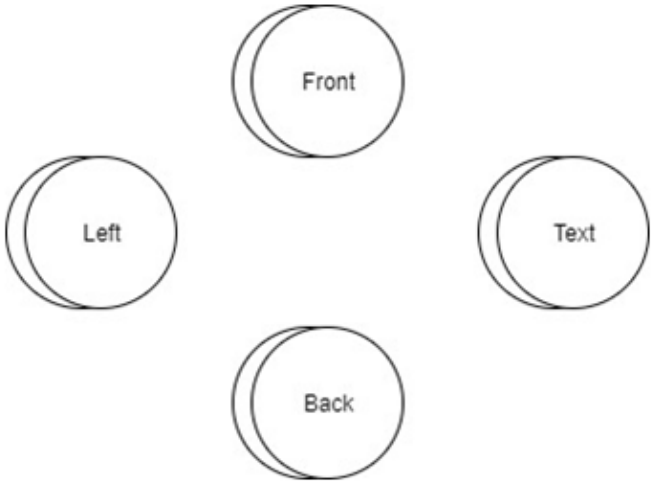

Fig 4: Arrangement of 8 vibrational motors

The vibrational motors are the components that produce vibration, providing stimuli to the user on excitation. Their strength of vibration increases with increase in input supply. Out of the various types of vibrational motors, the most suitable one for this project are the disc types which are flat disc types vibrational motors. Since their surface area is larger compared to other type of motors like the 'pager' or 'enclosed type' it can give vibrations to a larger area compared to others. This project incorporates 8 vibrational motors. There are 4 pair in total, each pair used to indicate a direction or a part of body to be given stimuli depending on the event in the game. As we have used output of two GPIO pins for each and every motor, these two outputs have to be combined into a single connection as each and every vibrational motor has one wire provided for input and the other one for ground. Out of the two inputs, one is to be directly given from the raspberry pi itself and the other one is to be indirectly given through voltage to current converter. The vibrational motors are stitched onto the glove for this project which serves as a prototype of its kind. Depending on the way the controller is to be held, the vibrational motors can be positioned to give directional notification of the different events occurring in the game.

The vibrational motors are used in pairs. If the user has to be notified in the any particular part of the glove, vibrations provided will be stronger if they are provided from both sides of the palm, the front and back. Taking example of a simple game like Space Invaders, if the spaceships that is being operated by the user gets hit in the front, then the vibration

produced will be done by the two motors attached in the front of the glove simultaneously. Similar operation will take place for the vibrational motors attached on the opposite sides of the glove which lie most further behind. As for the vibrational motors that are to indicate some changes in the left and right of the vehicle being steered in the game, it can be attached on the opposite side of the glove, at the front or back if the controller is a stick to be handled like the controller of Wii, or the two vibrational motors could be attached on the same side off the glove while handling a controller of PlayStation or an Xbox. In the latter, it won't make sense to attach both the vibrational motors on the opposite side of the glove as the glove is held in a lateral position, unlike the vertical position of the glove while holding a vertical object like the remote controller of Wii.

IV. METHODOLOGIES

The intermediate part of the project involves a voltage to current converter for getting an output whose current is proportional to input voltage. But even without doing so, the glove will be functional. There is a specific reason for using this technique and it involves the graph of vibrational strength versus supply current. The graph in figure 5 shows us the relation between the vibrational strength and the supply current of the motors. It can be seen that the vibrational strength has a linear relation with the supply current up to 120mA but after that, incremental change in supply current causes little change in increase in vibrational strength and it reaches saturation. The part that is important for this project is the linear incremental change obtained up to 120mA of current. One GPIO pin provides 3.3Volts and 40mA of current as supply.

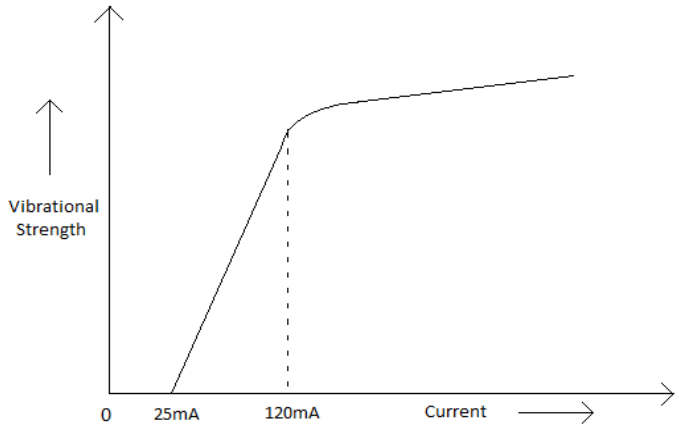

Fig 5: Graph of vibrational strength vs supply current

Two of them will give a total supply of 6.6Volts and 80mA. It is known that a motor is more sensitive to incremental change in current over voltage. Providing 6.6 V of voltage and the 80mA of current with won't produce a high strength of vibration. A technique by which the voltage becomes half of its previous value and the current becoming double of its original value will yield the same power overall.

$$P = V * I \qquad P = \left(\frac{V}{2}\right) * (2 * I) = V * I$$

The advantage with this technique is that by this technique, the current obtained is 80mA and if we combine it with the output current of other GPIO pin(40mA) for a single motor, it becomes 120 mA. Because of this, we are able to achieve maximum strength in vibration possible. The concept of converting voltage to current can be done using various possible ways. Transistors and MOSFETS can be operated in linear region to increase the supply and power supply management is also feasible. However, this method will not produce significant increase in current and will not produce more than 55mA of current even at the highest input level. Conventional motor drivers can be employed. They contain the Darlington pair which have the property of current multiplication. Using such ICs like IC ULN2003 will achieve increase in current to sufficient levels for maximum vibrational strength. However, these ICs require a large supply voltage, somewhere between 12 to 24 volts. Providing the power supply for this would be an issue as an external power source will be required. The raspberry Pi cannot provide more than 5 V of power supply at a time. Also, this would not make the glove portable which dissolves the whole purpose of the project. Hence, we require something which can convert voltage to convert smoothly, give a linear operation and do all this with supply provided from the supply GPIO pins of Raspberry Pi. The ideal match would be a voltage to current converter using an operational amplifier. Operational amplifiers have low power requirements and a very high voltage and current gain. Additionally, dual operational amplifier packages are available and since they are 8 pin ICs, 2 or more can be fitted on a single printed or soldering board. Therefore, voltage to current converter using operational amplifier is the best and the most feasible solution to this problem.

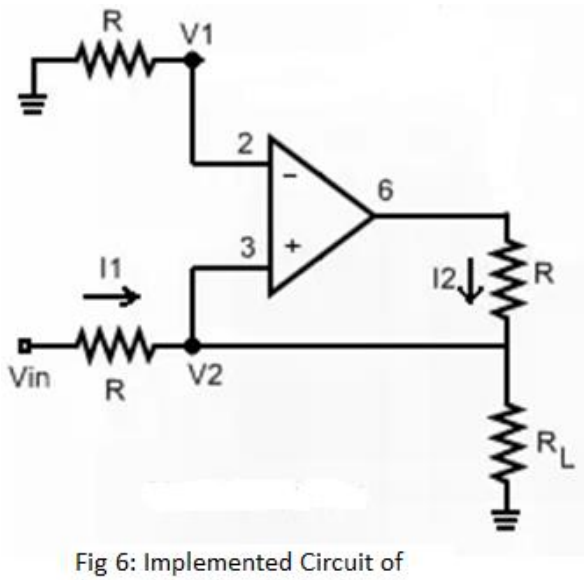

Fig 6: Implemented Circuit of Voltage to Current converter

Another tool of Raspberry pi that is being utilized is the Pulse Width Modulation to give a more realistic gaming experience. The events that take place in a game that trigger the vibration of the vibrational motors can occur consecutively. Considering the example of Space Invaders. The space ship that is being controlled may get hit by obstacles multiple times consecutively. Providing the same vibrational strength would just be felt like a vibrational feedback for an extended period of time. In the event of such a case, the vibrational strength would need to gradually increase in accordance with the event to make sure that the operator realizes the seriousness of the situation. This can be done by varying the output of one of the pins gradually between its lowest value and the highest value. In this way, by using two pins directly to trigger the vibrational motors, we can obtain two 3 different levels of output. But when we use Pulse Width Modulation, we can vary the level of one of the output pins anywhere between its range and thus we can set any possible number of possible output levels. For this project, we have set 4 levels of output using PWM. Although this number can be increased, if the difference between the different vibrational strength of the motor corresponding to the different supply voltages cannot be perceived, then having more levels of output will not be desirable. Thus, the number of output level of vibration, such that the difference between the successive levels can be perceived properly is 4. The vibrational strengths of the intermediate levels between the minimum and maximum vibrational strength can be set according to our needs.

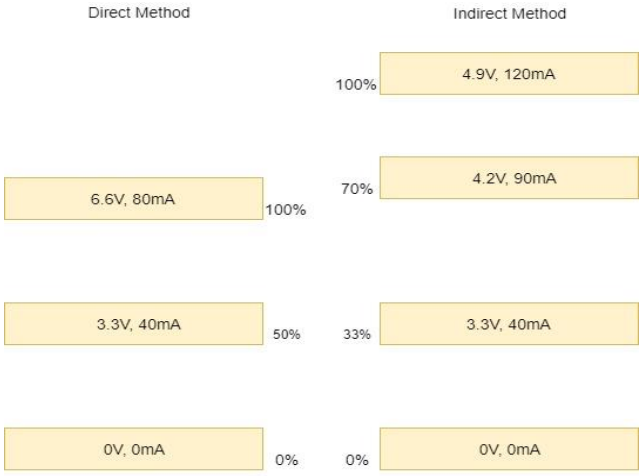

Fig 7: Comparison of direct method vs indirect method

As it can be seen in the above figure, the two different levels with their output level can be compared side to side. It can be easily observed that the technique using PWM not only provides a higher range of output but also provides the freedom to choose output in any range corresponding to the supply of 40 to 80mA. The 2nd method provides two outputs in the intermediate range whose levels can be adjusted and the total range is only restricted by power supply. By this way, the maximum output that can be exhibited does provide maximum vibrational strength. A combination of Pulse Width Modulation and usage of voltage to current converter is the key in bringing out the full capabilities of the project and in maximizing its efficiency.

V. RESULTS

The length of the wires selected for different purpose must match the required specifications as seen in fig 7, the wires from the output of circuit board to vibrational motors are many in number and these might get tangled among themselves. The wires of similar functioning motors must be grouped together in case of troubleshooting as it will be difficult to identify the exact wire facing issues.

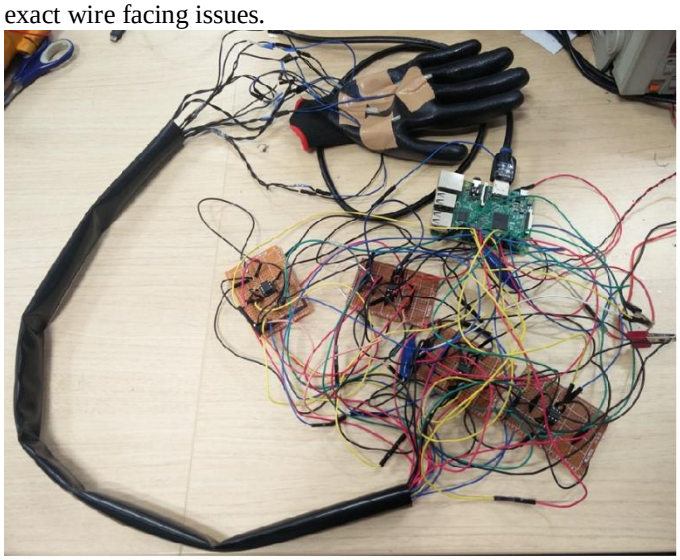

Fig 8: Image of the completed project

The wires that are connected to the vibrational motors directly from the GPIO pins of Raspberry pi are also very long in length and they must be grouped together with the wires that are taken indirectly from circuit board. All of these wires are to be passed through a polystyrene tube as there needs to be a sufficient distance between the glove and the circuit board. Polystyrene tube also contains the two dozen wires in a container and keeps them intact.

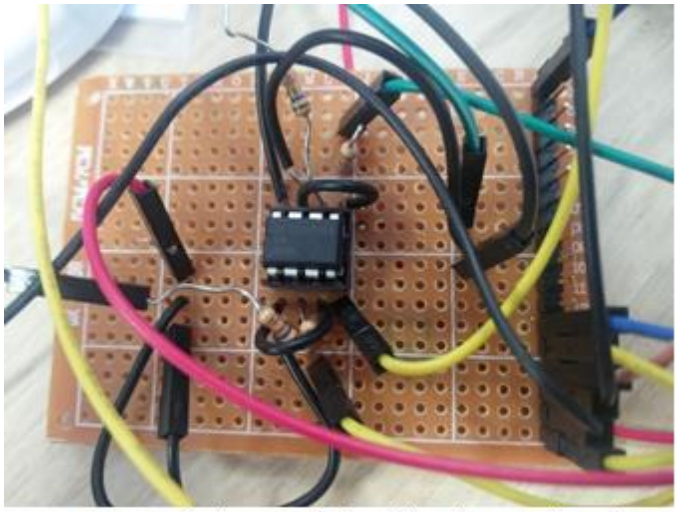

Fig 9: magnified image of the soldered circuit board

The soldered circuit board has many connections and it is better to do individually solder them one by one using Male to Male connector pins. The orientation of all the ICs must be similar so that the ground and supply voltage pins are not put in the wrong positions. The size of the circuit board selected for soldering must be large enough to comfortably accommodate all the connections and fit the path but also no be too large to occupy too much space. Making the glove portable and light weight is also an important objective.

The strength of vibrations was successfully obtained to be varying with the input and after comparing vibrational strength for supply of different currents, the motors vibrated with maximum strength at a supply of 120mA. There was also an issue regarding static charges being stored in the vibrational motors. These were being stored in the capacitor and in some cases, it was giving problem by not providing the vibration on receiving command. These were being discharged on mechanical excitation and this is an issue that can be solved with further research.

VI. CONCLUSION

The program for demonstration of the operation of vibrational motors written in python was successfully demonstrated. All the vibrational motors could successfully vibrate at different strengths and it was shown to be increasing gradually. This was a proof of how pulse width modulation could be simultaneously used on all the 8 vibrational motors by dividing the operational time of the concurrently operating motors by total number of motors operating in the same time period. The glove was designed to be fully fit to operate for any game that can be played on raspberry pi and its working and efficiency is dependent on the programming of the game in accordance with the different events in the game that cause the vibrations to trigger. Its essence can only be truly felt in case of cascading events that trigger multiple vibrations whose strength gradually increases with time. The implementation of voltage to current converter for supply escalation did eliminate the use of external power source. Enclosing the wires in polystyrene tubes could solve the issue of multiple wire tangling with other components of the project and the above two factors successfully made the project portable. The vibrations of the motors at maximum input supply did create a numbing effect in some areas of the palms and the objective of providing a more real gaming experience was successfully achieved.

VII. FUTURE SCOPES

The project is basically a glove that is made to be operated for gaming purpose, and only for the games on raspberry pi. The concept can be expanded to other platforms or mini computers. The glove doesn't necessarily need to be operated on platforms that can run games on them. They can be operated by other hardware development boards that control the vibrational motors according to the instructions received from the game. These development boards basically serve as an intermediate device that receive instructions from the main software of the game and act in response to the instructions. The vibrational motors that are used are operated in pairs. Similar command is given to another vibrational motor and both act in concurrence to give a larger effect. However, if the same effect can be brought about by a single motor then 8 motors can be used to give stimulation to different areas. Also, if the number of vibrational motors can be increased, the precision and the efficiency with which the haptic feedback is given will increase significantly.

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