

Group Project

by Jade Williams

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Wireless Inductor Coil Charger With Controller For Gaming

By

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Abstract

The growing popularity of wireless gaming controllers has exposed the limitations of traditional wired charging systems, which can cause cable clutter, wear on charging ports, and inconvenience for users. This project presents the development of a wireless inductive charging system designed specifically for gaming controllers, offering a solution that complements the wireless nature of modern devices. Using electromagnetic induction, the system transfers power between a transmitter coil in a charging dock and a receiver coil within the controller, removing the need for physical connectors.

Extensive research into both conventional and resonant inductive charging technologies highlighted key advantages, including improved durability, user convenience, and cleaner aesthetics. Several receiver coils were designed and tested to optimise output voltage and integration within the compact confines of a controller. Of the coils tested, a 24-turn coil produced the most suitable output—3V from a 15V input—remaining below the 4.2V battery charging limit and providing consistent performance. Thermal issues with the switching transistor were resolved through the application of a heatsink, ensuring safe operation.

Materials for housing the circuit were evaluated, with ABS chosen for its heat resistance and impact strength, while PLA was used during the prototyping phase due to its affordability and ease of printing. The system was tested for efficiency, electromagnetic field (EMF) safety, and ease of use, demonstrating both reliable performance and user-friendly operation.

This project validates the potential of wireless inductive charging as a practical, efficient alternative to conventional wired methods. It enhances the user experience while contributing to improved device longevity and reduced mechanical wear. With further refinement, including optimised coil design and user trials, this system could set a new benchmark for charging technologies in the gaming industry.

Introduction

In the ever-evolving world of gaming technology, wireless gaming controllers have rapidly gained popularity, revolutionizing the way players interact with their favourite games. These controllers offer unparalleled convenience, mobility, and ergonomic designs that enhance the overall gaming experience. As gaming becomes increasingly immersive, players are constantly seeking solutions that elevate comfort and performance. One such area that has garnered attention is the charging system for gaming controllers. Traditionally, controllers rely on wired connections for charging, a method that, while functional, has inherent drawbacks. These traditional charging solutions often come with issues like tangled cables, wear and tear on

cables, and stress on the controller's charging ports. As gaming systems become more advanced, players are also demanding more efficient, reliable, and user-friendly charging methods that align with the wireless nature of modern gaming devices.

The need for a more seamless, hassle-free charging experience has prompted innovation in the field of wireless charging technology. Wireless charging, which eliminates the need for physical connectors, presents an opportunity to resolve many of the challenges faced by gamers. The introduction of a wireless inductive charging system for gaming controllers is a proposed solution that aims to deliver a charging experience that matches the freedom and flexibility offered by wireless controllers themselves. This system would utilize inductive charging technology, which allows for power transfer through electromagnetic induction between a charging pad and a controller. By using this method, players can simply place their controller on a charging surface, and it will begin charging automatically, without the need to plug in any cables.

One of the primary advantages of this wireless charging approach is the elimination of the physical connectors that are typically used in wired charging systems. This removes the common problem of wear and tear on both the charging cables and the controller's charging port, which can degrade over time due to frequent plugging and unplugging. In addition, with no physical connectors involved, the risk of damaging the controller or the charging port is minimized, ensuring the long-term durability and reliability of the device. Another significant benefit is the convenience of not having to fumble with cables. With traditional wired chargers, users often have to locate and connect the correct cable, which can be frustrating, especially in dark or cluttered gaming environments. Wireless charging removes this inconvenience, offering a more intuitive and user-friendly experience.

This proposal outlines the goals, objectives, and methodology for developing a wireless inductive charging system specifically designed for gaming controllers. The project aims to create a solution that not only charges controllers more efficiently but also enhance the overall user experience. By implementing wireless charging technology, gamers will be able to simply place their controllers on a charging dock or pad, eliminating the need for any physical connection. This wireless system is expected to provide faster charging speeds compared to traditional wired solutions, and potentially even extend battery life by reducing wear and tear caused by repeated plugging in and unplugging.

The expected outcomes of this project are far-reaching. Not only will the development of a wireless charging system improve the user experience, but it will also contribute to the ongoing shift toward more streamlined, hassle-free technology in the gaming industry. As gaming hardware continues to evolve, integrating efficient and convenient charging systems will become increasingly important. The introduction of wireless inductive chargers for gaming

controllers could set a new standard for the industry, offering a future where charging is as effortless as the gaming itself. This proposal represents a forward-thinking solution designed to meet the growing demands of modern gamers worldwide.

Research and Literature Review

The gaming industry has experienced significant advancements over the past decade, particularly in wireless gaming controllers. These controllers offer enhanced mobility and convenience, allowing gamers to enjoy greater freedom of movement without being tethered by cables. However, despite the popularity of wireless controllers, the issue of charging remains a challenge. Current charging methods for gaming controllers primarily rely on a physical connection between the controller and the charging dock. While functional, this system introduces several drawbacks, including wear and tear on the connection points, potential damage to the controller's charging interface, and the inconvenience of having to manually align the charging ports. This review explores existing literature on wireless and inductive charging technologies, and how they could be applied to replace physical connections with inductive charging in gaming controllers.

Traditional gaming controllers, including those for platforms like PlayStation and Xbox, use a charging dock that requires a physical connection between the controller and the dock to charge the device. These docks typically feature a physical interface—such as metal contacts or pins—that connect to corresponding contacts in the controller's charging port. For example, Xbox controllers use a charging dock system with a battery pack, where metal connectors align with the charging dock's pins. PlayStation controllers, such as the DualShock 4 and DualSense, use similar docking systems with metal connectors to establish a power transfer.

While this physical connection method is effective, it has notable downsides. The repeated plugging and unplugging of controllers can lead to wear on both the charging pins and the controller's charging port. Over time, this wear can result in poor connections, slower charging, or even permanent damage to the controller's hardware. Furthermore, this system introduces clutter with cables and connectors, which detracts from the convenience that wireless controllers are meant to provide.

Inductive charging, or wireless charging, eliminates the need for physical connectors by transferring energy via electromagnetic induction. This method uses two coils: a transmitter coil in the charging pad and a receiver coil in the device. When the device is placed on the charging pad, the electromagnetic field created by the transmitter coil induces a current in the receiver coil, thus charging the device.

The most common standard for inductive charging is the Qi standard, developed by the Wireless Power Consortium (WPC). This system has been successfully integrated into consumer

electronics, including smartphones, tablets, and wireless earbuds. Inductive charging offers several key advantages: it removes the need for physical contact between the charging device and its charger, reduces wear on connectors, and enhances convenience for users.

However, as of now, inductive charging has not yet been widely implemented for gaming controllers. Existing charging solutions for controllers still rely on physical connections, with charging docks designed to interface with connectors on the controller. Despite inductive charging being successfully applied to many other industries, its adoption for gaming controllers remains.

The integration of inductive charging into gaming controllers offers a promising solution to the challenges of physical connection-based charging. If a receiver coil were embedded directly into the controller, it would be possible to use a charging dock that contains only a transmitter coil. This system would allow users to charge their controllers without having to plug them in or worry about aligning metal connectors. By replacing physical connectors with inductive charging coils, the overall user experience could be improved, offering more convenience, and reducing the risk of wear or damage to the controller.

Previous studies have highlighted the potential of inductive charging in consumer electronics. For example, S. M. Kwon et al. [1] discuss how wireless charging systems have been successfully used for mobile devices, offering several advantages such as increased durability, ease of use, and safety. This research indicates that the same benefits could be realized in gaming controllers by replacing physical connectors with inductive charging coils. In addition, the study emphasizes the ability of inductive charging to reduce wear on devices by eliminating the need for frequent plugging and unplugging.

Moreover, the introduction of resonant inductive coupling, a more advanced form of inductive charging, could address some of the limitations of conventional inductive charging systems. Traditional inductive charging systems require accurate alignment between the charging pad and the device, which can be a challenge for users. However, resonant inductive charging allows for more forgiving alignment, enabling greater flexibility and ease of use. According to Z. Zhang et al. [2], resonant inductive coupling has the potential to improve charging efficiency and make wireless charging more practical for a wider range of devices, including gaming controllers.

One of the main obstacles to implementing inductive charging in gaming controllers is the speed of power transfer. Inductive charging systems are generally slower than traditional wired charging systems, which could be problematic for gamers who need to charge their controllers quickly. However, recent advancements in resonant inductive coupling and high-frequency energy transfer have demonstrated that faster and more efficient wireless charging is possible.

J. R. Lee et al. [3] show that the efficiency of inductive charging can be significantly improved through the use of high-frequency resonant inductive systems, which could allow for faster charging times and make the transition from physical connections to wireless charging more feasible for gaming controllers.

By replacing the physical connection with inductive charging, several benefits can be realized:

- **Durability:** The elimination of physical connectors reduces the wear and tear associated with frequently plugging and unplugging charging cables. This increases the lifespan of both the controller and the charging dock.
- **Convenience:** Gamers would no longer need to worry about aligning metal pins or physically connecting the controller to the dock. Placing the controller on the charging pad would automatically initiate the charging process, providing a seamless experience.
- **Enhanced Aesthetics:** Inductive charging eliminates the clutter of cables, making the gaming setup cleaner and more organized. This aligns with the increasing demand for minimalistic and streamlined designs in gaming accessories.
- **Safety and Reliability:** Without the need for physical contacts, the risk of short-circuiting or damaging connectors is significantly reduced. This makes the charging system more reliable over time.

The application of inductive charging technology to replace the physical connection in gaming controllers offers several advantages, including improved durability, convenience, and a cleaner user experience. Although inductive charging has been widely used in other sectors, its integration into gaming controllers has been limited to date. Research shows that inductive charging, particularly through resonant inductive coupling, could overcome the challenges associated with efficiency and charging speed. The future of gaming controller charging systems may very well lie in wireless power transfer, providing gamers with a more convenient and durable solution that aligns with the wireless nature of modern gaming devices.

Research and Development

Induction charging operates through electromagnetic induction, where electrical energy is transferred between two coils without direct contact. When an alternating current flows through the transmitter coil, it generates a time varying magnetic field. If a receiver coil is placed within its magnetic field, voltage is sent across the coil, allowing power to be transferred to charge a battery. [9]

Standard inductive charging requires relatively precise alignment to ensure energy transfer takes place. Resonant inductive charging is one step beyond standard inductive charging by

enabling energy transfer at a greater distance, as well as less precise alignment tolerances. By tuning the coils to resonate at a similar frequency, the energy transfer is maximized through resonance efficiency. Covering greater positions tolerances and distance is why adding resonant inductive charging is desirable. [10]

Other wireless charging methods include capacitive coupling, by using electric fields rather than magnetic fields and radio frequency RF charging this is done by using far-field electromagnetic wave. Inductive and resonant inductive charging are distinguished by higher power transfer efficiency and safety for high-current applications like controller charging. [11]

Qi is the dominant standard for inductive charging developed by Wireless Power Consortium (WPC). Qi specifies power levels, communication systems between charger and device, and safety. Qi standards are based on safety in power transfer, detection of foreign objects, and interoperability across many brands and devices. [12]

Wireless charging systems use several main components: transmitter and receiver coils, capacitors (to tune the resonance), power electronics (i. e. Inverters and rectifiers), control circuits, and shielding materials to contain the magnetic field. The coils may have a backer of a high-permeability ferrite material to increase the directionality and efficiency of the field. [13]

The coil shape, wire gauge, number of turns, and overall geometry have direct/indirect implications for how efficient charging is. To help with minimizing skin effect and proximity losses at greater frequencies, Litz wire, which consists of many thin insulated wires together braided, is often desirable. A flat spiral coil design is often used on smaller/easier-to-integrate devices, such as gaming controllers. [14]

High transfer efficiency is crucial for minimizing power loss and heat generation. well-designed inductive systems typically have a transfer rate above 70%, whilst resonant systems can achieve efficiencies of 80% and higher in ideal conditions. [15]

The resonant frequency is determined by the inductance value of the coils and the value of the capacitance of the tuning capacitors. Using RF energy at frequencies around 100 kHz to several MHz is typical, and a final frequency is selected to balance efficiency, safety and electromagnetic interference (EMI) issues. [16]

Conventional inductive charging requires close proximity (2–5 mm). Resonant inductive systems can stretch this to 10–40 mm. However, misalignment still reduces efficiency, making good mechanical alignment design critical for consistent performance. [17]

Common battery types for controllers are lithium-ion (Li-ion) and lithium-polymer (LiPo) cells, chosen for their high energy density, low self-discharge, and relatively simple charging requirements.

A charger now consists of an AC-to-DC rectifier or the input from the coil, a voltage regulator, a battery management system, and protection circuits that will ensure that charging is done safely and efficiently. [11]

The receiver coil carries power in AC power; therefore, you must rectify it. This can be done with a bridge rectifier to produce a voltage suitable for battery charging. [18]

Voltage regulation is crucial to match the rectified voltage to the safe charging voltage range of the battery. Low-dropout regulators (LDOs) or buck converters are often utilized to set a stable charging voltage.

Protection circuits provide safeguards against overvoltage, overcurrent, short-circuiting, and overheating, which protects the battery's health and longevity

Protection circuits help prevent overvoltage, overheating and overcurrent, ensuring long lasting components and safety for users. Modern battery protection circuits often rely on integrated circuits. These compact ICs manage multiple protection tasks while communicating with the device's main controller over I2C or SPI interfaces. [19]

The dock design must accurately fit an Xbox controller to ensure the coils within the dock and the controller line up for efficient charging. Without this, the controller could move around and decrease the area which the coils can reach one another, reducing the efficiency of the charging and increasing charging times.

The circuit within the controller must be designed compactly within the controller without disrupting any of the other components within the controller. Therefore designing a small and efficient circuit is needed as too much heat could disrupt other components within the controller and could have a negative effect on the user, such as buttons not working or increasing latency between button presses.

Efficiency can be increased by optimizing coil coupling, using higher-quality materials, minimizing resistive losses, tuning for perfect resonance, and implementing dynamic power control. [20]

Adaptive charging systems are in place to prolong the battery life. It works by learning your charging habits and will charge most of the way (typically 80%) then will fully charge about an

hour before you normally unplug your device. this makes sure that your device isn't constantly charging for long periods of time such as overnight. [21]

Using multiple small coils on a charging mat can increase efficiency by creating a larger surface area in which you are able to charge your device.

Resonant inductive charging is an advanced application of wireless power transfer. It is a sophisticated extension of traditional inductive charging that enhances the efficiency of energy transfer at distance, even if the transmitter and receiver are not precisely aligned. The key principle behind resonant inductive charging is magnetic resonance coupling. In a resonant system, the transmitter coils and receiver coils are both capacitively coupled to accompany each other as LC circuits. [22]

one of the main safety concerns with wireless charging is electromagnetic field(emf). whilst wireless charging on its own emits only small amounts of emf, when added on to all the other devices used, these all start to add up and are recommended to only keep your device on the charger when necessary and stay away from the charging if possible to reduce contact with emf. prolonged charging can have negative effects on your device as it generates but normal day to day use shouldn't have any adverse effects on your devices if they are used. [23]

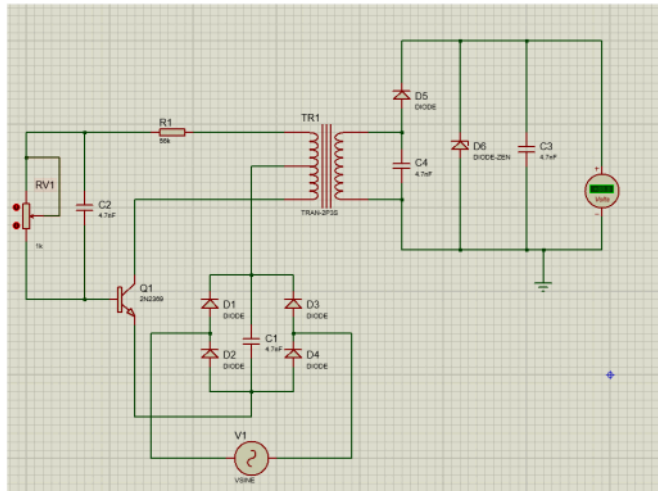
Wireless chargers add other electronic components like transmitter coils, PCBs, control chips, and shielding materials. They need: Copper and rare earth elements, Ferrite cores and other specialty components, Plastic casing, typically petroleum-based polymer-based. Increased complexity means greater material footprint per charge unit. Wireless charging devices are also typically non-modular and non-repairable, contributing to electronic waste if they happen to be damaged or are obsolete. [24]

The wireless charging market has rapidly grown over the past decade, rapidly improving in efficiency, cost and uses. there are now chargers for most types of devices including controllers and smart watches. the reason for this is the ease of use they provide whilst also allowing companies to make more profit by providing more ways to charge your devices.

Design and Implementation

The circuit is a basic SMPS (switched-mode power supply) which is designed to convert an AC input into a DC output. It has electrical isolation and voltage conversion using a set of copper induction coils, represented by a transformer in the digital prototype. In the initial design, the AC input is first rectified using a bridge rectifier which converts AC to pulsating DC. This is then smoothed with a capacitor. The resulting DC voltage is then supplied to the primary winding of the transformer where switching is controlled by an NPN transistor. The transistor operates as a

high-speed switch, which is driven by a timing circuit consisting of a variable resistor a resistor and a capacitor. This timing circuit determines the switching frequency, which will cause the transistor to rapidly switch on and off. The rapid switching then induces a voltage in the secondary winding of the transformer through electromagnetic induction. On the receiver side, a diode is used to rectify the induced AC voltage, while a Zener diode is used as a voltage regulator, clamping the output to a specific voltage. Capacitors are then used as filters to reduce the output ripple which stabilises the output voltage. In place of a battery is a voltmeter to ensure the correct output voltage is achieved.



The second prototype involves a similar design, with a few components removed for simplicity. The components in the transmitter side include the variable resistor, the resistor, the two capacitors, and the transistors. The main difference on this side of the circuit is that the bridge rectifier is replaced with a capacitor. This is connected to the transmitter coil. On the receiver side, the components include a variable capacitor, a diode, a capacitor, and the battery or voltmeter.

The housing for both the controller and the charger stand are both to be 3D printed. To ensure usability and functionality, the chosen material needed to be heat resistant, lightweight, and sturdy. The two choices were ABS (Acetonitrile Butadiene Styrene) and PLA (Polylactic acid).

The ABS filament was chosen over PLA as it's the more lightweight option out of the two materials. PLA was used for the prototypes as it's a more cost-effective option. It is easy to print with as it requires lower printing temperatures and is also biodegradable. If used in a room temperature environment and kept out of sunlight, PLA will last for up to 20 years before degrading. It also offers good strength and stiffness. However, it is brittle and less flexible making it more susceptible to cracking or breaking under stress. It is not as heat resistant

compared to other materials meaning there is a possibility of the housing deforming if the circuit were to overheat. Due to it being biodegradable, if it were to be left in direct sunlight, the material will begin to degrade after only around a year. ABS however has better impact resistance and can withstand more stress. It is also more heat resistant and more flexible than PLA, while still being cost-effective. On the other hand, the material is harder to print with as it needs higher printing temperatures and an enclosure to control the temperature to prevent warping while printing.

Testing

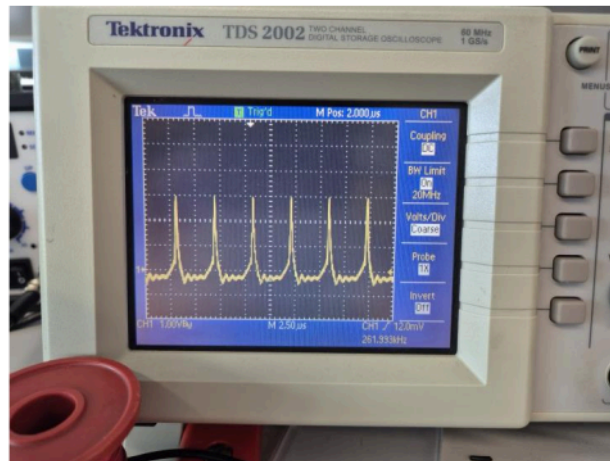
In the testing stage, the charging speed and efficiency will need to be determined by measuring the power delivered to the battery and the energy consumed by the charger while in use. This involves measuring the voltage and the current at both the charger and the battery, then using the results to calculate the power. The efficiency is then determined by dividing the energy delivered to the battery by the energy consumed by the charger. During these tests the power loss can also be calculated.

The battery life and safety will be determined by finding the charging speed and efficiency. Part of the safety testing will also include solutions for temperature management and overcharge protection to prevent the circuit overheating and the charger overcharging the battery. The circuit will also need to be tested on EMF exposure to ensure the electromagnetic fields are within safe limits. Foreign object detection will also need to be tested. Electromagnetic compatibility will need to be tested to ensure the charger does not interfere with any other electronic devices.

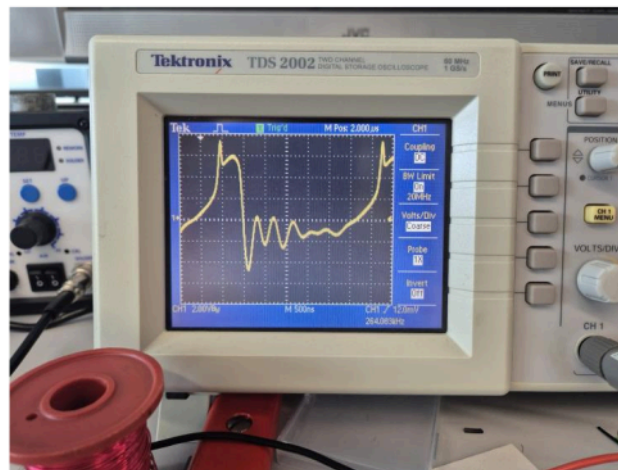
The user experience testing will need to be done also to ensure that aesthetics and comfort are at a good standard.

Evaluation

During testing, multiple coils were tested to see which one was the most effective. Firstly, a coil with 5 turns was tested against a transmitter coil with 100 turns, as this wouldn't take up much room in the controller. After testing that coil, no significant output voltage was shown on the oscilloscope. The next coil to be tested was a coil with 24 turns, which gave an output of 3V when 15V was supplied.



The third coil to be tested against the transmitter coil had 50 turns to determine the output voltage for this turns ratio. The coil with 50 turns produced an output of 7V when 15V was applied. This is not only too high a voltage for the battery, which has a maximum charging voltage of 4.2V, but was also very unstable as seen in the picture below. The closest output to the ideal output of 4V was that of the coil with 24 turns with an output of 3V.



By having a smaller coil in the controller, it makes the circuit smaller and therefore the size of the controller will not need to be changed. When using the circuit, it was noted that the transistor was overheating quite a bit. To combat this, heatsink was put on it and the tests were run again to determine if the transistor would still overheat. The output voltage achieved through these tests was determined to be 3V with a stable output voltage.

Conclusions and Recommendations

The final circuit, which utilised a 24-turn receiver coil, performed as intended and delivered a stable output of 3V when supplied with 15V. This output remained within a safe margin below the battery's 4.2V maximum charging voltage, ensuring safe and efficient operation. Although the circuit met the project's objectives, further time would have allowed for more extensive coil testing to optimise the number of turns for maximum efficiency, size, and voltage regulation. In addition, further development of the physical housing for both the controller and the charging dock would have helped to refine the overall user experience and ensure proper alignment of the coils for optimal performance. While ABS was selected for its durability and heat resistance, additional iterations could have improved the fit, aesthetics, and thermal performance. Lastly, with an extended deadline, comprehensive user testing could have been conducted to evaluate comfort, ease of use, and long-term reliability in real-world scenarios.

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Group Project

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

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JADE WILLIAMS

65.50

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



Engagement with an extensive range of literature. Engagement with a limited range of mostly relevant and credible sources but with some reliance on information gained through class contact. Generally sound referencing, with no/very few inaccuracies or inconsistencies. Sources used are informed by the latest research.

11.25

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.



Knowledge is reasonably extensive. Exhibits very competent critical understanding of the well-established concepts and principles of the subject and the main methods of enquiry. Breadth and depth of knowledge.

13

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.



Sound critical evaluation and analysis of concepts. Is selective in the range of evidence used and synthesises rather than describes. Ability to devise arguments that show awareness of different stances, and use evidence convincingly, to support appropriate and valid judgements.

15

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A very good application of a range of established methods, materials, tools and/or techniques. Very good consideration of the context of the application, with perceptive insights. Consistent, accurate and logical application of theory to practice, making appropriate links between the two. Can identify problems and propose appropriate solutions outside the context in which they were first studied. Evidence of some creativity. You have developed a well-rounded solution that effectively addresses multiple stakeholder needs while considering key ethical, societal, and commercial factors Your practical skills are well-developed, allowing you to investigate problems effectively and generate meaningful insights. You have demonstrated decision-making skills in selecting materials and technologies suited to the problem at hand.

15

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



Can communicate professionally confidently and consistently in a suitable medium for the audience. Work is coherent, very fluent and is presented proficiently. Demonstrates excellent skills for employment requiring the exercise of personal responsibility and decision-making and an appetite for further development. You have demonstrated strong teamwork skills, collaborating effectively with peers and taking initiative when needed. You communicate complex technical concepts clearly and concisely, making them accessible to both technical and non-technical audiences.

11.25