

Evolution of Video Game Controllers:
How Simple Switches Lead to the Development of the
Joystick and the Directional Pad

By

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INTRODUCTION

Throughout the history of video games, one of the most important aspects of console video games is the controller. This piece of hardware is the one with which the players interact the most and is by far the most memorable component. Hours upon hours are spent learning the intricacies of the controller – the location of the various buttons, the distance between the buttons for the most efficient button presses, and the subtlety of pushing the buttons just right so that the desired operation is performed – to finally master it. When used correctly, the controller provides an immersing experience where the controls are mere extensions of the player’s thoughts; however, when used incorrectly, the controller becomes the most frustrating aspect of video games, eliciting anger and frustration. Failures in video games are often attributed to the controller for failing to do what the player wanted to do. Countless controllers have suffered the fate of being martyrs as they are smashed or thrown due to player frustration.



Figure 1: Video game controllers as a source of anger and frustration. Video game controllers serve as the whipping boy for players taking out their anger and frustration. Of note is how each controller embodies the essence of the particular console in players' memories. In each case, the controller is as memorable as the particular console, if not even more so. (Krahulik and Holkins, Penny Arcade)

The design of a video game controller should not be taken lightly. Aside from removing the barrier between the player and the virtual environment, the controller also specifies the type of experience the player will have by defining what types of games are best played on it due to its design. For example, the Nintendo GameCube controller has already developed a reputation for being bad for fighting games due to its button layout, which discourages button mashing, whereas the Microsoft Xbox controller, with its shoulder triggers that mimic actual triggers, has become a favorite for first person shooters, which contributes to the success of the popular first-person shooter Halo on the Xbox. (Takahashi, Opening the Xbox)

Despite the importance of video game controllers, it is the most neglected aspect of video games. Most histories on video game consoles describe the components that go into the generic black boxes – which generally resemble a video cassette recorder (VCR) – with merely a paragraph on how the designers developed the controllers. Only until recently has the focus shifted towards more user testing in the design process to emphasize the importance of the video game controller. Prior to this, controllers mainly developed as designers tried to cope with the challenges of the particular console problems such as avoiding damage to expensive equipment or coherently organizing complicated buttons. To understand the process that led to the design of today's video game controllers as well as why certain controller elements have been universally

adopted, one must examine the history of video game controllers. Only then can we hope to develop better controllers.

SPACEWAR: THE ORIGIN

Like most other aspects of video games, the controller traces its origin all the way back to Spacewar, arguably the first video game.¹ Spacewar was the brainchild of Steve Russell and his cohorts Wayne Witanen and J. Martin Graetz. The group was inspired by the Skylark and Lensmen series of novels by Edward E. Smith, PhD., which featured science fiction heroes who “had a strong tendency to get pursued by the villain across the galaxy and have to invent their way out of their problem while they were being pursued.” (Triplanetary, 1948 as cited by Rollingstone, 1972) In the strictest sense, Spacewar was a space combat game in which players controlled different spaceships and tried to destroy each other while avoiding enemy fire by firing torpedoes and maneuvering their ships.

Originally envisioned as a demonstration of the computing power of MIT’s new TX-0, Spacewar was finally developed on a PDP-1 that was installed next door in 1961. In the original Spacewar, ships were controlled with four of the eight Test Word switches on the PDP-1. The switches determined whether the ship turned left, turned right, whether the rocket was on, and whether torpedoes were being fired. (Net Memories of Spacewar, 1994) “‘You had four controls,’ Russell recalls, ‘rotate counterclockwise, rotate clockwise, turn on your rocket thrust, which caused a little tail of rocket exhaust to

¹ *Joystick Nation* and *L’Univers des jeux video* both erroneously attribute Spacewar as the first video game; however, as explained by *Trigger Happy* and *Phoenix: The Fall and Rise of Videogames*, the first video game was developed by William A. Higinbotham at the Brookhaven National Laboratory in 1958. (Rosenthal, Fun With an Oscilloscope) Higinbotham was trying to develop an entertaining exhibit for visiting members of the public. To that end, he developed a rudimentary tennis game featuring bouncing balls on an oscilloscope that were controlled by a button and a knob. The game never left the laboratory and Higinbotham never patented it as he thought “the whole idea so obvious that it never occurred to me to think about a patent.” (Poole, Trigger Happy and Herman, Phoenix: The Fall and Rise of Videogames)

show on the screen, and torpedo.’” (Herz, Joystick Nation) This immediately ran into problems. Playing Spacewar this way meant that one player always had the advantage since the screen of the PDP-1 was to one side of the switches. (Spacewar) Also, the table upon which the switches stood was at an inconvenient height so that after periods of play, the players’ elbows often got tired. (Herz, Joystick Nation) Further, there was always the risk of damage to the expensive equipment, and if the player is not careful, he can easily hit the start switch by mistake and shutdown the entire computer. (Graetz, The Origin of Spacewar!) Finally, having four switches lined up next to each other on the switchboard meant that players had to memorize what each of the switches did. There was no natural mapping between the location of the switches and the function of the switches. As a result, Spacewar was game for expert players, who had the advantage over novices. In order to solve all of these problems, control boxes were developed for Spacewar, giving birth to the first video game controllers.

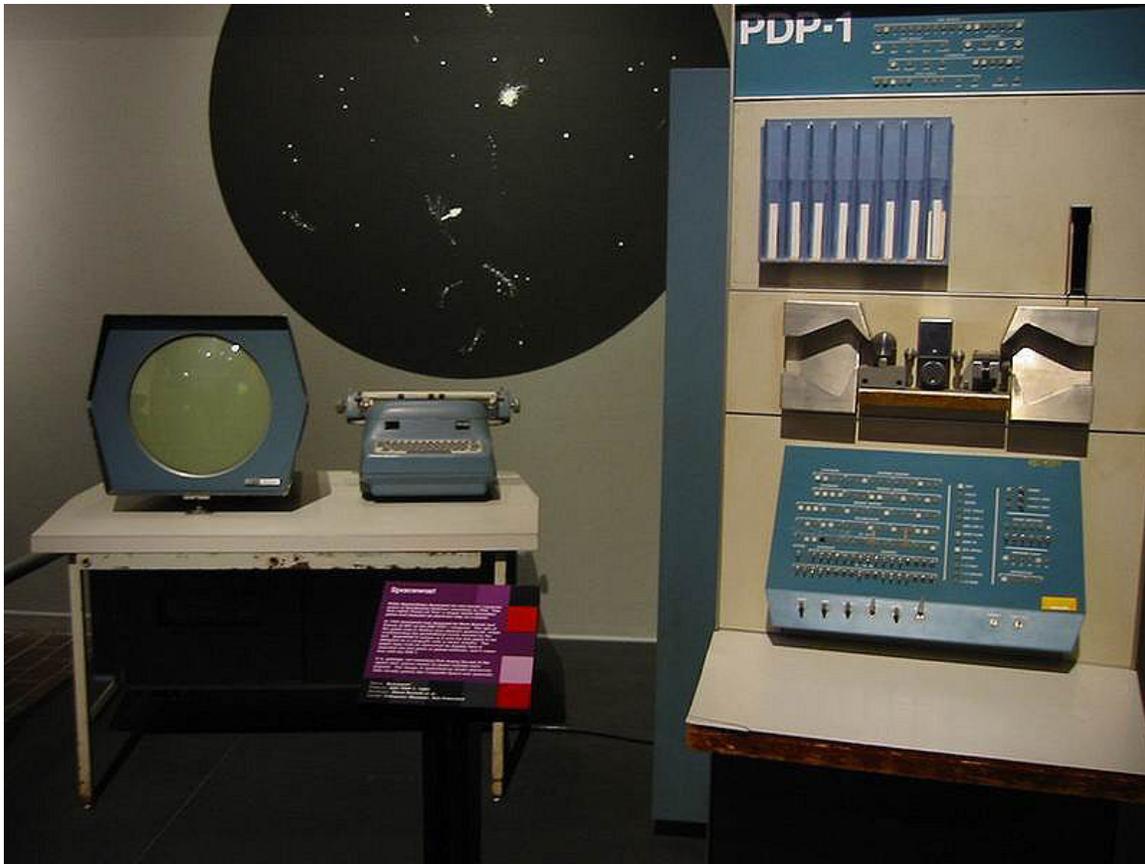


Figure 2: The PDP-1 Spacewar was originally developed on. Spacewar was originally developed on a PDP-1 similar to that pictured here. Note how the oscilloscope screen (left) is to one side of the switches (right) leading to an advantage for one player and the need to develop control boxes. (Game On Exhibition @ Barbican Gallery, London, 29.8.2002)

Using their knowledge as members of the Tech Model Railroad Club, Alan Kotok and Robert A. Saunders developed the first Spacewar control box. The boxes featured two double-throw switches and a button. The double-throw switches controlled the rotation of the spaceship as well as the acceleration. The button determined whether a torpedo was fired. Contrary to what the controllers seemed like, these controllers did not feature a joystick, which was not available until later. (Graetz, The Origin of Spacewar!) The throw-able switches were in fact only switches, which turned on when they were thrown to either side, but turned off when they are left in the center. There was no

relative difference in how far the switch was thrown, the switches were either on or off – that is, they were digital. Conveniently, the first MIT boxes positioned the switches so that the double-throw switch that controlled the left and right turns of the ship was horizontal and the double-throw switch that fired the rocket to accelerate the ship was vertical. This solved the problem of having to remember what each of the switches did since the switches were in the same direction the ship would move, relatively. With these new control boxes, players could be fairly separated from the PDP-1 screen without endangering the equipment or giving either player an unfair advantage.

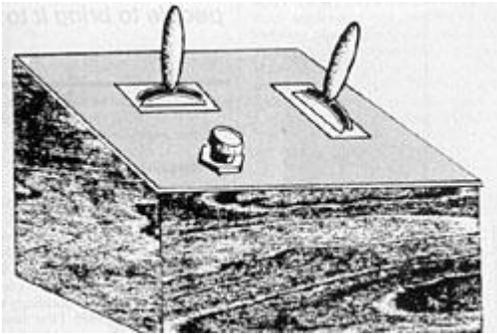


Figure 3: A sketch of the original control box of Spacewar. As described by J. M. Graetz in *The Origin of Spacewar!*:

The box is wood with a Bakelite top. The two switches are double-throw; the button is a silent momentary switch. Their functions are as follows:

- a. Rotation control – It is pushed to the left to rotate the ship counterclockwise, to the right to rotate clockwise.
- b. A two-function control – Pulled back it is the rocket accelerator; the rocket continues to blast as long as the switch is thrown. Pushed forward, the switch is the hyperspace control, as described below.
- c. The torpedo button – It had to be silent so that your opponent could not tell when you were trying to fire. (There was a fixed delay between shots "to allow the torp tubes to cool" and fire was not automatic; you had to keep pushing the button to get off a missile.)

As Spacewar proliferated around the country, spreading to university computers of the time, numerous different designs for the control boxes sprang up. Variations included buttons for all 5 functions (right rotation, left rotation, accelerate, hyperspace, and fire) implemented by momentary switches or banks of eight switches that allowed players to control the ships much like they did on the original PDP-1. (Yasaki, Computing at Stanford) These control boxes were the first generation of button-based

controllers that proliferated into early arcades of the time, which offered multiple buttons that controlled the elements on the screen.



Figure 4: Early arcades featured button-based controls. Computer Space, an early arcade version of Spacewar, featured button-based controls reminiscent of its ancestor. (Game On Exhibition @ Barbican Gallery, London, 29.8.2002)

ATARI AND THE JOYSTICK

With the advent of switch-based buttons, the joystick was soon to follow. The basic design of a generic joystick is quite simple. For a joystick to function, it merely needs to have four different switches, each corresponding to a different direction. (Engdal, Joystick Documents) When the stick is moved in a particular direction, a tiny metal disc makes a connection with the circuit board turning the switch on and generating an electrical signal that indicates that the joystick was moved in a particular direction. An additional switch can be added to control firing. (Harris, How Joysticks Work) Joysticks based on this design in which the switches were either on or off were the so called digital joysticks.

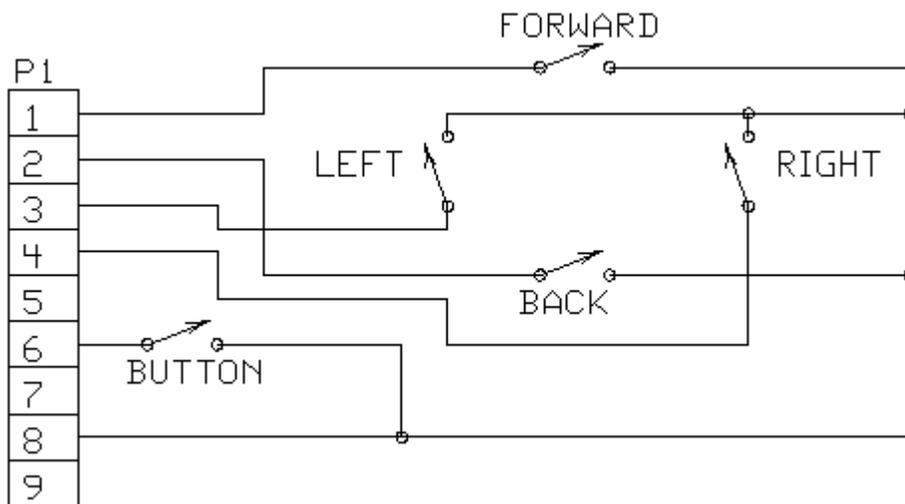


Figure 5: A simple circuit diagram for a basic joystick. A basic joystick can easily implemented with four switches, each of which turned on (closed the circuit so that a current would flow) when the stick is moved in the appropriate direction. (Engdal, Digital joystick connector pinouts)

Despite the simplicity of the basic joystick, most modern day joysticks evolved from a different ancestor. For the history of this development, it is necessary to focus on another trend of the 60s. Following Spacewar, button-based controllers persisted; however, another totally different video game was quickly gaining popularity. That game was Pong. Pong dates back to Higinbotham's "Tennis for Two" in 1958. (Rosenthal, Fun With an Oscilloscope) Magnavox also made a version with the Odyssey; however, Pong did not really take off in popularity until the version by Al Alcorn and Atari since it was Atari who popularized home video games. Pong was a simple arcade game in which a dot on the screen bounces back and forth between two paddles. Like tennis, points were scored when your opponent couldn't return the ball. Originally developed by Al Alcorn as a training exercise before working on Computer Space, Pong did so well as its own arcade game that it spawned a franchise of its own. (Al Alcorn Interview)



Figure 6: The paddle controller. The paddle controller was a requisite for home consoles due to the popularity of Pong. (Atari Home Pong)

Since its birth, the paddles on Pong have been controlled using potentiometers, which were little knobs that, when turned, moved the paddle up and down on the screen. Due to the immense popularity of Pong, the first few Atari home consoles shipped to play Pong featured the de facto paddle controller. (AtariAge, Atari 2600 History) The paddle controller was unique in that it featured two potentiometers on two different halves of one

big controller board so that one controller allowed two people to play. (Cassidy, Warlords) The importance of Pong in the home console market heavily influenced the design of home console controllers.

In the midst of the Pong frenzy, Fairchild Camera and Instrument released the Channel F in 1976. It was known as the Video Entertainment System (VES) and retailed for about \$170. (Hunter, Player 3: Home Systems) While offering other buttons to control direction like up, down, left, and right, the VES controller felt the pressure of Pong and offered a twistable top that allowed the player to turn the controller top to the left or the right. All of this was packaged in a dynamite detonator-like controller. (Dyer and Webb, Fairchild Channel F Faq) This detonator-like controller was a sufficient departure from the paddle controllers of its time and featured a central shaft and rotational elements that was influential in the design of the Atari 2600 joystick a year later.



Figure 7: Channel F. The detonator-like controller of the Channel F and the twistable top shows a gradual evolution to the joystick of the Atari 2600. (Hunter, Player 3: Home Systems)

The invention of the first joystick that consisted of a central shaft and a pivotal point is credited to Stephen D. Bristow. By 1978, when Bristow received the patent for

the Atari joystick, there were many other designs for joysticks. In part, this was due to the simplicity with which a crude joystick can be made as mentioned above. What separated the Atari joystick was that it consisted of a central shaft that pivoted to make the connections to give the five directions (up, down, left, and right) and a fire button. (Yung and Hsu, Journey to the Joystick) In its design, the departure from the paddle controller continued the trend started by the VES controller. The pivotal rotation was similar to the twistable top in using rotational elements in controller design. In 1977, Atari offered the Atari joystick along with the de facto paddle controller for Pong with its Atari 2600 Video Computer System (VCS), thereby giving birth to the first joystick on a video game console.

[54] **JOYSTICK WITH ATTACHED CIRCUIT ELEMENTS**
 [75] Inventor: Stephen D. Bristow, Santa Clara, Calif.
 [73] Assignee: Atari, Inc., Sunnyvale, Calif.
 [21] Appl. No.: 782,976
 [22] Filed: Mar. 30, 1977
 [51] Int. Cl.² G08C 21/00
 [52] U.S. Cl. 178/18; 338/114
 [58] Field of Search 178/18, 19, 20; 338/2, 338/6, 114; 336/137

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 3,864,515 2/1975 Fee, Jr. 178/18

Primary Examiner—Thomas A. Robinson
 Attorney, Agent, or Firm—Flehr, Hohbach, Test, Albritton & Herbert

[57] **ABSTRACT**

An improved joystick having an operating shaft mounted on a base with a ball and socket joint and a plurality of circuit elements directly actuated by the operating shaft. The circuit elements vary in impedance in correspondence to the displacement of the operating shaft so that the displacement of the operating shaft is converted into corresponding electrical signals.

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6 Claims, 11 Drawing Figures

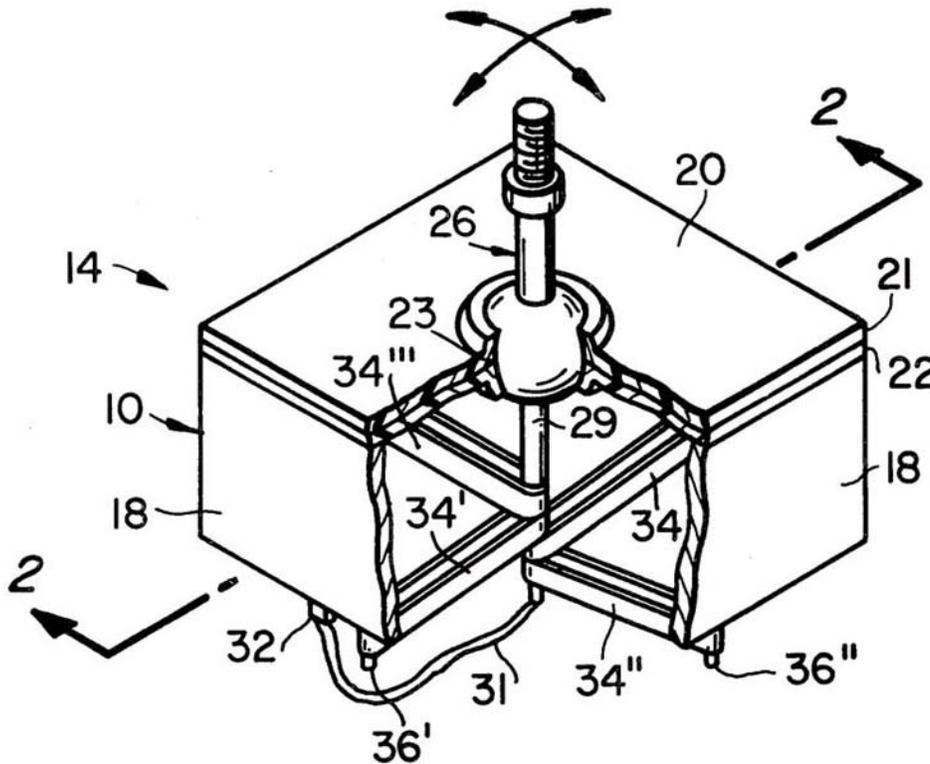


Figure 8: The original joystick patent awarded to Stephen D. Bristow of Atari. (U.S. Patent Office)

NINTENDO AND THE DIRECTIONAL PAD (D-PAD)

From the joystick, the development of the directional pad was a necessary step backwards in controller evolution. In order to understand the development of the directional pad, a brief history of Nintendo is necessary. Nintendo Koppai was found in Meiji 22 (1889) by Fusajiro Yamauchi to produce and sell handmade hanafuda cards.² In 1959, following a successful licensing agreement with Disney to produce playing cards, Nintendo officially became NCL – Nintendo Company, Ltd. – and the company sought to branch out into new businesses. One of the people hired during this period of expansion was Gunpei Yokoi. Yokoi was originally hired to maintain the assembly-line machines that made the playing and hanafuda cards, but was transferred into the engineering department several months later to make something for Nintendo to sell for Christmas. For this project, Yokoi developed Nintendo's first toy, the Ultra Hand, which is a groping extension of the hand that solidified Yokoi's position as he continued to develop Nintendo's Ultra line of toys, with more engineers added to his department.

Yokoi continued to develop toys, tinkering with electronics and oscilloscopes in his spare time. With the miniaturization of electronics and the growing influence of video game machines in the 70s, Nintendo sought to branch into this new industry. In 1977, Nintendo had already entered the market with the Color TV Game 6, which played six versions of Pong-like tennis. It was followed by the Color TV Game 15; however, Hiroshi Yamauchi, the president of Nintendo, wanted to go in a different direction and pressured Yokoi and his engineers to think of new ways of making video games. Inspired

² Hanafuda cards consisted of forty-eight cards in a deck and were painted with a scheme of symbols like a deer, the wind, a chrysanthemum, a boar, or the moon. A popular game played with these cards is matching flowers, which was a simple game requiring that the images be matched in pairs. (Scheff, Game Over)

by the miniaturization of electronic calculators, Yokoi sought to take advantage of this technology. (Game Over, 1993) What Nintendo came up with was a game called Game & Watch in 1980. (History of Nintendo)



Figure 9: Game & Watch. Game & Watch was the Nintendo video game that led to the development of the directional pad. (Cuciz, Total Control – A History of Game Controllers)

Initially, Game & Watch consisted of a digital clock, alarm, and a game controlled by two switches that moved left or right. The game soon became more complex and required four directions. Since it wasn't feasible to put a joystick-like control on the small game unit, it was decided that a switch would be placed for each direction. This arrangement, however, made the game awkward since it faced the same problem as the original Spacewar of not being clear which switch controlled which direction. To solve this awkwardness, Yokoi came up with the solution of developing "cross-shaped, thumb-operated, micro-switched lever capable of moving in four directions and addressing up to eight." (Cuciz, Total Control – A History of Game Controllers) Thus, the directional pad, or D-pad, was born.

The direction pad was eventually incorporated into a video game console with Nintendo's launch of the Famicom, which is known as the Nintendo Entertainment

System (NES) in the United States. Following Game & Watch, Nintendo branched into producing a series of coin-operated arcade games, including Donkey Kong. While making coin-op games, Yamauchi was inspired by the home computer systems that were emerging and the potential of a computer system disguised as a toy – a so called Trojan Horse that could penetrate the home market. While most machines on the market at the time cost between \$200 to \$350, Yamauchi wanted a system less than \$75, and had to be better with more features than all the other systems. To save money on selling what is essentially a computer, all of the frills were eliminated including the keyboard, the modem, and the disk drive. Removing the keyboard meant that there needed to be another way for the player to communicate with this computer. The solution to this problem became the Nintendo controller featuring two buttons on the right controller with a directional pad. With the inclusion of the NES controller, the directional pad was firmly established in the history of video game consoles. (Game Over, 1993)



Figure 10: Nintendo NES controller featuring the directional pad. The original NES controller continues the legacy started by the Game & Watch.
(http://www.ntrautanen.fi/computers/other/images/nintendo_nes-004.jpg)

MODERN CONTROLLERS

Since the introduction of Sony's PlayStation dual shock controller, the controller components of the directional pad and the joystick have been combined into one controller. Although derived from the same histories, the variation in the directional pad and the joystick offered different control options and tradeoffs in different situations. For example, even though the joystick allowed greater range of motion, the early joystick were more prone to damage compared to the directional pad. The dual shock controller on the PlayStation combined the directional pad, two joysticks, and a plethora of buttons (14 buttons to be exact, including the directional pad). Unlike the original Atari digital joystick, the joysticks on the dual shock controller were analog. Analog joysticks descended from digital joysticks and differed in that two potentiometers – similar to the ones used on the original Pong controllers – were attached to the joystick to measure the amount of the joystick has moved in the horizontal and the vertical directions so that the switches were not simply on and off, but depended on how far the joystick was moved. Further, these joysticks were also force feedback, which meant that two motors controlled by a processor were added to each joystick to make the stick move in a particular direction when the need arose. (Tyson, How PlayStation Works)

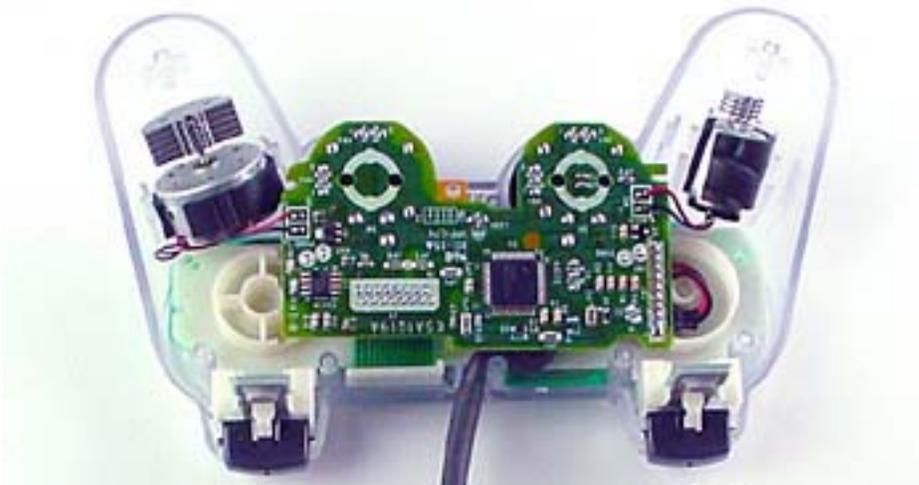


Figure 11: Sony PlayStation Dual Shock Controller. Today's controllers mainly consist of designs similar to the dual shock controller, which combines both the joystick and the directional pad. (Tyson, "How PlayStation Works")

Most of the modern day controllers descend from this model and feature two joysticks, the directional pad, and several other buttons. The locations of the various elements differ as per the design and user testing, leading to each console's unique controller design. The different kinds and amounts of control as well as the tradeoffs offered by the directional pad and the joystick have led to their development and their own particular places in today's controllers. From the humble origin of Spacewar, the need for controllers and the design of controllers slowly evolved, giving rise to the directional pad and the joystick, which together, form the controllers we have today. Although technical problems lead to the rise of each of the controller elements, today's controllers no longer face the same problems. Instead, a greater degree of freedom exists allowing more innovative design. Knowing how these elements have evolved, it is now possible to develop new controllers that take advantage of better design.

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