NAME: ABAI OLAWALE DAVID

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ASSIGNMENT II

ANSWERS

**Feed-forward**, sometimes written **feedforward**, is a term describing an element or pathway within a [control system](https://en.wikipedia.org/wiki/Control_system) that passes a controlling signal from a source in its external environment, often a command signal from an external operator, to a load elsewhere in its external environment. A control system which has only feed-forward behavior responds to its control signal in a pre-defined way without responding to how the load reacts; it is in contrast with a system that also has [feedback](https://en.wikipedia.org/wiki/Feedback), which adjusts the output to take account of how it affects the load, and how the load itself may vary unpredictably; the load is considered to belong to the external environment of the system.

In a feed-forward system, the control variable adjustment is not error-based. Instead it is based on knowledge about the process in the form of a mathematical model of the process and knowledge about or measurements of the process disturbances.[[1]](https://en.wikipedia.org/wiki/Feed_forward_%28control%29#cite_note-1)

Some prerequisites are needed for control scheme to be reliable by pure feed-forward without feedback: the external command or controlling signal must be available, and the effect of the output of the system on the load should be known (that usually means that the load must be predictably unchanging with time). Sometimes pure feed-forward control without feedback is called 'ballistic', because once a control signal has been sent, it cannot be further adjusted; any corrective adjustment must be by way of a new control signal. In contrast 'cruise control' adjusts the output in response to the load that it encounters, by a feedback mechanism.

With feed-forward or Feedforward control, the disturbances are measured and accounted for before they have time to affect the system. In the house example, a feed-forward system may measure the fact that the door is opened and automatically turn on the heater before the house can get too cold. The difficulty with feed-forward control is that the effects of the disturbances on the system must be accurately predicted, and there must not be any unmeasured disturbances. For instance, if a window was opened that was not being measured, the feed-forward-controlled thermostat might still let the house cool down.

The term has specific meaning within the field of CPU-based [automatic control](https://en.wikipedia.org/wiki/Automatic_control). The discipline of “feedforward control” as it relates to modern, CPU based automatic controls is widely discussed, but is seldom practiced due to the difficulty and expense of developing or providing for the [mathematical model](https://en.wikipedia.org/wiki/Mathematical_model) required to facilitate this type of control. [Open-loop control](https://en.wikipedia.org/wiki/Open-loop_controller) and [feedback control](https://en.wikipedia.org/wiki/Feedback_controller), often based on canned [PID control](https://en.wikipedia.org/wiki/PID_controller) algorithms, are much more widely used.[[2]](https://en.wikipedia.org/wiki/Feed_forward_%28control%29#cite_note-ISA1-2)[[3]](https://en.wikipedia.org/wiki/Feed_forward_%28control%29#cite_note-3)[[4]](https://en.wikipedia.org/wiki/Feed_forward_%28control%29#cite_note-4)



The Three types of Control System (a) Open Loop (b) Feed-forward (c) Feedback (Closed Loop) Based on Hopgood (2002)

There are three types of control systems: open loop, feed-forward, and feedback. An example of a pure open loop control system is manual non-power-assisted steering of a motor car; the steering system does not have access to an auxiliary power source and does not respond to varying resistance to turning of the direction wheels; the driver must make that response without help from the steering system. In comparison, [power steering](https://en.wikipedia.org/wiki/Power_steering) has access to a controlled auxiliary power source, which depends on the engine speed. When the steering wheel is turned, a valve is opened which allows fluid under pressure to turn the driving wheels. A sensor monitors that pressure so that the valve only opens enough to cause the correct pressure to reach the wheel turning mechanism. This is feed-forward control where the output of the system, the change in direction of travel of the vehicle, plays no part in the system. See [Model predictive control](https://en.wikipedia.org/wiki/Model_predictive_control).

If you include the driver in the system, then he does provide a feedback path by observing the direction of travel and compensating for errors by turning the steering wheel. In that case you have a feedback system, and the block labeled "System" in Figure(c) is a feed-forward system.

In other words, systems of different types can be nested, and the overall system regarded as a [black-box](https://en.wikipedia.org/wiki/Black-box).

Feedforward control is distinctly different from open loop control and [teleoperator](https://en.wikipedia.org/wiki/Teleoperator%22%20%5Co%20%22Teleoperator) systems. Feedforward control requires a mathematical model of the plant (process and/or machine being controlled) and the plant's relationship to any inputs or feedback the system might receive. Neither open loop control nor teleoperator systems require the sophistication of a mathematical model of the [physical system](https://en.wikipedia.org/wiki/Physical_system) or plant being controlled. Control based on operator input without integral processing and interpretation through a mathematical model of the system is a teleoperator system and is not considered feedforward control.

A **feedback loop** is a common and powerful tool when designing a control system. Feedback loops take the system output into consideration, which enables the system to adjust its performance to meet a desired output response.

When talking about control systems it is important to keep in mind that engineers typically are given existing systems such as actuators, sensors, motors, and other devices with set parameters, and are asked to adjust the performance of those systems. In many cases, it may not be possible to open the system (the "plant") and adjust it from the inside: modifications need to be made external to the system to force the system response to act as desired. This is performed by adding controllers, compensators, and feedback structures to the system.

Basic Feedback Structure[[edit](https://en.wikibooks.org/w/index.php?title=Control_Systems/Feedback_Loops&action=edit&section=2)]



This is a basic feedback structure. Here, we are using the output value of the system to help us prepare the next output value. In this way, we can create systems that correct errors. Here we see a feedback loop with a value of one. We call this a **unity feedback**.

**Here is a list of some relevant vocabulary, that will be used in the following sections:**

**Plant**

The term "Plant" is a carry-over term from chemical engineering to refer to the main system process. The plant is the preexisting system that does not (without the aid of a controller or a compensator) meet the given specifications. Plants are usually given "as is", and are not changeable. In the picture above, the plant is denoted with a P.

**Controller**

A controller, or a "compensator" is an additional system that is added to the plant to control the operation of the plant. The system can have multiple compensators, and they can appear anywhere in the system: Before the pick-off node, after the summer, before or after the plant, and in the feedback loop. In the picture above, our compensator is denoted with a C.

Some texts, or texts in other disciplines may refer to a "summer" as an **adder**.

**Summer**

A summer is a symbol on a system diagram, (denoted above with parenthesis) that conceptually adds two or more input signals, and produces a single sum output signal.

**Pick-off node**

A pickoff node is simply a fancy term for a split in a wire.

**Forward Path**

The forward path in the feedback loop is the path after the summer, that travels through the plant and towards the system output.

**Reverse Path**

The reverse path is the path after the pick-off node, that loops back to the beginning of the system. This is also known as the "feedback path".

**Unity feedback**

When the multiplicative value of the feedback path is 1.

Negative vs Positive Feedback[[edit](https://en.wikibooks.org/w/index.php?title=Control_Systems/Feedback_Loops&action=edit&section=3)]

It turns out that negative feedback is almost always the most useful type of feedback. When we subtract the value of the output from the value of the input (our desired value), we get a value called the **error signal**. The error signal shows us how far off our output is from our desired input.

Positive feedback has the property that signals tend to reinforce themselves, and grow larger. In a positive feedback system, noise from the system is added back to the input, and that in turn produces more noise. As an example of a positive feedback system, consider an audio amplification system with a speaker and a microphone. Placing the microphone near the speaker creates a positive feedback loop, and the result is a sound that grows louder and louder. Because the majority of noise in an electrical system is high-frequency, the sound output of the system becomes high-pitched.