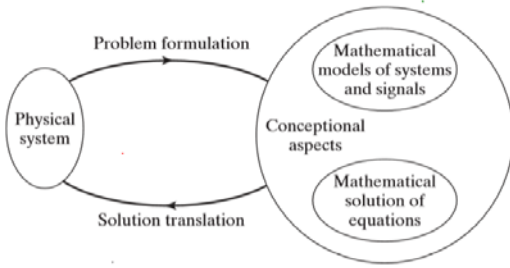


EE103 lect #2 | Nov 17, 2017



The idea of the integrated circuit was conceived by Jeffrey Dummer (1909–2002), a radar scientist working for the Royal Radar Establishment of the British Ministry of Defence. Dummer presented the idea to the public at the Symposium on Progress in Quality Electronic Components in Washington, D.C. on 7 May 1952.^[7] He gave many symposia publicly to propagate his ideas and unsuccessfully attempted to build such a circuit in 1956.

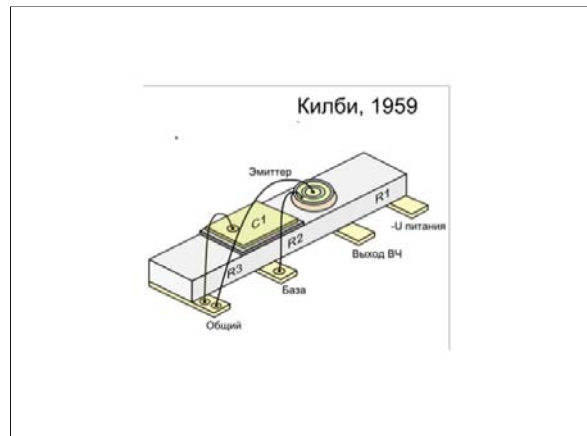
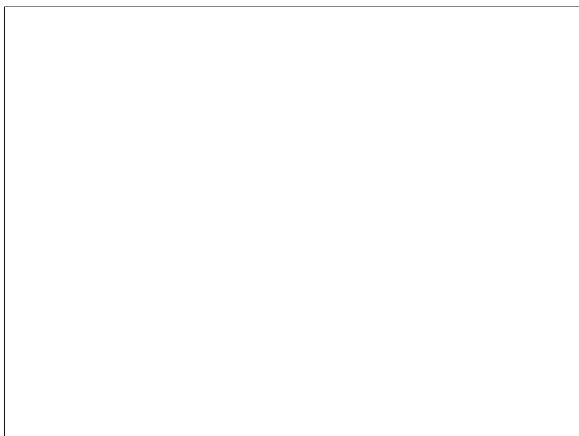
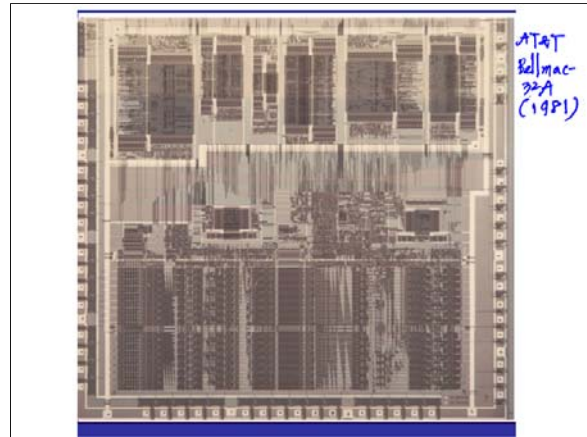
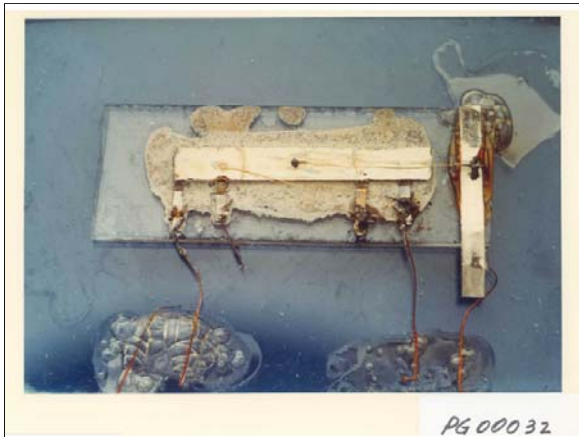
A precursor idea to the IC was to create small ceramic squares (wafers), each containing a single miniaturized component. Components could then be integrated and wired into a bidimensional or tridimensional compact grid. This idea, which seemed very promising in 1957, was proposed to the US Army by Jack Kilby and led to the short-lived Micromodule Program (similar to 1957's Project Tinkerb)^[7] However, as the project was gaining momentum, Kilby came up with a new, revolutionary design, the IC.

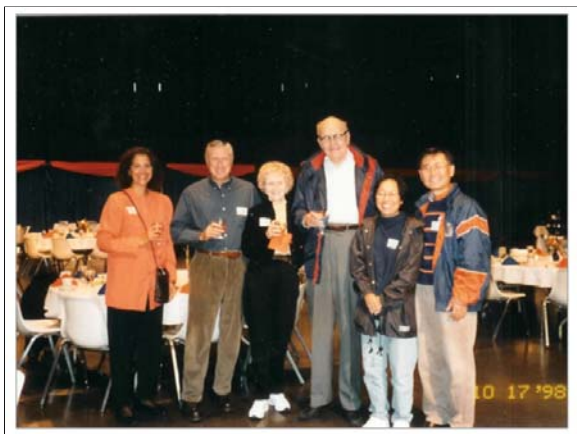
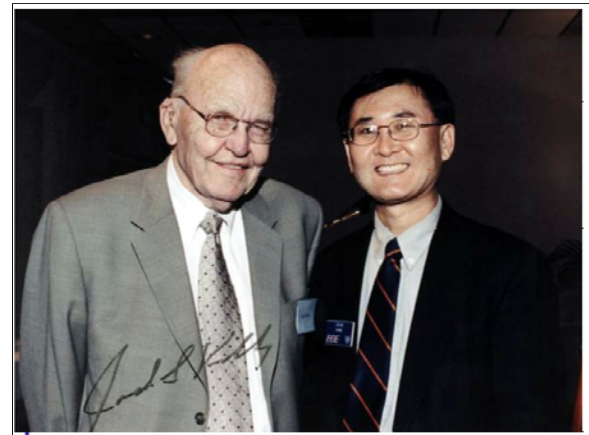
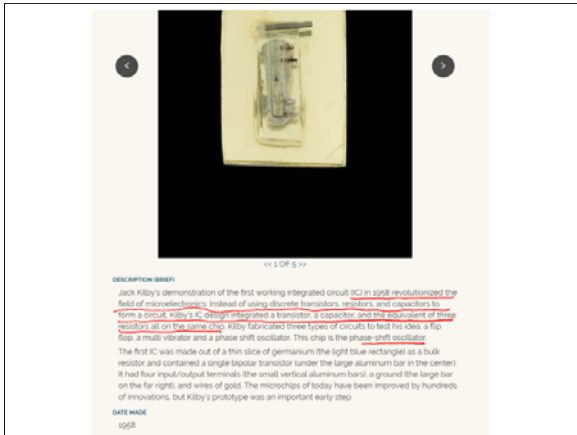
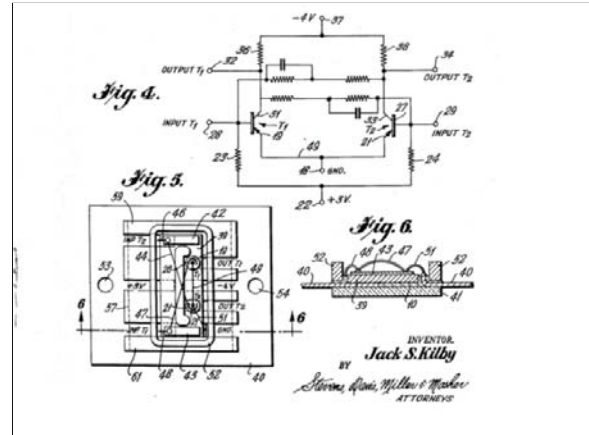
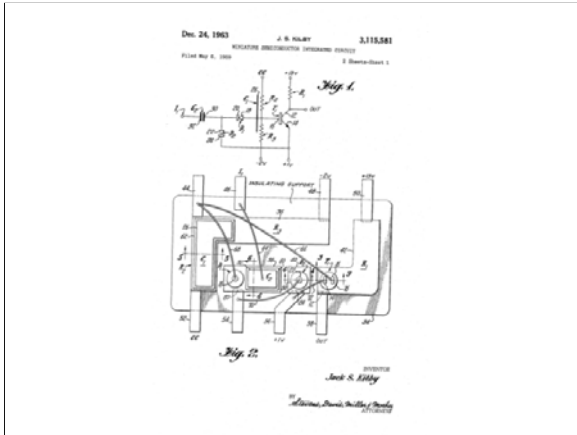
Newly employed by Texas Instruments, Kilby recorded his initial ideas concerning the integrated circuit in July 1958, successfully demonstrating the first working integrated example on 12 September 1958.^[8] In his patent application of 6 February 1959,^[9] Kilby described his new device as a body of semiconductor material—silicon—where all the components of the electronic circuit are completely integrated.^[10] The first customer for the new invention was the US Air Force.^[11]

Kilby won the 2000 Nobel Prize in Physics for his part in the invention of the integrated circuit.^[12] His work was named an IEEE Milestone in 2009.^[13]

Half a year after Kilby, Robert Noyce of Fairchild Semiconductor developed his own idea of an integrated circuit that solved many practical problems Kilby's had not. Noyce's design was made of silicon, whereas Kilby's chip was made of germanium. Noyce created Ron LeVore of Sprague Electric for the principle of p-n junction isolation, a key concept behind the IC.^[14] This isolation allows each transistor to operate independently despite being parts of the same piece of silicon.

Fairchild Semiconductor was also home of the first silicon-gate IC technology with self-aligned gates, the basis of all modern CMOS computer chips. The technology was developed by Italian physicist Federico Faggin in 1966. In 1979, he joined Intel in order to develop the first single-chip central processing unit (CPU) microprocessor, the Intel





Mathematical Models of physical Elements

	Time Domain t	Freq Domain ω Fourier Transform	Complex S domain Laplace Transform
$R \begin{pmatrix} V \\ I \end{pmatrix}$	$v = Ri$ Ohm's Law	$V(\omega) = RI(\omega)$	$V(s) = RI(s)$
$C \begin{pmatrix} V \\ I \end{pmatrix}$	$i = C \frac{dv}{dt}$ $v = \frac{1}{C} \int i dt$	$I(\omega) = j\omega C V(\omega)$ $V(\omega) = \frac{1}{j\omega C} I(\omega)$	$I(s) = sC V(s)$ $V(s) = \frac{1}{sC} I(s)$
$L \begin{pmatrix} V \\ I \end{pmatrix}$	$v = L \frac{di}{dt}$ $i = \frac{1}{L} \int v dt$ ordinary diff. eq.	$V(\omega) = j\omega L I(\omega)$ $I(\omega) = \frac{1}{j\omega L} V(\omega)$ Algebra	$V(s) = sL I(s)$ $I(s) = \frac{1}{sL} V(s)$ Algebra

Laplace, Pierre (1748-1827)



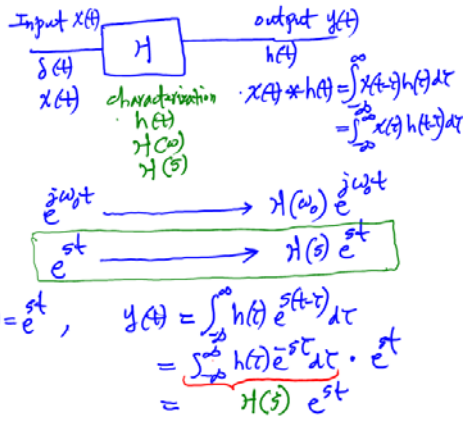
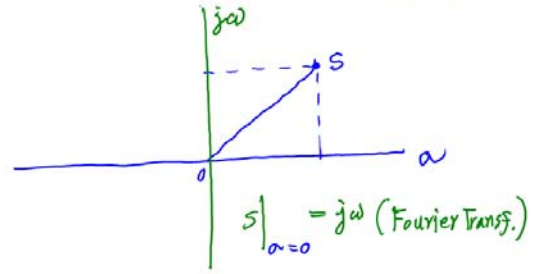
Pierre Laplace and his contemporaries who put the final seal on mathematical physics by summarizing and extending the work of his predecessors in the last volume of the Encyclopédie Générale de Mécanique (1781-1824). This work was important because it formalized the geometrical study of mechanics. It used by Fourier to use based on calculus to show as physical mechanics. In Mécanique Générale, Laplace proved the dynamical stability of the solar system (with his method generally on short time scales on long time scales, however, this question was proven false in the early 1900s). Laplace solved the problem of the Moon. In the work, he frequently omitted deductions, leaving only results with the remark "It is not a star" it is easy to see. It is said that the formal could not allow "It" in the derivations later without ideas of work. For a reading book, see the remark made by Laplace's translator Grattan-Guinness. After reading Mécanique Générale, Heppner is said to have complimented Laplace on the need to mention "God" in open contrast to Fourier's view on the subject. Laplace replied that he had no need for that (Grattan-Guinness 1984, p. 585).

Laplace also summarized and extended combinatorics theory in "Essai Philosophique sur les Probabilités" (Philosophical Essay on Probability, 1814). He was the first to explain the value of the Gaussian integral, $\int_{-\infty}^{\infty} e^{-x^2} dx = \sqrt{\pi}$. He studied the Laplace Transform. Although Fourier developed the hydrology study, he proposed that the solar system had formed from a rotating nebula which with help breaking up and forming the planets. He discussed the theory in Exposition de système du monde (1796), the content but that would be controversial. If assuming for physics, but small value. Laplace formulated his mathematical theory of comprehension laws which would be applied to mechanical, thermal, and optical phenomena. This theory was released in the 1820s, but its importance on a wider physical view was important.

For Laplace, after calculus theory of the subjected to the determined specific leads for many substances using a combination of his own design. Laplace formulated the mechanical universal law, but thought it was wrong. He showed the mechanical universal law of heat and showed it disproved calculus calculus. A simple space after being reported to the interest of Napoleon, Laplace was dismissed with the comment that "the career the spirit of the industry shall end the management of affairs" (Boyer 1986, p. 586).

Laplace believed the universe to be completely deterministic.

s-plane ($s = \alpha + j\omega$)



$$H(s) = \int_{-\infty}^{\infty} h(t) e^{-st} dt$$

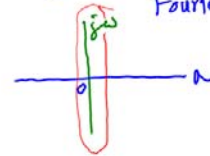
generally $F(s) = \int_{-\infty}^{\infty} f(t) e^{-st} dt$

Bilateral Laplace Transform

When $s = j\omega$

$$F(j\omega) = \int_{-\infty}^{\infty} f(t) e^{-j\omega t} dt$$

Fourier Transform



For $\alpha > 0$

$$\int_{-\infty}^{\infty} [f(t) e^{-\alpha t}] e^{-j\omega t} dt = \int_{-\infty}^{\infty} f(t) e^{-(\alpha + j\omega)t} dt$$

$$= \int_{-\infty}^{\infty} f(t) e^{-(\alpha + j\omega)t} dt$$

$$= F(\alpha + j\omega) = F(s) = \int_{-\infty}^{\infty} f(t) e^{-st} dt$$

Also $f(t) e^{-\alpha t} = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(\alpha + j\omega) e^{j\omega t} d\omega$

$$f(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(\alpha + j\omega) e^{(\alpha + j\omega)t} d\omega$$

$$= \frac{1}{2\pi} \int_{-\infty}^{\infty} F(s) e^{st} ds \cdot \frac{1}{j} = \frac{1}{2\pi j} \int_{\alpha - j\infty}^{\alpha + j\infty} F(s) e^{st} ds$$

$s = \alpha + j\omega$
 $ds = j d\omega$
 or $d\omega = ds/j$

$$f(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(\alpha + j\omega) e^{(\alpha + j\omega)t} d\omega$$

$$= \frac{1}{2\pi} \int_{-\infty}^{\infty} F(\alpha + j\omega) e^{(\alpha + j\omega)t} e^{-\alpha t} d\omega$$

$$f(t) = \frac{1}{2\pi} \int_{-\infty}^{\infty} F(\alpha + j\omega) e^{(\alpha + j\omega)t} d\omega$$

$$= \frac{1}{2\pi j} \int_{\alpha - j\infty}^{\alpha + j\infty} F(s) e^{st} ds$$

Inverse Laplace Transform

$s = \alpha + j\omega$
 $ds = j d\omega$
 $d\omega = \frac{1}{j} ds$

single-sided (unilateral) Laplace Transformation

$$\mathcal{L}[f(t)] = \int_0^{\infty} f(t) e^{-st} dt$$

$$\mathcal{L}_b[f(t)] = \int_{-\infty}^{\infty} f(t) e^{-st} dt$$

Example

$$f(t) = u(t) = \begin{cases} 1 & t > 0 \\ 0 & t < 0 \end{cases}$$

at $t=0$ discontinuity can be $\frac{1}{2}$, 1 or 0 or ---

$$\mathcal{L}[u(t)] = \int_0^{\infty} 1 e^{-st} dt = \left. -\frac{1}{s} e^{-st} \right|_0^{\infty} = \frac{1}{s} (1 - \lim_{t \rightarrow \infty} e^{-st}) = \frac{1}{s} \text{ when } \text{Re}(s) > 0$$

TABLE 7.2 Laplace Transforms

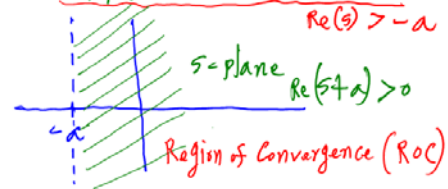
$f(t), t \geq 0$	$F(s)$	ROC
1. $\delta(t)$	1	All s
2. $u(t)$	$\frac{1}{s}$	$\text{Re}(s) > 0$
3. t	$\frac{1}{s^2}$	$\text{Re}(s) > 0$
4. t^n	$\frac{n!}{s^{n+1}}$	$\text{Re}(s) > 0$
5. e^{-at}	$\frac{1}{s+a}$	$\text{Re}(s) > -a$
6. te^{-at}	$\frac{1}{(s+a)^2}$	$\text{Re}(s) > -a$
7. $t^n e^{-at}$	$\frac{n!}{(s+a)^{n+1}}$	$\text{Re}(s) > -a$
8. $\sin bt$	$\frac{b}{s^2 + b^2}$	$\text{Re}(s) > 0$
9. $\cos bt$	$\frac{s}{s^2 + b^2}$	$\text{Re}(s) > 0$
10. $e^{-at} \sin bt$	$\frac{b}{(s+a)^2 + b^2}$	$\text{Re}(s) > -a$
11. $e^{-at} \cos bt$	$\frac{s+a}{(s+a)^2 + b^2}$	$\text{Re}(s) > -a$
12. $t \sin bt$	$\frac{2bs}{(s^2 + b^2)^2}$	$\text{Re}(s) > 0$
13. $t \cos bt$	$\frac{s^2 - b^2}{(s^2 + b^2)^2}$	$\text{Re}(s) > 0$

Example $u(t-t_0)$

$$\begin{aligned} \mathcal{L}[u(t-t_0)] &= \int_0^{\infty} u(t-t_0) e^{-st} dt \\ &= \int_{t_0}^{\infty} e^{-st} dt = \left. -\frac{e^{-st}}{s} \right|_{t_0}^{\infty} \\ &= \frac{1}{s} (e^{-st_0} - \lim_{t \rightarrow \infty} e^{-st}) \\ &= \frac{1}{s} e^{-st_0} \text{ for } \text{Re}(s) > 0 \end{aligned}$$

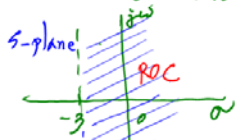
Example $f(t) = e^{-at}$

$$\begin{aligned} \mathcal{L}[f(t)] = F(s) &= \int_0^{\infty} e^{-at} e^{-st} dt = \int_0^{\infty} e^{-(s+a)t} dt \\ &= \left. -\frac{e^{-(s+a)t}}{s+a} \right|_0^{\infty} = \frac{1}{s+a} (1 - \lim_{t \rightarrow \infty} e^{-(s+a)t}) \\ &= \frac{1}{s+a} \text{ when } \text{Re}(s+a) > 0 \end{aligned}$$



$f(t) = e^{-3t}$

$$\mathcal{L}[e^{-3t}] = \frac{1}{s+3}$$



pole at $s_p = -3$

$f(t) = e^{+3t}$

$a = -3 < 0$

$$\mathcal{L}[e^{+3t}] = \frac{1}{s-3}$$



pole at $s_p = +3$

$\mathcal{L}[\cos \omega_0 t] = ?$

$$\begin{aligned} &= \int_0^{\infty} \left(\frac{e^{+j\omega_0 t} + e^{-j\omega_0 t}}{2} \right) e^{-st} dt \\ &= \frac{1}{2} \int_0^{\infty} [e^{-(s-j\omega_0)t} + e^{-(s+j\omega_0)t}] dt \\ &= \frac{1}{2} \left(\frac{1}{-(s-j\omega_0)} + \frac{1}{-(s+j\omega_0)} \right) \Big|_0^{\infty} \\ &= \frac{1}{2} \left(\frac{1}{s-j\omega_0} (1 - e^{-(s-j\omega_0)t}) \Big|_0^{\infty} + \frac{1 - e^{-(s+j\omega_0)t}}{s+j\omega_0} \Big|_0^{\infty} \right) \\ &= \frac{1}{2} \left(\frac{1}{s-j\omega_0} + \frac{1}{s+j\omega_0} \right) \\ &= \frac{1}{2} \frac{s+j\omega_0 + s-j\omega_0}{s^2 + \omega_0^2} = \frac{s}{s^2 + \omega_0^2} \end{aligned}$$

Example

$$\mathcal{L}\left[e^{-at} \cos \omega_0 t\right] = ?$$

$$e^{-at} \cos \omega_0 t = e^{-at} \left[\frac{e^{+j\omega_0 t} + e^{-j\omega_0 t}}{2} \right]$$

$$= \frac{1}{2} \left[e^{-(a-j\omega_0)t} + e^{-(a+j\omega_0)t} \right]$$

↓ \mathcal{L}

$$\frac{1}{2} \left[\frac{1}{s+a-j\omega_0} + \frac{1}{s+a+j\omega_0} \right]$$

$$= \frac{1}{2} \left[\frac{s+a+j\omega_0 + s+a-j\omega_0}{(s+a-j\omega_0)(s+a+j\omega_0)} \right] = \frac{(s+a)}{(s+a)^2 + \omega_0^2}$$

Example

$$\mathcal{L}\left[\frac{d}{dt} f(t)\right] = ?$$

$$\int_0^{\infty} \left[\frac{d}{dt} f(t)\right] e^{-st} dt$$

$$\stackrel{\text{Re } s > 0}{=} f(t) e^{-st} \Big|_0^{\infty} - \int_0^{\infty} f(t) d(e^{-st})$$

$$= 0 - f(0) - \int_0^{\infty} f(t) (-s) e^{-st} dt$$

$$= sF(s) - f(0)$$

$$\mathcal{L}[f(t)] = \int_0^{\infty} f(t) e^{-st} dt = 1$$

$$\mathcal{L}[u(t)] = \frac{1}{s}$$

$$f(t) = \frac{d}{dt} u(t)$$

↓ \mathcal{L} ↓ \mathcal{L}

$$1 \qquad \qquad \qquad s \left(\frac{1}{s} - u(s) \right)$$

$$\qquad \qquad \qquad s \left(\frac{1}{s} - 0 \right)$$

$$\qquad \qquad \qquad = 1$$

Example

$$\sin \omega_0 t = \left(-\frac{1}{\omega_0}\right) \frac{d}{dt} (\cos \omega_0 t)$$

↓ \mathcal{L}

$$\left(-\frac{1}{\omega_0}\right) \left(s \left[\frac{s}{s^2 + \omega_0^2} \right] - 1 \right)$$

$$= -\frac{1}{\omega_0} \frac{s^2 - s^2 - \omega_0^2}{s^2 + \omega_0^2} = \frac{\omega_0}{s^2 + \omega_0^2}$$

(same)

Alternatively

$$\sin \omega_0 t = \frac{e^{+j\omega_0 t} - e^{-j\omega_0 t}}{2j} = \frac{1}{2j} \left[e^{+j\omega_0 t} - e^{-j\omega_0 t} \right]$$

$$\mathcal{L} \rightarrow \frac{1}{2j} \left[\frac{1}{s-j\omega_0} - \frac{1}{s+j\omega_0} \right] = \frac{1}{2j} \left[\frac{s+j\omega_0 - s+j\omega_0}{s^2 + \omega_0^2} \right] = \frac{\omega_0}{s^2 + \omega_0^2}$$

TABLE 7.3 Laplace Transform Properties

Name	Property
1. Linearity, (7.10)	$\mathcal{L}\{a f(t) + b f(t)\} = a F(s) + b F(s)$
2. Derivative, (7.15)	$\mathcal{L}\left[\frac{df(t)}{dt}\right] = sF(s) - f(0^+)$
3. nth-order derivative, (7.29)	$\mathcal{L}\left[\frac{d^n f(t)}{dt^n}\right] = s^n F(s) - s^{n-1} f(0^+) - \dots - f^{(n-2)}(0^+) - f^{(n-1)}(0^+)$
4. Integral, (7.31)	$\mathcal{L}\left[\int_0^t f(\tau) d\tau\right] = \frac{F(s)}{s}$
5. Real shifting, (7.22)	$\mathcal{L}\{f(t - t_0)u(t - t_0)\} = e^{-st_0} F(s)$
6. Complex shifting, (7.20)	$\mathcal{L}\{e^{-at} f(t)\} = F(s + a)$
7. Initial value, (7.36)	$\lim_{t \rightarrow 0^+} f(t) = \lim_{s \rightarrow \infty} sF(s)$
8. Final value, (7.38)	$\lim_{t \rightarrow \infty} f(t) = \lim_{s \rightarrow 0} sF(s)$
9. Multiplication by t , (7.34)	$\mathcal{L}\{t f(t)\} = -\frac{dF(s)}{ds}$
10. Time transformation, (7.42) ($a > 0, b \geq 0$)	$\mathcal{L}\{f(at - b)u(at - b)\} = \frac{e^{-bs/a}}{a} F\left(\frac{s}{a}\right)$
11. Convolution	$\mathcal{L}\{f_1(t) f_2(t)\} = \int_0^t f_1(\tau) f_2(t - \tau) d\tau$ $= \int_0^t f_1(t - \tau) f_2(\tau) d\tau$
12. Time periodicity	$\mathcal{L}\{f(t)\} = \frac{1}{1 - e^{-sT}} F(s)$, where $f(t) = f(t + T), t \geq 0$ $F(s) = \int_0^T f(t) e^{-st} dt$

→ LTI →

$$x_1 \longrightarrow y_1$$

$$x_2 \longrightarrow y_2$$

$$ax_1 + bx_2 \longrightarrow ay_1 + by_2$$

$$\mathcal{L}[ax_1 + bx_2] = a \mathcal{L}x_1 + b \mathcal{L}x_2$$

Oliver Heaviside

From Wikipedia, the free encyclopedia

"Heaviside" redirects here. For other uses, see Heaviside (disambiguation).

Oliver Heaviside FRS¹ (/ˈheɪvɪsaɪd/ *HEI-vayd*; 18 May 1850 – 3 February 1925) was an English self-taught electrical engineer, mathematician, and physicist who adopted complex numbers to the study of electrical circuits, invented mathematical techniques for the solution of differential equations (equivalent to Laplace transforms), reformulated Maxwell's field equations in terms of electric and magnetic fields and energy flux, and independently discovered vector calculus. Although at odds with the scientific establishment for most of his life, Heaviside changed the face of telecommunications, mathematics, and science for years to come.^[2]

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