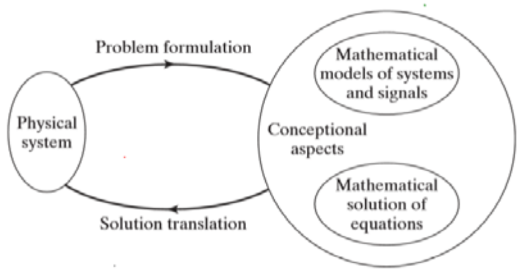
EE 103 Lect #21 Nov 17, 2017



The idea of the integrated circuit was conceived by Geoffrey 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.[6] 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 1951's Project Tinkertoy).[7] However, as the project was gaining momentum, Kilby came up with a new, revolutionary design: the IC.

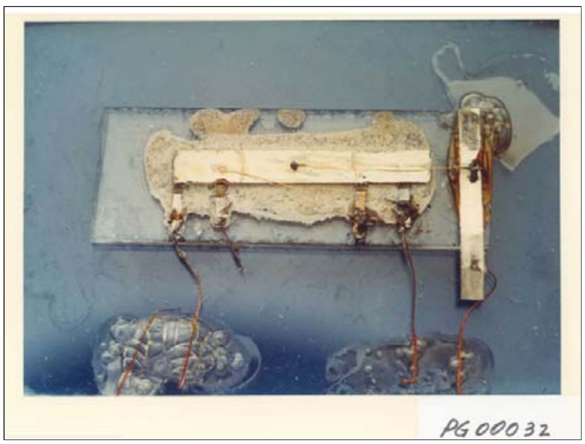
Newly employed by Texas Instruments, Kilby recorded his initial ideas concerning the integrated circuit in July 1958, successfully demonstrating the first working integrated example on 12 September 1958.[8] In his patent application of 6 February 1959,[9] Kilby described his new device as "a body of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

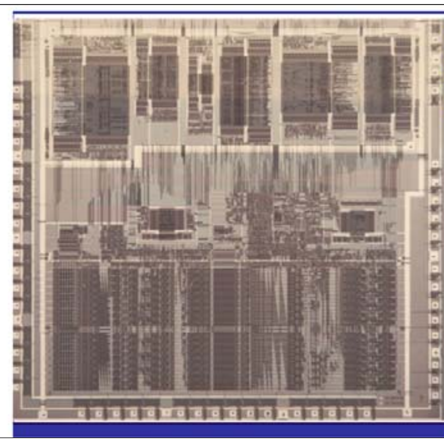

Jack Kilby's original integrated circuit

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 at 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 credited Kurt Lehovec 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.

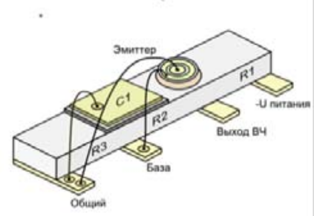
Fairchild Semiconductor was also home of the first silicon-gate IC technology with self-aligned gates, the basis of all modern CMOS computer chips. The technology was developed by Italian physicist Federico Faggin in 1968. In 1970, he joined Intel in order to develop the first single-chip central processing unit (CPU) microprocessor, the Intel

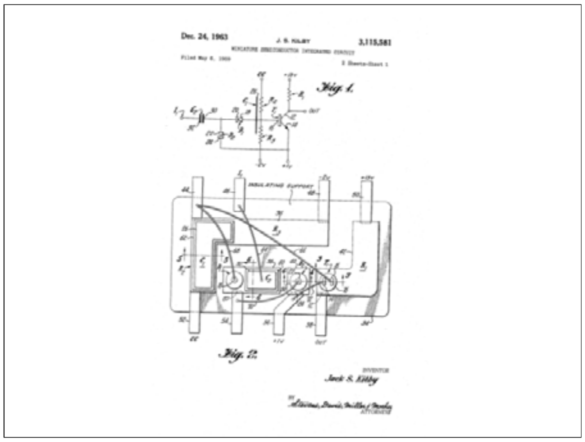


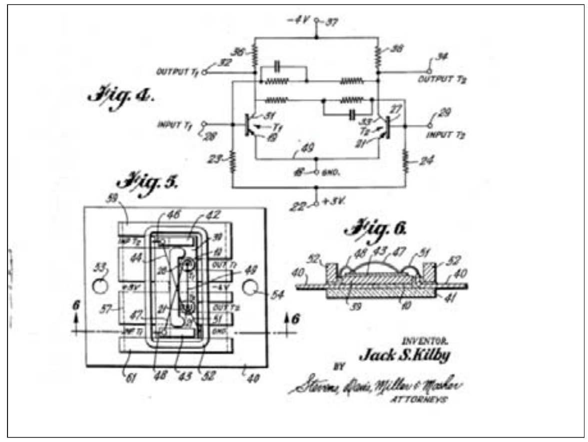


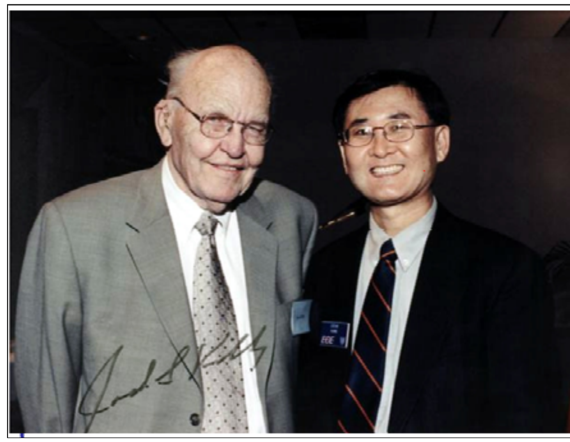
AT&T Bellmac-32A (1981)

Килби, 1959









Mathematical Models of physical Elements

	Time Domain t	Freq Domain ω Fourier Transform	Complex s domain Laplace Transform
R (i, $+\ v\ -$)	$v = Ri$ Ohm's Law	$V(\omega) = R\,I(\omega)$	$V(s) = R\,I(s)$
C (i, $+\ v\ -$)	$i = C\frac{dv}{dt}$ $v = \frac{1}{C}\int_{-\infty}^{t} i(\tau)\,d\tau$	$I(\omega) = j\omega C\,V(\omega)$ $V(\omega) = \frac{1}{j\omega C} I(\omega)$	$I(s) = sC\,V(s)$ $V(s) = \frac{1}{sC} I(s)$
L (i, $+\ v\ -$)	$v = L\frac{di}{dt}$ $i = \frac{1}{L}\int_{-\infty}^{t} v(\tau)\,d\tau$	$V(\omega) = j\omega L\,I(\omega)$ $I(\omega) = \frac{1}{j\omega L} V(\omega)$	$V(s) = sL\,I(s)$ $I(s) = \frac{1}{sL} V(s)$
	ordinary diff. eq	Algebra	Algebra

Laplace, Pierre (1749-1827)

French physicist and mathematician who put the final capstone on mathematical astronomy ...

Laplace believed the universe to be completely deterministic.

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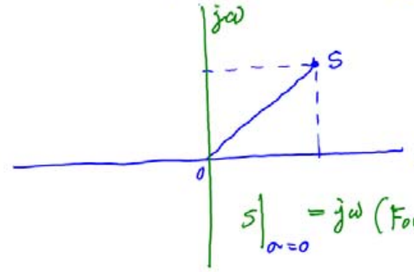
s-plane ($s = \sigma + j\omega$)



$s\big|_{\sigma=0} = j\omega$ (Fourier Transf.)

Input $x(t)$ → $\boxed{H}$ → output $y(t)$

$\delta(t)$ → $h(t)$

$x(t)$ characterization: $h(t)$, $H(\omega)$, $H(s)$

$x(t) * h(t) = \int_{-\infty}^{\infty} x(t-\tau)h(\tau)d\tau = \int_{-\infty}^{\infty} x(\tau)h(t-\tau)d\tau$

$e^{j\omega_0 t} \longrightarrow H(\omega_0)e^{j\omega_0 t}$

$$\boxed{e^{st} \longrightarrow H(s)e^{st}}$$

For $x(t) = e^{st}$, $\quad y(t) = \int_{-\infty}^{\infty} h(\tau) e^{s(t-\tau)} d\tau$

$= \underbrace{\int_{-\infty}^{\infty} h(\tau) e^{-s\tau} d\tau}_{} \cdot e^{st}$

$= H(s)\, e^{st}$

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

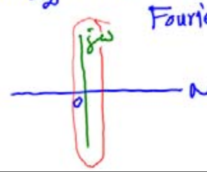
Generally $F(s) = \int_{-\infty}^{\infty} f(t) e^{-st} dt$

Bilateral Laplace Transform

When $s = j\omega$

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

Fourier Transform



For $\sigma > 0$

$\mathcal{F}[f(t)e^{-\sigma t}] = \int_{-\infty}^{\infty} f(t) e^{-\sigma t} \cdot e^{-j\omega t} dt$

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

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

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

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

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

$s = \sigma + j\omega$
$ds = j\,d\omega$
or $d\omega = ds/j$

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

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

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

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

Inverse Laplace Transform

$s = \sigma + j\omega$
$ds = j\,d\omega$
$\boxed{d\omega = \frac{1}{j} ds}$

Single-sided (Unilateral) Laplace Transformation

$\mathcal{L}[f(t)] = \int_{0}^{\infty} f(t)\, e^{-st}\, dt$

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

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 - - -

$\mathcal{L}[u(t)] = \int_0^{\infty} 1\, e^{-st}\, dt = \frac{1}{-s}\, e^{-st} \Big|_0^{\infty}$

$= \frac{1}{s}\left(1 - \lim_{t \to \infty} e^{-st}\right) = \boxed{\frac{1}{s}}$ when $Re(s) > 0$

TABLE 7.2 Laplace Transforms

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

Example $u(t-t_0)$

$\mathcal{L}[u(t-t_0)] = \int_0^{\infty} u(t-t_0)\, e^{-st}\, dt$

$= \int_{t_0}^{\infty} e^{-st}\, dt = \frac{e^{-st}}{-s} \Big|_{t_0}^{\infty}$

$= \frac{1}{s}\left(e^{-st_0} - \lim_{t \to \infty} e^{-st}\right)$

$= \frac{1}{s} e^{-st_0}$ for $Re\, s > 0$

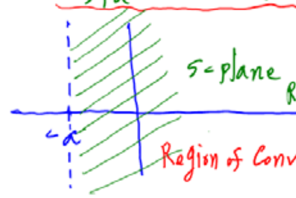
Example $f(t) = e^{-at}$

$\mathcal{L}[f(t)] = F(s) = \int_0^{\infty} e^{-at} \cdot e^{-st}\, dt = \int_0^{\infty} e^{-(s+a)t}\, dt$

$= \frac{e^{-(s+a)t}}{-(s+a)} \Big|_0^{\infty} = \frac{1}{s+a}\left(1 - \lim_{t \to \infty} e^{-(s+a)t}\right)$

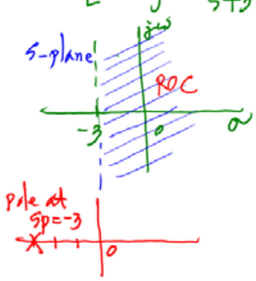
$= \frac{1}{s+a}$ when $Re(s+a) > 0$

$Re(s) > -a$



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

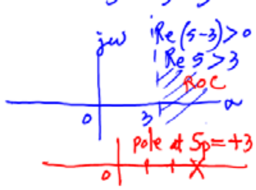
$\mathcal{L}[e^{-3t}] = \frac{1}{s+3}$



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

$a = -3 < 0$

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



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

$= \int_0^{\infty} \left(\frac{e^{+j\omega_0 t} \overset{-}{+} e^{-j\omega_0 t}}{2} \right) e^{-st}\, dt$

$= \frac{1}{2} \int_0^{\infty} \left[e^{-(s-j\omega_0)t} + e^{-(s+j\omega_0)t} \right] dt$

$= \frac{1}{2} \left(\frac{e^{-(s-j\omega_0)t}}{-(s-j\omega_0)} + \frac{e^{-(s+j\omega_0)t}}{-(s+j\omega_0)} \right) \Big|_0^{\infty}$

$= \frac{1}{2} \left(\frac{1}{s-j\omega_0}\left(1 - e^{-(s-j\omega_0)t}\right) \Big|_{\lim t \to \infty} + \frac{1 - e^{-(s+j\omega_0)t}}{s+j\omega_0} \Big|_{\lim t \to \infty} \right)$

$\overset{Re\, s > 0}{=} \frac{1}{2} \left[\frac{1}{s-j\omega_0} + \frac{1}{s+j\omega_0} \right]$

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

Example

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

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

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

$$\downarrow \mathcal{L}$$

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

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

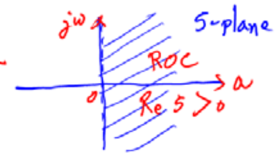
$$\mathcal{L}\left[\frac{d}{dt}f(t)\right] = ?$$

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

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

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

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



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

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

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

$$\mathcal{L}\downarrow \qquad \downarrow\mathcal{L}$$

$$1 \qquad sU(s) - u(0)$$

$$s\frac{1}{s} - 0$$

$$= 1$$

Example

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

$$\downarrow \mathcal{L}$$

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

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

same

Alternatively

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

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

TABLE 7.3 Laplace Transform Properties

Name	Property
1. Linearity, (7.10)	$\mathcal{L}[a_1f_1(t) + a_2f_2(t)] = a_1F_1(s) + a_2F_2(s)$
2. Derivative, (7.15)	$\mathcal{L}\left[\frac{df(t)}{dt}\right] = sF(s) - f(0^+)$
3. nth-order derivative, (7.29)	$\mathcal{L}\left[\frac{d^nf(t)}{dt^n}\right] = s^nF(s) - s^{n-1}f(0^+) - \cdots - sf^{(n-2)}(0^+) - f^{(n-1)}(0^+)$
4. Integral, (7.31)	$\mathcal{L}\left[\int_0^t f(\tau)d\tau\right] = \frac{F(s)}{s}$
5. Real shifting, (7.22)	$\mathcal{L}[f(t-t_0)u(t-t_0)] = e^{-t_0s}F(s)$
6. Complex shifting, (7.20)	$\mathcal{L}[e^{-at}f(t)] = F(s+a)$
7. Initial value, (7.36)	$\lim_{t\to 0^+} f(t) = \lim_{s\to\infty} sF(s)$
8. Final value, (7.39)	$\lim_{t\to\infty} f(t) = \lim_{s\to 0} sF(s)$
9. Multiplication by t, (7.34)	$\mathcal{L}[tf(t)] = -\frac{dF(s)}{ds}$
10. Time transformation, (7.42) ($a > 0; b \geq 0$)	$\mathcal{L}[f(at-b)u(at-b)] = \frac{e^{-sb/a}}{a}F\left(\frac{s}{a}\right)$
11. Convolution	$\mathcal{L}^{-1}[F_1(s)F_2(s)] = \int_0^t f_1(t-\tau)f_2(\tau)\,d\tau = \int_0^t f_1(\tau)f_2(t-\tau)d\tau$
12. Time periodicity $[f(t) = f(t+T)], t \geq 0$	$\mathcal{L}[f(t)] = \frac{1}{1-e^{-sT}}F_1(s)$, where $F_1(s) = \int_0^T f(t)e^{-st}\,dt$

$$x_1 \longrightarrow y_1$$

$$x_2 \longrightarrow y_2$$

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

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

Oliver Heaviside

From Wikipedia, the free encyclopedia

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

Oliver Heaviside FRS[1] (/ˈɒlɪvər ˈhɛvisaɪd/; 18 May 1850 – 3 February 1925) was an English self-taught electrical engineer, mathematician, and physicist who adapted 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 forces and energy flux, and independently co-formulated vector analysis. 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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Oliver Heaviside