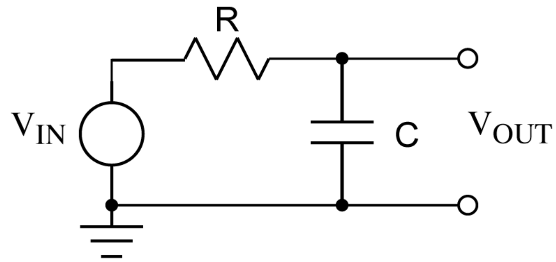
BANDWIDTH – RISETIME RELATIONSHIP

Consider the single-time-constant circuit:
(also called "first order" since it has one
independent energy storage element, C)



Using the impedances Z_R=R and Z_C=1/jwC,
the voltage divider relationship gives

$$H(\omega) = \frac{v_{out}}{v_{in}} = \frac{Z_C}{Z_R + Z_C} = \frac{1}{1 + j\omega RC} \qquad \text{with } \omega = 2\pi f \qquad H(f) = \frac{1}{1 + j2\pi fRC} \qquad [1]$$

for the transfer function in the frequency domain for sinusoidal v_{in} and v_{out}
The frequency at which the H(f) magnitude is a factor of 1/√2 (-3dB) of its maximum defines the bandwidth (3-dB frequency) $$f_{3dB} = \frac{1}{2\pi RC} \qquad [2]$$

and we can express H(f) as $H(f) = \dfrac{1}{1 + j\left(\dfrac{f}{f_{3dB}}\right)}$ which is often easier to work with.

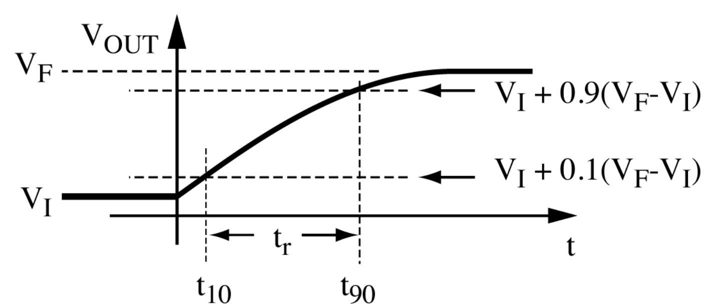
We can relate the bandwidth to the step response in the time domain. Recall the general exponential step response

$$V(t) = V_F - (V_F - V_I)e^{-t/\tau}$$

in which solving the differential equation gave the time constant τ = RC [3]

From [2], [3] bandwidth and time constant are related by $$f_{3dB} = \frac{1}{2\pi\tau} \qquad [4]$$

In practice, a measurement that is usually easier to make is the "rise time" t_r defined as the time for the output to rise from 10% to 90% of the step size:



Using the general step response for the specific times t_{10} and t_{90} and subtracting

$$V_F + 0.1(V_F - V_I) = V_F - (V_F - V_I)e^{-t_{10}/\tau} \quad \text{and} \quad V_F + 0.9(V_F - V_I) = V_F - (V_F - V_I)e^{-t_{90}/\tau}$$

After some math, we have $t_r = 2.2\tau$ [5]

And with [4] and [5] we get $$f_{3dB} \times t_r = 0.35$$

National Semiconductor

August 2000

LM741
Operational Amplifier

General Description

The LM741 series are general purpose operational amplifiers which feature improved performance over industry standards like the LM709. They are direct, plug-in replacements for the 709C, LM201, MC1439 and 748 in most applications.

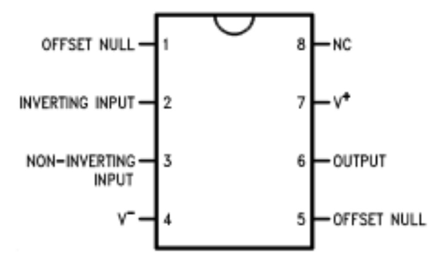
The amplifiers offer many features which make their application nearly foolproof: overload protection on the input and output, no latch-up when the common mode range is exceeded, as well as freedom from oscillations.

The LM741C is identical to the LM741/LM741A except that the LM741C has their performance guaranteed over a 0˚C to +70˚C temperature range, instead of −55˚C to +125˚C.

Features

Connection Diagrams

Dual-In-Line or S.O. Package



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Order Number LM741J, LM741J/883, LM741CN
See NS Package Number J08A, M08A or N08E

Parameter	Conditions	LM741A			LM741			LM741C			Units
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Transient Response	T_A = 25˚C, Unity Gain										
Rise Time			0.25	0.8		0.3			0.3		μs
Overshoot			6.0	20		5			5		%
Bandwidth (Note 6)	T_A = 25˚C	0.437	1.5								MHz

Note 6: Calculated value from: BW (MHz) = 0.35/Rise Time(μs).