

# UTMC APPLICATION NOTE

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## Operational Frequency versus Load Capacitance for UTMC's RadHard MSI Product Family

### Introduction

The following defines the operational frequency versus load capacitance for UTMC's RadHard MSI product family. It contains examples and information related to maximum part frequency based on load capacitance and current density. Capacitance loading limits for UTMC's RadHard MSI Logic devices are also described. The loading limit is defined by the capacitive load that can be driven at the device's maximum operating frequency and/or at the device's current density limit. For reliable operation, both limits should be met for the intended operating frequency and device loading. In addition, information is presented for output rise/fall times which may be a consideration in overall system timing.

### Maximum Frequency Based on Load Capacitance

The maximum frequency for any given device in UTMC's RadHard MSI Logic Product handbook can be derived using the device's AC Electrical Parameters  $t_{PHL}$  and  $t_{PLH}$ . The sum of  $t_{PHL}$  and  $t_{PLH}$  is equal to the reciprocal of the maximum frequency of the device driving a load capacitance ( $C_L$ ) of 50pF as shown in equation 1.0.

Equation 1.0 :

$$f_{MAX} = \frac{1}{(t_{PLH} + t_{PHL})}$$

As  $C_L$  increases, the maximum sustainable toggle frequency ( $f$ ) decreases. The maximum frequency for a given device under different load capacitance can be obtained through use of equation 1.0 by adding a delay derating ( $\Delta t_p$ ) to each AC electrical parameter ( $t_{PLH}$  and  $t_{PHL}$ ) as shown in equation 1.1. Values for delay deratings as a function of output load capacitance are given in table 1 and table 2 for the 8mA and 12mA drivers respectively.

Equation 1.1 :

$$f_{AC} = \frac{1}{(t_{PLH} + t_{PHL} + \Delta t_{PLH} + \Delta t_{PHL})}$$

Where:  $t_{PLH}$  and  $t_{PHL}$  are values specified in the RadHard MSI Logic Product Handbook for a specific device under worst case conditions.

$\Delta t_{PLH}$  and  $\Delta t_{PHL}$  are delay deratings as a function of output load capacitance given in tables 1 and 2.

**Table 1: Propagation delay deratings for RadHard MSI 8mA devices at higher loading**

8mA Devices	Load	$\Delta t_{PLH}$	$\Delta t_{PHL}$
CMOS	50pF	0ns	0ns
	100pF	8ns	8ns
	200pF	25ns	26ns
	300pF	42ns	44ns
TTL	50pF	0ns	0ns
	100pF	4ns	7ns
	200pF	13ns	23ns
	300pF	21ns	38ns

**Table 2: Propagation delay deratings for RadHard MSI 12mA devices at higher loading**

12mA Devices	Load	$\Delta t_{PLH}$	$\Delta t_{PHL}$
CMOS	50pF	0ns	0ns
	100pF	5ns	6ns
	200pF	15ns	17ns
	300pF	28ns	29ns
TTL	50pF	0ns	0ns
	100pF	3ns	5ns
	200pF	9ns	14ns
	300pF	15ns	25ns

**Example:**

Calculate the maximum frequency for device UT54ACS02, (8mA) operating with a load capacitance of 200pF.

The RadHard MSI Logic Product Handbook specifies maximum propagation of  $t_{PHL} = 13\text{ns}$  and  $t_{PLH} = 11\text{ns}$ , from table 1,  $\Delta t_{PLH} = 25\text{ns}$  and  $\Delta t_{PHL} = 26\text{ns}$ .

Therefore, equation 1.1 becomes:

$$f_{AC} = \frac{1}{(11\text{ns} + 13\text{ns} + 25\text{ns} + 26\text{ns})} = 13.33\text{MHz}$$

where  $f_{AC}$  = maximum operating frequency for worst case conditions.

### Maximum Frequency Based on Current Density

Equation 2.0 defines the relationship between maximum operating frequency and load capacitance based upon current density.

Equation 2.0 :

$$f_{MAX} = \frac{3765 \text{ pF-MHz}}{C_L}$$

To determine the maximum number of loads a device can drive (i.e., fan-out) modify equation 2.1 as follows:

Equation 2.1 :

$$\text{fan-out} = \frac{3765 \text{ pF-MHz}}{(C_{IN}) (f_{OP})}$$

Where  $f_{OP}$  defines the frequency of operation or toggle rate  
 $C_{IN}$  defines input capacitance of the load device.

### Example:

Calculate fan-out for a UT54ACS02 operating with a maximum toggle rate of 18.8MHz. Assume the UT54ACS02 is driving other UTMC RadHard MSI Logic devices which have an input capacitance of 15pF each.

$$\text{fan-out} = \frac{3765 \text{ pF-MHz}}{(15\text{pF}) (18.8\text{MHz})} = 13.35\text{loads} \approx 200\text{pF}$$

### Loading Versus Rise/Fall Times

The loading versus rise/fall times for 8mA or 12mA drivers can be determined by using the equations shown in graph 1, 2, 3, or 4. Graphs 1, 2, 3, and 4, represent the relationship between rise/fall time and loading for three different processing and operating conditions. In many cases it is desirable to maintain a rise/fall time of 5ns or less.

### Example:

Calculate the maximum number of loads that a nominally processed UT54ACS02 can drive while maintaining a rise/fall time of 5ns and assuming nominal operating conditions.

From graph 1:  $y = (.048 \text{ ns/pF}) (x \text{ pF}) + 1.18\text{ns}$

$$x = \frac{5\text{ns} - 1.18 \text{ pF}}{.048} = 79.58\text{pF}$$

All UTMC RadHard MSI devices have an input load ( $C_{IN}$ ) of 15pF which yields:

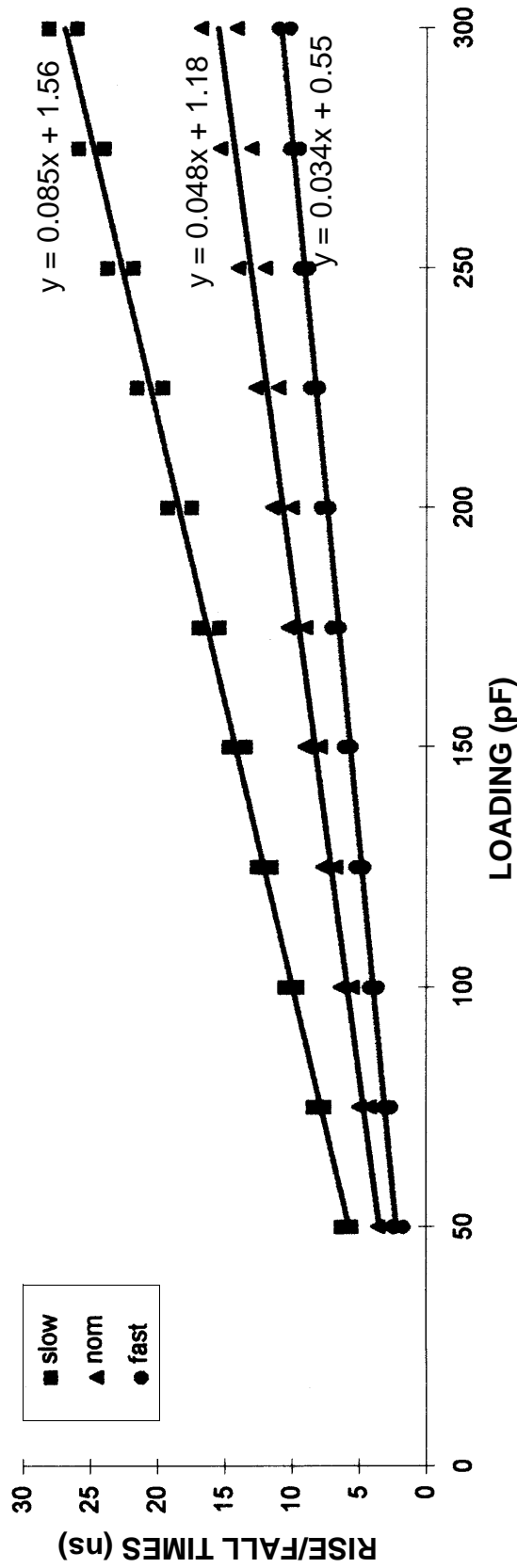
$$x \div 15\text{pF} = \frac{79.58\text{pF}}{15\text{pF}} = 5.3\text{loads}$$

Therefore, operating under nominal process and nominal conditions, the number of loads a UT54ACS02 (8mA driver) can drive while maintaining a 5ns rise time with input loads of 15pF each, is 5 loads.

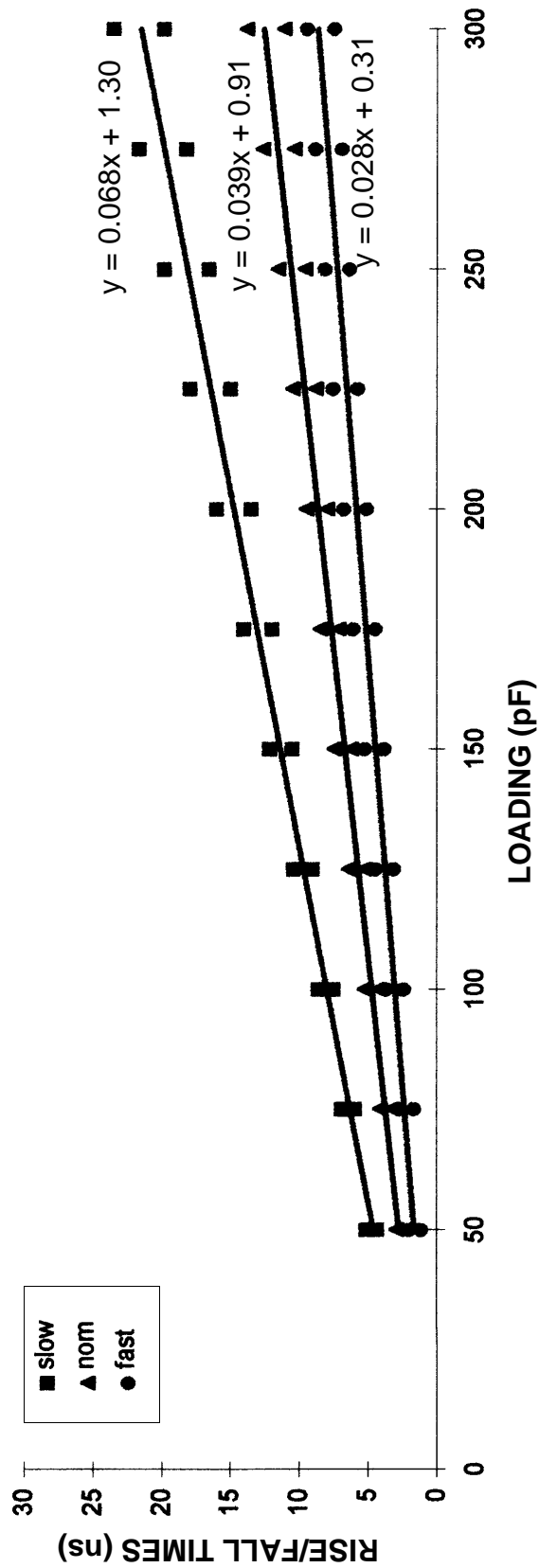
## Summary

This applications note focuses on AC contributions to the operating frequency based on load capacitance. In addition, DC load currents must be considered when determining the maximum number of loads that an output can drive. The DC loading limit is defined by the device's DC sink and/or source specifications.

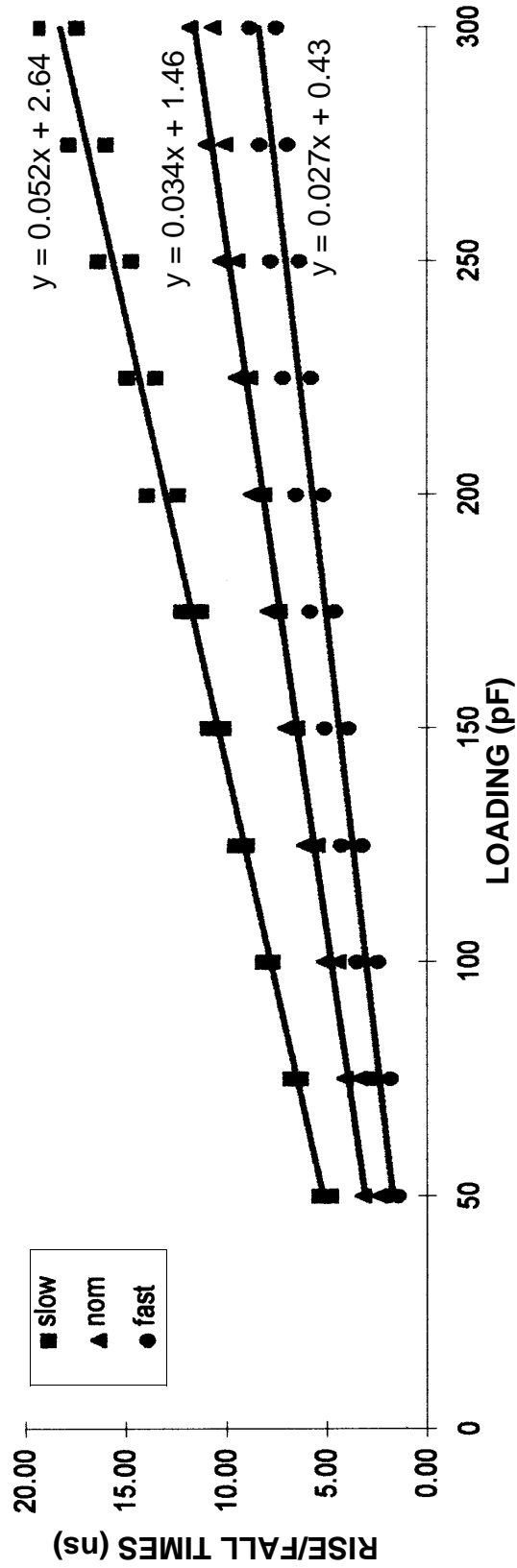
**GRAPH 1: Rad-Hard MSI 8mA CMOS Devices  
Rise/Fall Times vs. Loading**



**GRAPH 2: RadHard MSI 8mA TTL Devices  
Rise/Fall Times vs. Loading**



**GRAPH 3: Rad-Hard MSI 12mA CMOS Devices  
Rise/Fall Times vs. Loading**



**GRAPH 4: RadHard MSI 12mA TTL Devices  
Rise/Fall Times vs. Loading**

