TECHNICAL INFORMATION

FUNCTIONAL TESTING OF DECOUPLING CAPACITORS FOR DYNAMIC RAMs

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Abstract:

Comparative performance of various types of distributed decoupling capacitors both with and without bulk tantalum capacitors is shown under actual operating conditions in a 64K dynamic RAM memory board designed especially for high-frequency in-use testing. Multilayer ceramic capacitors are shown to be effective and economical even without using bulk tantalum capacitors for decoupling.

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Utilization of the new 64K dynamic RAMs in digital electronic systems requires effective decoupling capacitors to minimize high-frequency transients in order to avoid "V bump" or "soft" error problems. Capacitors must also be capable of supplying bulk current requirements during the refresh cycle otherwise undesirable voltage variations ("V droops") will occur. Most capacitor specifications still reflect operation at lower frequencies, higher voltages, and employ dc testing procedures that are not characteristic of present high-speed circuits. For today's applications, particularly decoupling and bypassing, new methods of determining the capacitor performance parameters are required.

AVX has designed and constructed memory test boards to aid in studying the performance of capacitors under actual operating conditions. The results of these tests confirm that a more effective and economical means of decoupling dynamic RAMs can be obtained by increasing the capacitance values of the distributed multilayer ceramic (MLC) capacitors located adjacent to each memory IC, and by eliminating the high-value tantalum capacitors at the end of each row of memory ICs.

Memory Test Boards

Dynamic RAM memory boards were designed and fabricated to determine board noise level ("V bumps")

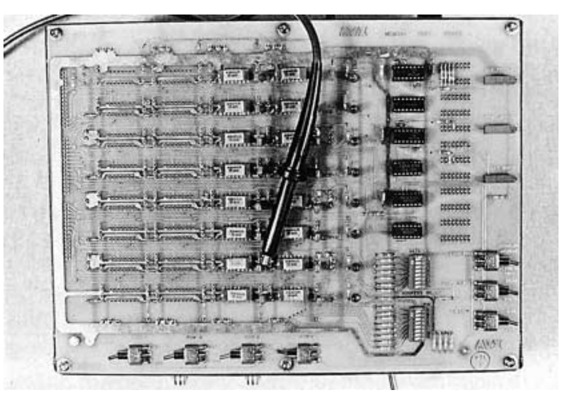

Figure 1. Scope Probe Connected to Terminals on Dynamic RAM Test Board

and voltage droop occurring during the refresh cycle. The two-sided boards (Figure 1) were constructed so as to permit the testing and comparison of various decoupling capacitors during actual use in a digital memory application. Facilities were provided for the insertion, in various patterns throughout the board, of capacitors being tested or compared (Figure 2). A number of test-probe points were placed at various locations for oscilloscope connections.

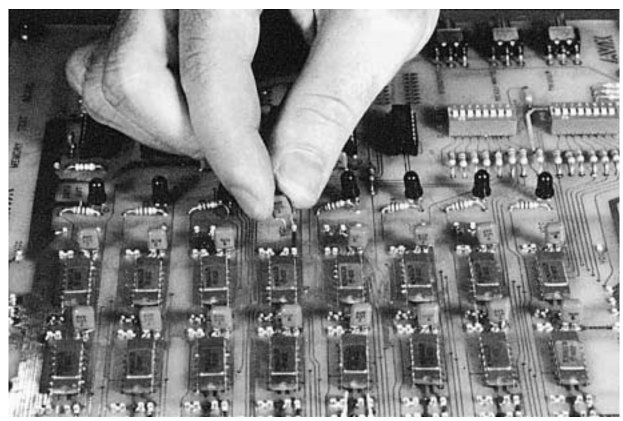

Figure 2. Inserting Capacitor on Memory Test Board

The test boards are for use with single power supply (Vcc = +5V) dynamic RAMs (16 or 64K) in an 8 by 4 array (that is, four rows of memory chips with eight ICs in each row). Two rows (16 units) were populated for these tests. A number of DRAMs from various manufacturers were used to make up several different boards, although on any given memory board memory circuits from a single manufacturer were used.

Each test board provides six variables that can be altered as follows:

Functions: Regular access or refresh only. The regular access occurs about every 500 ns and this is variable; the refresh cycles occur about every 2 ms, also variable.

Trigger: Selects signal to scope. The "RAS" pad provides the scope trigger signal for either regular or refresh modes while the "CAS" pad supplies signal for regular access mode only.

Row Select: A, B, C and D row switches. These determine the row or rows of memory ICs selected during access. The full board is on during refresh cycles.

Read/Write: Read or write from or to memory.

Data In: Applies 0s or 1s to memory chips in each row.

Address Select: Selects address locations (eight only) in each memory.

The last three functions above are provided only for memory verification through the use of LED readouts.

Test Method

Female PC sockets are used for inserting capacitors into the PC board next to each IC memory to provide for the distributed capacitance, and at the end of each memory row for the bulk capacitance. Different capacitor types of various values can be inserted in any combination desired for testing. When bulk capacitors are referred to, it is in reference to those required to supply current on an individual circuit level and not to the large, usually aluminum electrolytics, capacitors required for general power supply and system level filtering.

A high-speed wide-band scope with a bandwidth greater than 250 MHz, such as Tektronix 7834, is used to observe transients and bulk voltage variations between Vcc and ground. A typical scope trace showing the refresh pulse (top) and the resultant supply-line transients and voltage droop during the refresh cycle (bottom) are indicated in Figure 3. The scope displays a vertical deflection of 5 V/div. for the upper trace and 50 mV/div. for the lower trace. Sweep speed indicated is 100 ns/div. for the horizontal deflection.

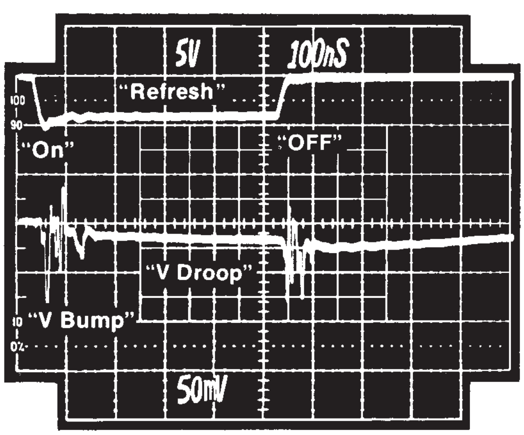

Figure 3. Typical Scope Trace Showing Significant Measurements

Measurements are taken of the "V bump," which is the largest amplitude transient of Vcc after the refresh pulse starts or ends, that is, when RAS goes low or high. Also, the "V droop" is observed as the greatest drift level of Vcc after RAS goes low or high.

Test Results Obtained

Some of the variables studied include the effects on voltage variations and noise resulting from eliminating the bulk capacitors, increasing capacitance values of distributed capacitors, using capacitors with different dielectrics, and using various styles of capacitors with the same dielectric.

The effectiveness of bulk capacitance was evaluated by comparing decoupling schemes using large-value tantalum bulk capacitors and small-value distributed MLC capacitors (Figure 4A) with an arrangement without the bulk capacitors, in which the MLCs were increased in value from 0.1 µF to 0.22 µF (Figure 4B).

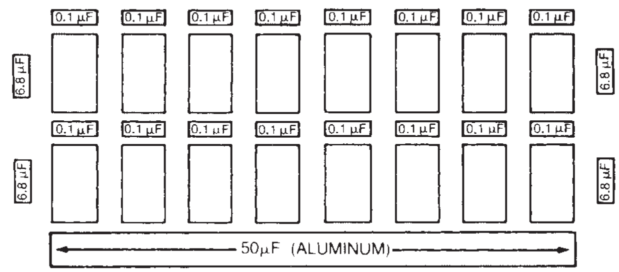

Figure 4A. Decoupling Scheme Using Combination of Bulk and Distributed Capacitors. The Aluminum Electrolytic Provides General Power-Supply Filtering

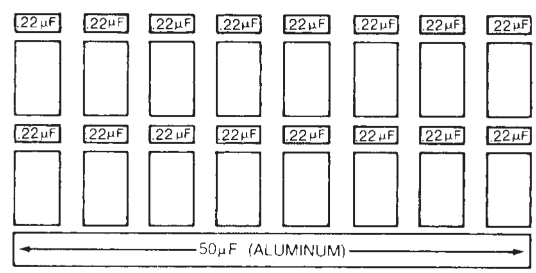

Figure 4B. More Efficient and Economical Decoupling Method Omits the Tantalum Bulk Capacitors and Increases Sizes of Distributed MLC Capacitors

The resulting scope traces produced by these decoupling schemes on the memory board are shown in Figure 5A and 5B. Note that there is no significant difference in either transient noise or bulk droop level using the two decoupling methods. However, the all-MLC approach represents a reduction of four, in the number of capacitors used, along with a reduction in cost of about $1.36 for the 8 by 2 matrix (Table I).

WITH TANTALUMS			
16 X .1 µF CER.	X $.07	=	$1.12
4 X 6.8 µF TA	X $.50	=	$2.00
TOTAL			$3.12
ALL CERAMICS			
16 X .22 µF MLC CER.	X $.11	=	$1.76

Table I. Cost Reduction Resulting from the Omission of the Bulk Capacitors

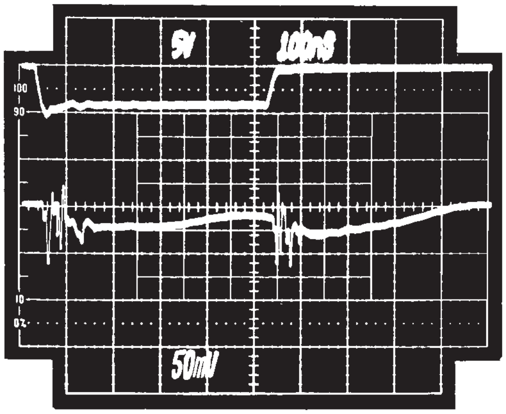

Figure 5A. Memory Board Scope Traces with Both 0.1 µF MLCs and Bulk Capacitors

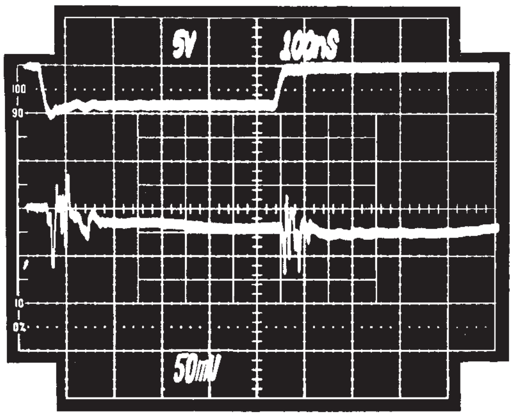

Figure 5B. With Bulk Capacitors Removed and Distributed MLCs Increased to 0.22 µF, Results are Similar

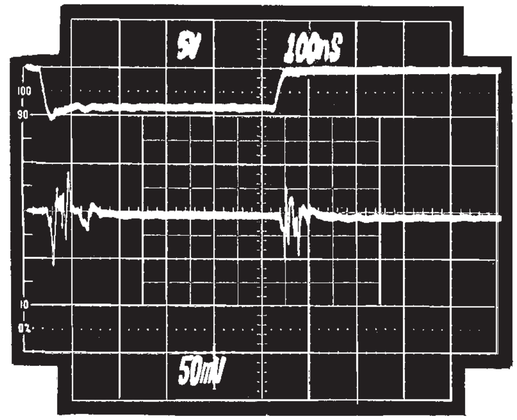

Figure 6A. Results of Increasing Value of Distributed MLCs to 1.0 µF

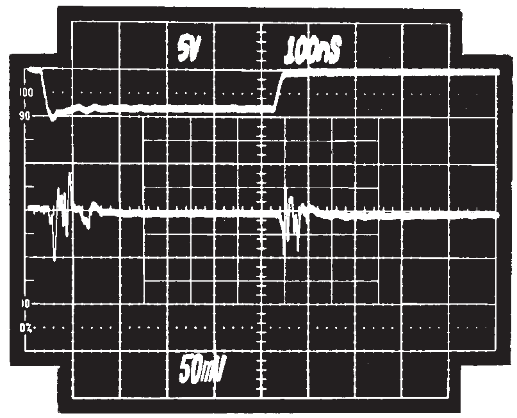

Figure 6B. Adding Bulk Capacitors to 1.0 µfd Distributed MLCs has no Effect on Waveform

Both bulk droop and transient noise are reduced by increasing the value of the distributed MLC capacitors still more to 1.0 µF (Figure 6A). No further reduction is obtained by the addition of the bulk tantalum capacitors as shown in Figure 6B. This approach would be more expensive than using only 0.22 µF MLCs but it does offer additional noise margin for more conservative or critical designs.

Reducing the distributed MLC capacitor values to less than 0.1 µF results in large voltage excursions even with the large-value 6.8 µF tantalum bulk capacitors present (Figure 7). This ineffectiveness of the bulk capacitors is partially contributable to their location and to the high ESR of the tantalum capacitor. This high ESR results from the manganese dioxide used as the counter (cathode) electrode which forms an RC time delay that prevents rapid charging and discharging of the tantalum capacitor. This limits their frequency response and makes their effective capacitance less at high frequencies.

Multilayer ceramic capacitors on the other hand have excellent high-frequency performance because of their layered construction, small size, low series inductance and low series resistance. These advantages are evident when the transient noise levels are compared with distributed capacitors using other dielectrics.

For example, Figure 8 compares the scope traces obtained on the memory board when 0.1 µF MLCs (Figure 8A), 0.1 µF film capacitors (Figure 8B), and 0.15 µF tantalum capacitors (Figure 8C) are used. In all three cases, the large bulk tantalum capacitors are not present. Note how the transients are increased with the use of film and tantalum distributed capacitors. Neither of these schemes represent valid decoupling approaches and are not used or recommended. They are presented here for comparison only.

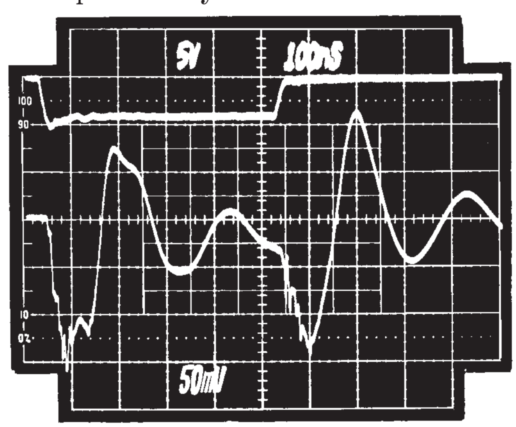

Figure 7. Effect of Using Too Small Values (0.01 µF) of Distributed Capacitors even with Bulk Tantalum Capacitors Present

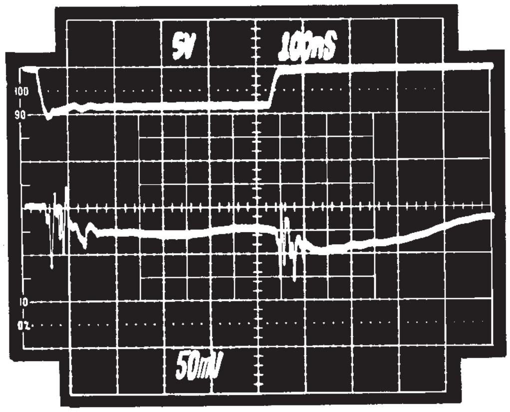

Figure 8A. Radial-lead MLCs Used for Decoupling with no Bulk Capacitors

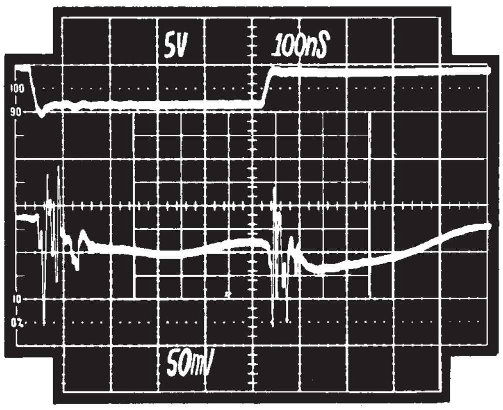

Figure 8B. Use of 0.1 µF Film Capacitors with no Bulk Capacitors

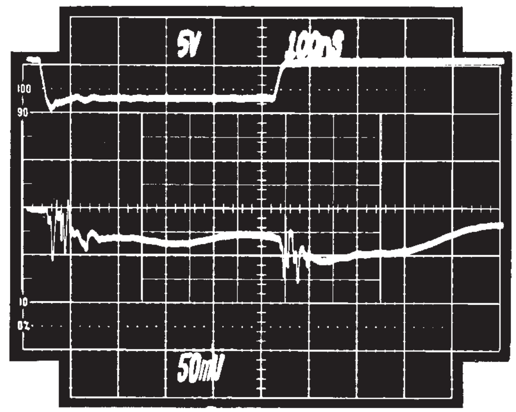

Figure 8D. Dual-in-line MLCs Used for Decoupling with no Bulk Capacitors

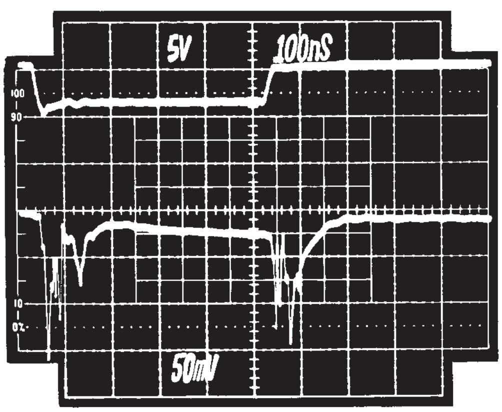

Figure 8C. Use of 0.15 µF Distributed Tantalums with no Bulk Capacitors

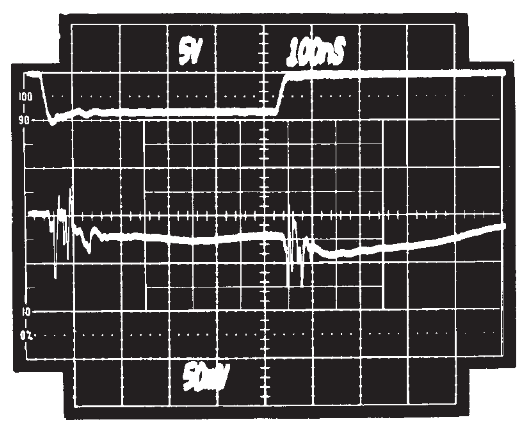

Figure 8E. Axial-lead MLCs Used for Decoupling with no Bulk Capacitors

Finally, different types of multilayer ceramic capacitors were tested in the 64K DRAM test boards. In all cases, the distributed MLCs had a capacitance of 0.1 µF and no bulk tantalum capacitors were used. In Figure 8A, the MLCs are conformally coated units with radial leads; in Figure 8D, they are molded 2-pin dual-in-line units designed to be compatible with standard DIPs; and in Figure 8E, the MLCs are molded axial lead units. Note that there are no significant differences between the decoupling performance of the three types of MLCs.

Summary and Conclusion

A summary of the test results obtained with the 64K memory test board is given in Table II. The table shows the millivolt variations of various types of distributed decoupling capacitors, both with and without bulk capacitors. Headings in the table indicate the values of the distributed capacitors while bulk capacitors, when used, were 6.8 µF tantalums.

It should be pointed out that all scope measurements were taken with the scope probe directly across the decoupling capacitors. Additional inductance exists between the IC chip and the capacitors due to bonding leads, package leads, socket leads and PC board lines. Such terms are not included in the photos comparing capacitors to delivered di/dt and the transients at the IC chip level are at least twice the test figures. It is, therefore, important that both effective board layout and decoupling methods be employed which will permit the memory chip to operate properly and without errors.

Improved decoupling can be accomplished economically through the proposed technique of increasing the distributed capacitance and through the elimination of the bulk level capacitors.

References

A. G. Martin, "Decoupling: 16 K and 64 K Dynamic RAMs" AVX Technical Paper (1981)

	0.01 µFD		0.1 µFD		0.15 µFD		0.22 µFD		1.0 µFD		
CAPACITOR TYPE	BULK	NO BULK	BULK	NO BULK	BULK	NO BULK	BULK	NO BULK	BULK	NO BULK	
FILMS											
BRAND D	—	—	105	130	—	—	—	—	—	—	TRANS.
	—	—	40	70	—	—	—	—	—	—	DROOP
TANTALUMS											
BRAND G	—	—	—	—	—	—	—	—	125	170	TRANS.
	—	—	—	—	—	—	—	—	15	20	DROOP
BRAND H	—	—	—	—	150	160	—	—	100	125	TRANS.
	—	—	—	—	20	25	—	—	10	10	DROOP
MLCs											
AVX RADIALS	—	—	65	80	—	—	60	70	55	60	TRANS.
	—	—	30	40	—	—	15	20	0	5	DROOP
AVX DIPGUARDS	160	200	65	80	—	—	—	—	—	—	TRANS.
	~	~	40	55	—	—	—	—	—	—	DROOP
AVX AXIALS	—	—	60	75	—	—	50	60	—	—	TRANS.
	—	—	25	45	—	—	10	15	—	—	DROOP

Table II. Summary of Test Results Obtained with Various Decoupling Schemes

(1) Variations measured at the capacitor, additional inductance to IC chip estimated to be approximately 6nH or 200 mV.

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