Around about the spring of 1976 John Dinkel contacted me from Road & Track looking for a more modern way to test cars. I had heard about micro computers and read a fair bit about them so I proposed a solution using a micro computer. We came to agreement on a $5,000 fixed price which on hind site was a huge gamble on my part.
I set to work and started to design an Intel 4040 based computer. It turned out to be an engineering nightmare and I was never able to get it to work. Electronic parts at that time required all sorts of voltage level changes. Integrated circuits were not all five volts or had no standardized I/O voltages. I gave up on the Intel 4040 and tried an RCA 1802 CMOS part with standardized I/O voltages. That computer worked sort of and I was able to get it to blink an LED. Along came MOS Technology just in time with a low cost KIM 1 6502 Micro computer. A KIM 1 had it all. A keyboard for writing programs, an LED program counter and data display and a way of storing programs on audio tape. This was several years before the Apple II came out.

I also had to expand the KIM 1 and add output for a printer and a LCD read out.
I also needed to find someway to select programs. That meant I needed an operating system. I wanted the printer to print data as soon as it was available and to display data in real time. For example; distance traveled and speed as well as elapsed time. I also had to get data into the computer someway from a fifth wheel sensor. I thought about it and thought about it and decided to add eight hardware interrupts. The KIM 1 came with only one usable. The display program would be interrupted at appropriate times to handle an incoming data message. These too had to be added to the basic KIM 1. So I added a large perforated PC board and a bunch of wire wrap sockets. Wire wrap was widely used at that time in telephone exchanges so it was very reliable. I used a printing calculator as general purpose small printers were unavailable at that time.

This was probably one of the very first uses of a micro computer in a so called embedded application. Now they are used in everything from watches to car engines.

I had little or no money at the time so I could not afford a mini computer and teletype machine required for writing programs in assemble language. Of course at the time I did not know what an assembler program really did. Later I learned that the assembler program converted the English like mnemonics into binary code the target micro computer could understand. It could also insert code into programs all ready written.

I had to write the program in hex instruction code. Here is a table showing the hex codes for a 6502. The mnemonics are in the right column. There could be as many as 256 individual instruction binary codes. Fortunately not all were implemented.

R6500 INSTRUCTION SET

INSTRUCTIONS		IMMEDIATE			ABSOLUTE			ZERO PAGE			ACCUM.			IMPLIED			(IND, X)		
MNEMONIC	OPERATION	OP	n	#	OP	n	#	OP	n	#	OP	n	#	OP	n	#	OP	n	#
ADC	A + M + C → A (4) (1)	69	2	2	6D	4	3	65	3	2							61	6	2
AND	A ∧ M → A (1)	29	2	2	2D	4	3	25	3	2							21	6	2
ASL	C ← [7 0] ← 0				0E	6	3	06	5	2	0A	2	1						
BCC	BRANCH ON C = 0 (2)																		
BCS	BRANCH ON C = 1 (2)																		
BEQ	BRANCH ON Z = 1 (2)																		
BIT	A ∧ M				2C	4	3	24	3	2									
BMI	BRANCH ON N = 1 (2)																		
BNE	BRANCH ON Z = 0 (2)																		
BPL	BRANCH ON N = 0 (2)																		
BRK	BREAK (See Fig. 1)													00	7	1			
BVC	BRANCH ON V = 0 (2)																		
BVS	BRANCH ON V = 1 (2)																		
CLC	0 → C													18	2	1			
CLD	0 → D													D8	2	1			
CLI	0 → I													58	2	1			
CLV	0 → V													B8	2	1			
CMP	A − M	C9	2	2	CD	4	3	C5	3	2							C1	6	2
CPX	X − M	E0	2	2	EC	4	3	E4	3	2									
CPY	Y − M	C0	2	2	CC	4	3	C4	3	2									
DEC	M − 1 → M				CE	6	3	C6	5	2									
DEX	X − 1 → X													CA	2	1			
DEY	Y − 1 → Y													88	2	1			
EOR	A ⊻ M → A (1)	49	2	2	4D	4	3	45	3	2							41	6	2
INC	M + 1 → M				EE	6	3	E6	5	2									
INX	X + 1 → X													E8	2	1			
INY	Y + 1 → Y													C8	2	1			
JMP	JUMP TO NEW LOC				4C	3	3												
JSR	JUMP SUB (See Fig. 2)				20	6	3												
LDA	M → A (1)	A9	2	2	AD	4	3	A5	3	2							A1	6	2
LDX	M → X (1)	A2	2	2	AE	4	3	A6	3	2									
LDY	M → Y (1)	A0	2	2	AC	4	3	A4	3	2									
LSR	0 → [7 0] → C				4E	6	3	46	5	2	4A	2	1						
NOP	NO OPERATION													EA	2	1			
ORA	A ∨ M → A	09	2	2	0D	4	3	05	3	2							01	6	2
PHA	A → Ms S − 1 → S													48	3	1			
PHP	P → Ms S − 1 → S													08	3	1			
PLA	S + 1 → S Ms → A													68	4	1			
PLP	S + 1 → S Ms → P													28	4	1			
ROL	└[7 0] ← [C]┘				2E	6	3	26	5	2	2A	2	1						
ROR	└[C] → [7 0]┘				6E	6	3	66	5	2	6A	2	1						
RTI	RTRN INT (See Fig. 1)													40	6	1			
RTS	RTRN SUB (See Fig. 2)													60	6	1			
SBC	A − M − C → A (1)	E9	2	2	ED	4	3	E5	3	2							E1	6	2
SEC	1 → C													38	2	1			
SED	1 → D													F8	2	1			
SEI	1 → I													78	2	1			
STA	A → M				8D	4	3	85	3	2							81	6	2
STX	X → M				8E	4	3	86	3	2									
STY	Y → M				8C	4	3	84	3	2									
TAX	A → X													AA	2	1			
TAY	A → Y													A8	2	1			
TSX	S → X													BA	2	1			
TXA	X → A													8A	2	1			
TXS	X → S													9A	2	1			
TYA	Y → A													98	2	1			

(1) ADD 1 to "N" IF PAGE BOUNDARY IS CROSSED

(2) ADD 1 TO "N" IF BRANCH OCCURS TO SAME PAGE
ADD 2 TO "N" IF BRANCH OCCURS TO DIFFERENT PAGE

(3) CARRY NOT = BORROW

(4) IF IN DECIMAL MODE, Z FLAG IS INVALID
ACCUMULATOR MUST BE CHECKED FOR ZERO RESULT

(IND), Y			Z. PAGE, X			ABS, X			ABS, Y			RELATIVE			INDIRECT			Z. PAGE, Y			PROCESSOR STATUS CODES	MNEMONIC
OP	n	#	OP	n	#	OP	n	#	OP	n	#	OP	n	#	OP	n	#	OP	n	#	7 6 5 4 3 2 1 0 N V • B D I Z C	
71	5	2	75	4	2	7D	4	3	79	4	3										N V • • • • Z C	ADC
31	5	2	35	4	2	3D	4	3	39	4	3										N • • • • • Z •	AND
			16	6	2	1E	7	3													N • • • • • Z C	ASL
												90	2	2							• • • • • • • •	BCC
												B0	2	2							• • • • • • • •	BCS
												F0	2	2							• • • • • • • •	BEQ
																					M_7 M_6 • • • • Z •	BIT
												30	2	2							• • • • • • • •	BMI
												D0	2	2							• • • • • • • •	BNE
												10	2	2							• • • • • • • •	BPL
																					• • • 1 • 1 • •	BRK
												50	2	2							• • • • • • • •	BVC
												70	2	2							• • • • • • • •	BVS
																					• • • • • • • 0	CLC
																					• • • • 0 • • •	CLD
																					• • • • • 0 • •	CLI
																					• 0 • • • • • •	CLV
D1	5	2	D5	4	2	DD	4	3	D9	4	3										N • • • • • Z C	CMP
																					N • • • • • Z C	CPX
																					N • • • • • Z C	CPY
			D6	6	2	DE	7	3													N • • • • • Z •	DEC
																					N • • • • • Z •	DEX
																					N • • • • • Z •	DEY
51	5	2	55	4	2	5D	4	3	59	4	3										N • • • • • Z •	EOR
			F6	6	2	FE	7	3													N • • • • • Z •	INC
																					N • • • • • Z •	INX
																					N • • • • • Z •	INY
															6C	5	3				• • • • • • • •	JMP
																					• • • • • • • •	JSR
B1	5	2	B5	4	2	BD	4	3	B9	4	3										N • • • • • Z •	LDA
									BE	4	3							B6	4	2	N • • • • • Z •	LDX
			B4	4	2	BC	4	3													N • • • • • Z •	LDY
			56	6	2	5E	7	3													0 • • • • • Z C	LSR
																					• • • • • • • •	NOP
11	5	2	15	4	2	1D	4	3	19	4	3										N • • • • • Z •	ORA
																					• • • • • • • •	PHA
																					• • • • • • • •	PHP
																					N • • • • • Z •	PLA
																					(RESTORED)	PLP
			36	6	2	3E	7	3													N • • • • • Z C	ROL
			76	6	2	7E	7	3													N • • • • • Z C	ROR
																					(RESTORED)	RTI
																					• • • • • • • •	RTS
F1	5	2	F5	4	2	FD	4	3	F9	4	3										N V • • • • Z (3)	SBC
																					• • • • • • • 1	SEC
																					• • • • 1 • • •	SED
																					• • • • • 1 • •	SEI
91	6	2	95	4	2	9D	5	3	99	5	3										• • • • • • • •	STA
																		96	4	2	• • • • • • • •	STX
			94	4	2																• • • • • • • •	STY
																					N • • • • • Z •	TAX
																					N • • • • • Z •	TAY
																					N • • • • • Z •	TSX
																					N • • • • • Z •	TXA
																					• • • • • • • •	TXS
																					N • • • • • Z •	TYA

X	INDEX X	+	ADD	M_7	MEMORY BIT 7
Y	INDEX Y	−	SUBTRACT	M_6	MEMORY BIT 6
A	ACCUMULATOR	∧	AND	n	NO. CYCLES
M	MEMORY PER EFFECTIVE ADDRESS	∨	OR	#	NO. BYTES
Ms	MEMORY PER STACK POINTER	⊻	EXCLUSIVE OR		

It took me a year to write the program and get everything working. I had to invent a way of inserting code into the program that I had already finished. What I came up with was a printed form that had some of the columns and other pieces of needed information. Here is what the form looked like.

Date ____________ PGM ____________ Rev: ____________ Page _____ of _____

	BINARY	HEXIDECIMAL ADDRESS	OP CODE AND/OR DATA	MNEMONIC	COMMENTS
0	0 0 0 0	0			
1	0 0 0 1	1			
2	0 0 1 0	2			
3	0 0 1 1	3			
4	0 1 0 0	4			
5	0 1 0 1	5			
6	0 1 1 0	6			
7	0 1 1 1	7			
8	1 0 0 0	8			
9	1 0 0 1	9			
10	1 0 1 0	A			
11	1 0 1 1	B			
12	1 1 0 0	C			
13	1 1 0 1	D			
14	1 1 1 0	E			
15	1 1 1 1	F			
16	0 0 0 0	0			
17	0 0 0 1	1			
18	0 0 1 0	2			
19	0 0 1 1	3			
20	0 1 0 0	4			
21	0 1 0 1	5			
22	0 1 1 0	6			
23	0 1 1 1	7			
24	1 0 0 0	8			
25	1 0 0 1	9			
26	1 0 1 0	A			
27	1 0 1 1	B			
28	1 1 0 0	C			
29	1 1 0 1	D			
30	1 1 1 0	E			
31	1 1 1 1	F			

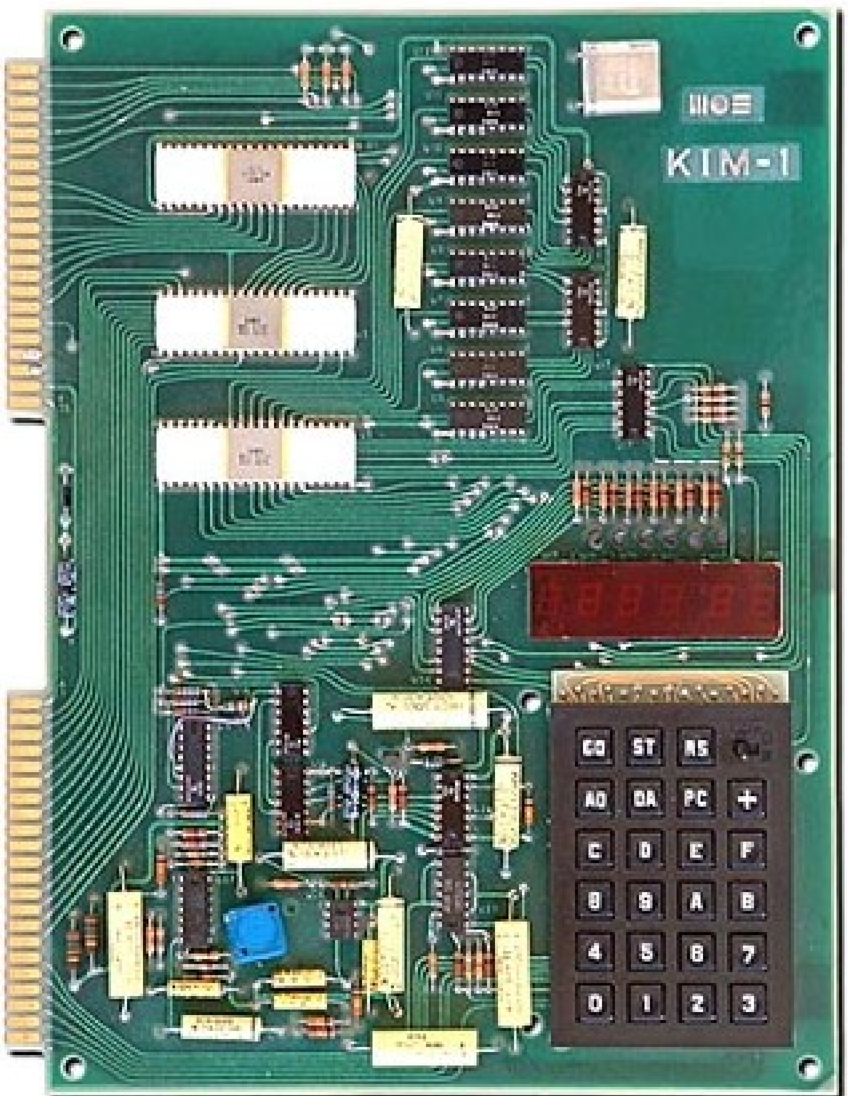
Date ________ PGM ________ Rev. ________ Page ____ of ____

LAMAR INSTRUMENTS / 1024 17th Street / Hermosa Beach, California 90254 / (213) 374-1673

PAGE NO.

I used about 2/3rds of the page and put no operation codes on the rest of the lines. That way I could make corrections and add a bit of code with out starting completely over.
 I would wake up in the morning and find the program had changed overnight and would no longer work. My wife and I had a cat named Kubla. The cat was a would be programmer and was sleeping on the KIM 1 computer keyboard at night because it was warm.
It took me a while to figure out what was happening.

In any event here is the results of all my hard work.



The greatest advance in road testing since the invention of the 5th wheel

BY JOHN DINKEL
Engineering Editor

Paul Lamar (foreground) designed R&T's new computerized road testing equipment. Here Paul and the Engineering Editor examine the data printed out by the modified Addo desk calculator following an acceleration run. On the dash is the microcomputer which takes the place of the electronic distance counter, the DC-AC converter, the electric speedometer, the electric tachometer and the stop watches used previously.

PHOTOS BY JOE RUSZ

COMPUTERIZED ROAD TESTING

WE DON'T BLOW our own horns very often at *Road & Track* so when we do you can figure it's for something very unusual. And special too, because we've totally revamped our road testing equipment, so starting with this issue our road test results will be even more accurate and meaningful than in the past.

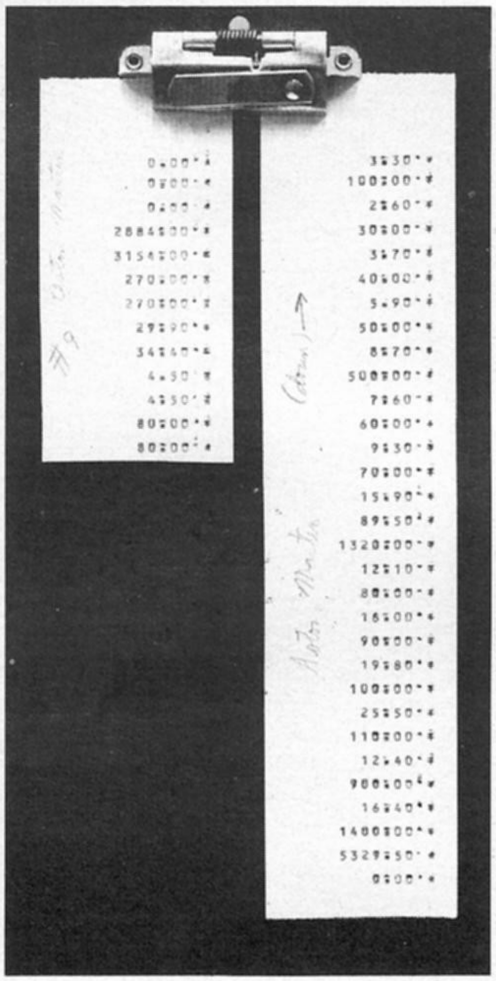
Don't get us wrong. We still feel our previous test procedures and results are the most accurate in the industry, but we'd be remiss if we didn't step back once in a while and take a look at recent advances in technology with an eye toward improving our road test procedures. After all, we strongly believe road tests are our most important product.

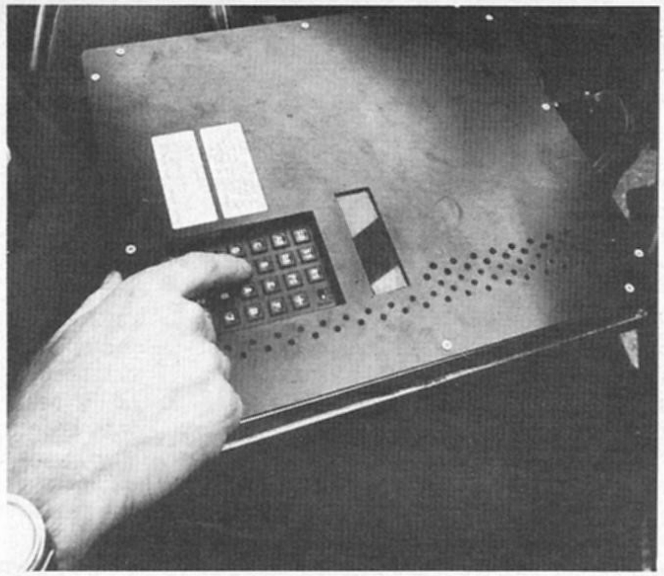
It all began about 1½ years ago when I undertook an investigation to determine if our road test equipment should be updated. The objectives included greater accuracy, 1-man operation for a savings in manhours and light, compact size so the equipment could be more easily carried to other parts of the country than the bulky 5th wheel and the heavy and cumbersome assortment of electrical and mechanical equipment we were using.

One of the people I talked to was Paul Lamar, a man of varied interests and talents. Constant readers of R&T may remember that Lamar provided the instrumentation for the Formula 1 Ferrari Phil Hill helped us test last May. But Lamar's interest in electrical and mechanical devices goes back much further than that. A physics major in college, Lamar went to work for Jim Hall in 1966, following a brief tenure as Chief Engineer for Polytechnic Engineering of Rockville, Maryland. Lamar was a pioneer in the conception and development of race car wings and spoilers for Hall's 2C, 2D and 2E Chaparrals and was also responsible for most of the body design of the Chaparral 2F. In the late Sixties Lamar migrated to California and started Lamar Engineering, designing wings for such racing cars as Chris Amon's 612 Can-Am Ferrari, Charlie Parson's Can-Am Lola and numerous Lola Formula A cars. His expertise in the area of vehicle dynamics and aerodynamics led to a contract with Pontiac for the development of the various spoilers and air ducts that appeared on the 1970 Trans Am Firebird, and in 1972 Lamar built a prototype mid-engine Firebird for Pontiac. Currently, Lamar runs a school of race car design and development (1024 17th St, Hermosa Beach, Calif. 90254; 213 374-1673), works as a consulting engineer and designs and builds automotive testing equipment in his spare time.

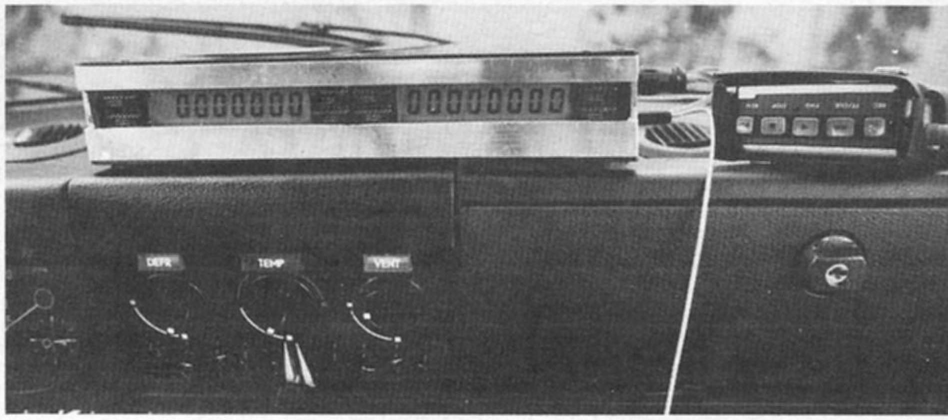
When I asked Lamar for suggestions his reply was quick and concise. "I recommend you consider a microprocessor," Lamar said. "It's the coming thing in electronics. Besides meeting all your objectives, a microprocessor possesses tremendous flexibility. It can generate the basic road test data—times to speeds and distances, braking distances, etc—but beyond that, if you wish to measure such things as lift and drag it's relatively simple and inexpensive to add the additional memory or programming."

A close-up of the printed data. On the left is the result of an 80–0 simulated panic stop. The first number (2884) is the distance at which braking was initiated, the next number (3154) is the distance at which the car came to a stop. Then, repeated twice is the subtraction of the above distances yielding a stopping distance of 270 ft. Next are the times at which braking began and ended; a subtraction gives a braking time of 4.5 sec. Following this is the speed at which braking was initiated, in this case 80 mph. On the right is the data from a typical acceleration run. Times to speed (example: 0–30 mph in 2.6 sec), times to distance (example: 0–100 ft in 3.3 sec) and the quarter-mile time and speed (15.9 sec at 89.5 mph) are obtained during each run.

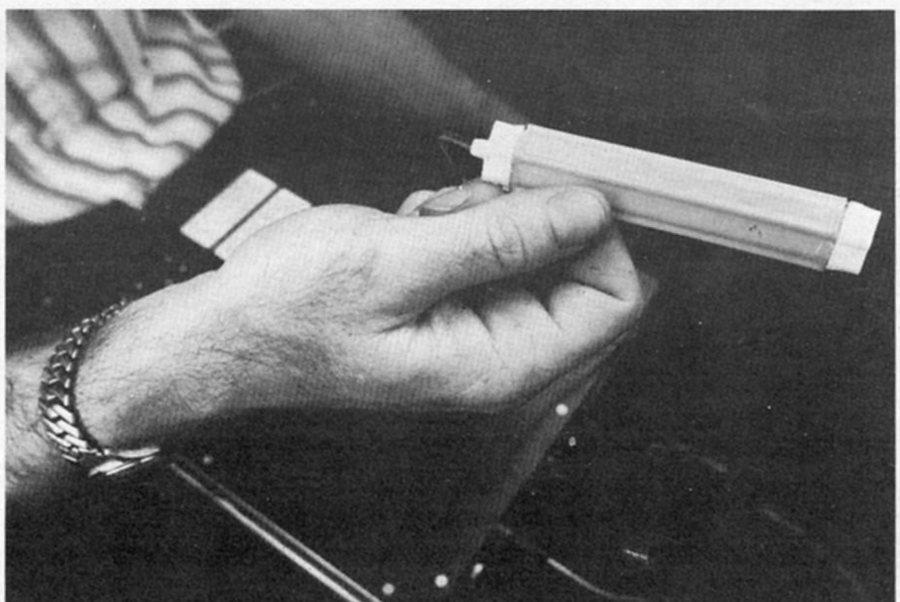




Keyboard portion of the microcomputer allows the operator to initiate the various programs by addressing the computer using hexadecimal language.



Microcomputer's liquid crystal display provides the driver with information on engine rpm, car speed in mph, distance traveled in ft and time in sec. Computer is programmed by a Sony cassette recorder.



Lightweight plastic tape switch attaches to the brake pedal and plugs into the microcomputer. Stepping on the switch actuates the braking program.

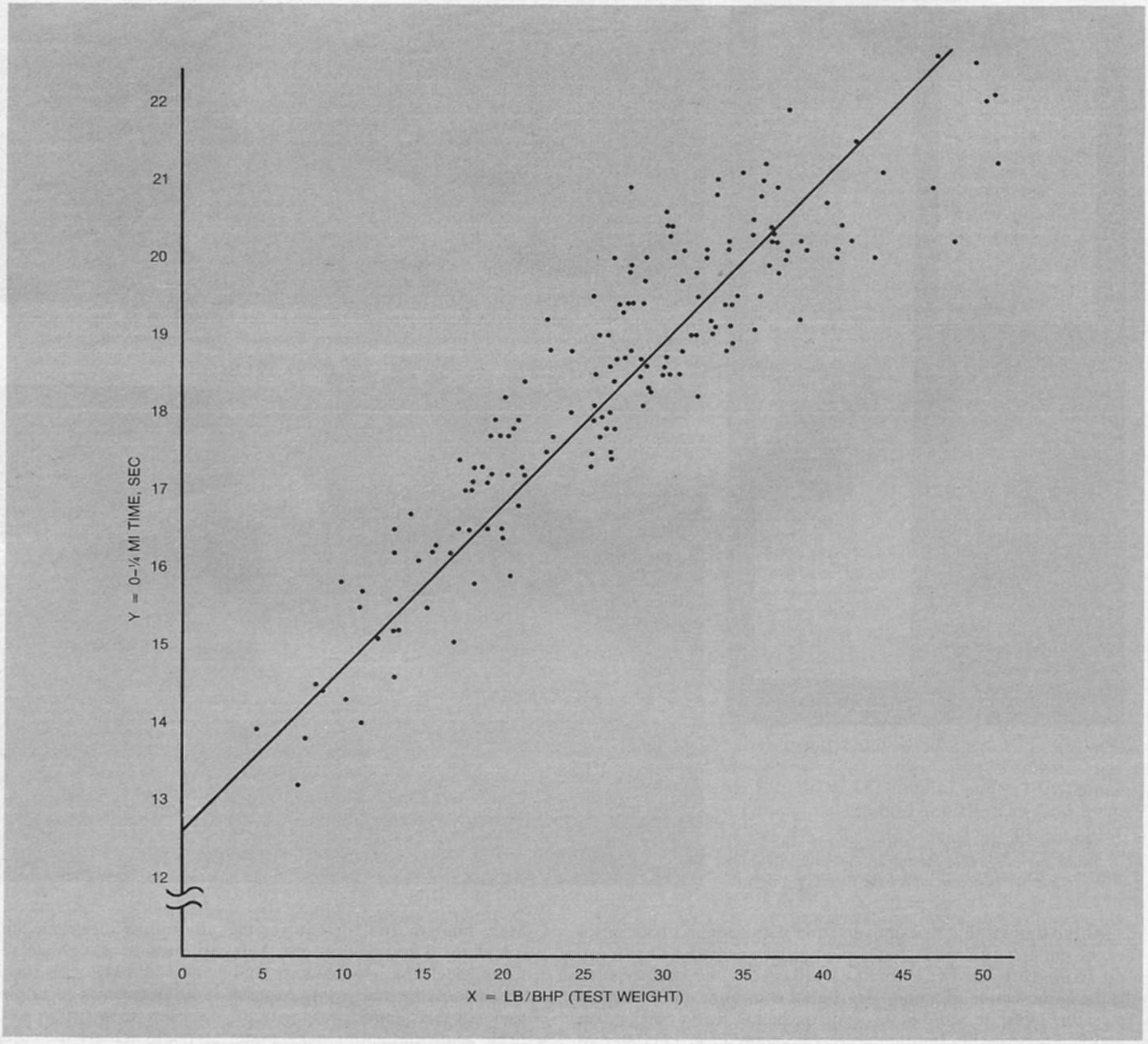
At the time of that first conversation with Lamar, I had only a vague understanding of what a microprocessor is and what it can do. In the past year I've learned a lot. Basically, a microprocessor is the logic section of a compact digital computer that incorporates the latest in solid-state semiconductor technology. Most people are probably familiar with solid-state televisions, stereos and computers, aerospace applications such as Lunar rovers and Mars landers and, of course, the ubiquitous electronic hand calculator. These devices owe their current state of sophistication to an electronics technology that began in 1947 with the invention of the transistor. Around 1960 electronics technology took another leap forward with the discovery that certain metal-oxide-semiconductor (MOS) materials could achieve the voltage amplification and low power dissipation characteristics of an ➛

electron tube. These minute solid-state devices were combined to form integrated circuits containing 100 or more components. Integrated circuits, in turn, led to large-scale integrated circuits with more than 16,000 components all in an area less than a ¼-in. square. Incredible.

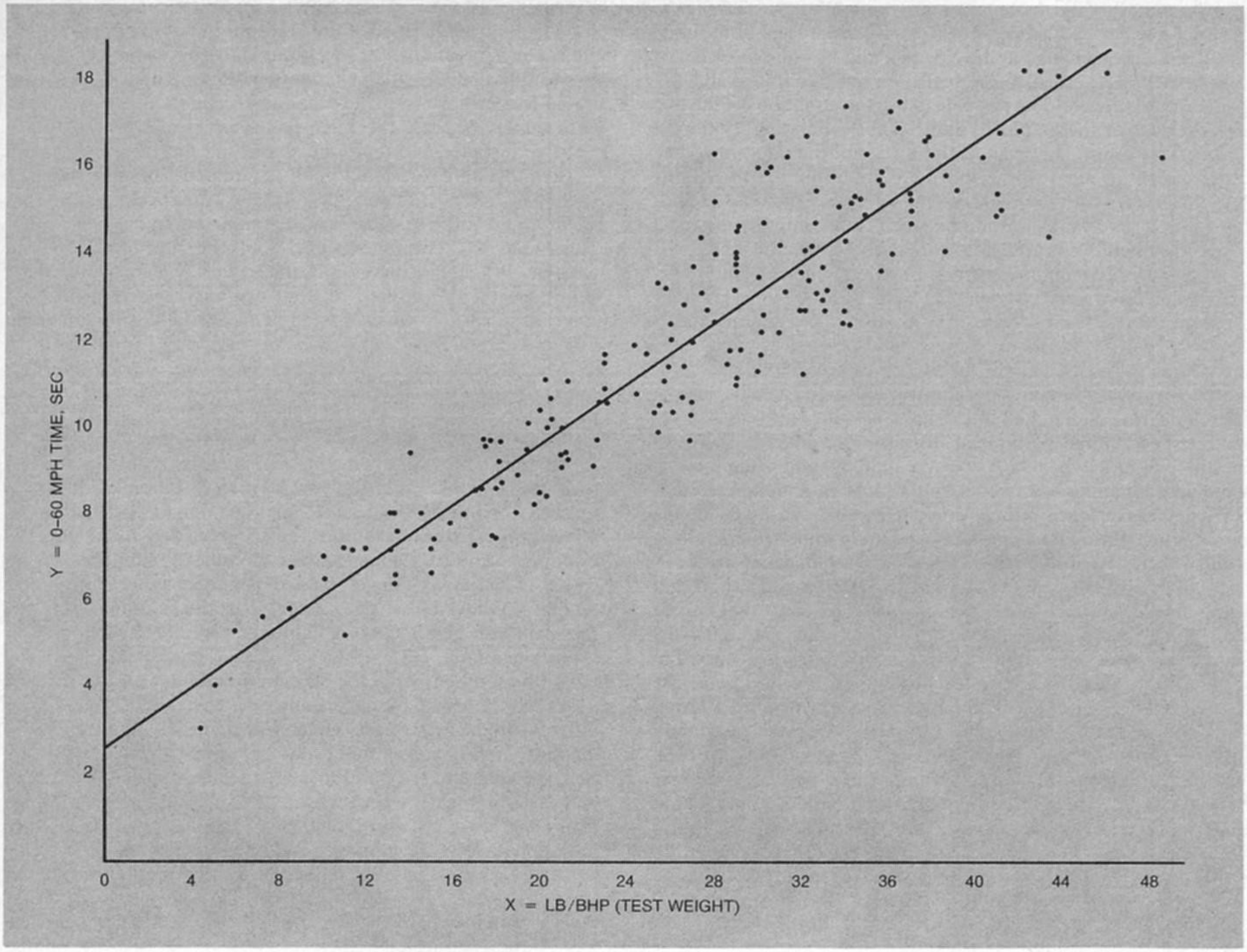
Although the AC alternator which first appeared in 1960 resulted directly from the development of solid-state diodes, until recently auto engineers have been slow in taking advantage of this new electronics technology. Current automotive applications include fuel injection control, electronic ignition control for lower emissions and better fuel economy as on Chrysler's lean-burn engines, and on-board monitoring devices such as Toyota's Electro Sensor Panel which monitors such things as engine oil and coolant levels and warns of burned-out brake and taillights. Other systems under evaluation include anti-skid brakes, digital instrumentation and a system to inhibit an intoxicated driver from operating a car. It is predicted that electronics will average 10 percent of car cost in the Eighties and that the automotive electronics market will expand more than five times by 1985.

Following a brainstorming session, Lamar and I decided that using a microprocessor for gathering our road testing data was not only feasible but practical and he proceeded with development. Briefly, the system consists of a microcomputer which incorporates the latest in microprocessor technology offered by MOS Technology, Inc (950 Rittenhouse Rd, Norristown, Pa. 19401). At the heart of the microcomputer is an MCS 6502 Microprocessor Array providing data and program storage and input/output pins allowing the microcomputer to be connected to other peripheral devices such as tape recorders and printers. The potential of this system is virtually unlimited because it is possible to expand the microcomputer to incorporate more memory, different types of memory or additional input/output capability. The keyboard portion of the microcomputer allows the operator to program the computer through the use of a hexadecimal language using a base 16 numbering system instead of the usual decimal or base 10 arithmetic and to initiate the various programs by addressing the computer. Once a program is written and checked out it is stored on a tape cassette. When a particular program is needed, it is entered into the computer via a Sony cassette tape recorder.

As with our previous test equipment, a 5th wheel provides the computer with the basic speed and distance data. However, the



For the graph of ¼-mi time versus lb/bhp the equation of the straight line calculated by the method of least squares is $Y = 0.21X + 12.6$.



For the graph of 0–60 mph time versus lb/bhp the equation of the straight line calculated by the method of least squares is $Y = 0.35X + 2.6$.

new wheel is unique. It can easily be disassembled for shipping and it's small and light. The diameter is only 20.0 in. and it weighs just 12 lb (our old 5th wheel is 26.5 in. across and weighs 40 lb). Instead of the metal clamps or 20-lb bumper adapter used to clamp the old wheel to a test car, the new 5th wheel attaches to a car by a light alloy bar and bungee cords. Bungee cords? Don't laugh. Rubber bungee cords have some unique stretching properties that allow the wheel to be easily and quickly attached to our test cars.

The computer receives a signal generated by a photoelectric pickup that senses rotation of the 5th wheel and assimilates, stores or processes the data as dictated by the program. In most instances the data will be printed out on the paper tape of a modified Addo type 9120 desk calculator. But if a printed copy of the data isn't immediately required, the output can be fed into the Sony cassette recorder and transcribed and analyzed back at the office.

The black box containing the microprocessor and the keyboard rests on the dash or the passenger seat and is secured by a couple of suction-cup turnbuckles or bungee cords. From the liquid crystal display (LCD) the driver can read car speed in mph, time in sec, distance in ft and engine speed in rpm.

What effect will the new test equipment have on the numbers in our data panels? The most noticeable difference will be in the acceleration times. For all but the heaviest and most powerful of the cars we test, the times to speed and times to distance we record will be faster than before because there will be one less person in the car and because the weight of the test equipment has dropped from 80–100 lb (depending upon the method of 5th-wheel attachment) to 25 lb.

There is also a difference in starting technique. In the past, the driver would say: "1-2-3-go" and this would signal the observer to start the stop watches. With the new equipment the computer starts counting as soon as the 5th wheel moves 1 ft.

To determine just how large a difference we might expect from the old to the new equipment we've tested several cars three different ways: with the old equipment, with the new equipment and with the new equipment and the car loaded down to simulate the test weight using the old equipment. The latter test would indicate how much, if any, of the difference between the new and old equipment was attributable to starting technique and possible human errors in reading the electric speedometer, the distance counter and starting and stopping the watches. Of the 10 cars tested, ranging from a VW bus to a Ferrari 308 GTB, the greatest variation in times between the old test method and the new with each car weighted down to simulate the old test weight was only 0.3 sec. This is within the range of normal experimental error and allows us to disregard the new equipment as a variable. This leaves the lighter test weight as the major factor contributing to the quicker times.

The accompanying curves are plots of lb/bhp (based on test weight and SAE net horsepower ratings) vs 0–60 mph times and 0–¼ mi times for road tests conducted by R&T during the years 1973–1976. In each case the straight line drawn through the data points was calculated by a statistical analysis process called the method of least squares. In general, the equation of a straight line is given by the equation: $Y = mX + b$ where Y = the value along the vertical axis (0–60 mph or 0–¼ mi times for the graphs →

given here), X = the value along the horizontal axis (lb/bhp in this instance), m = the slope of the line or the change in the Y value for a given change in the X value, and b = the intercept of the line with the vertical axis. Ideally, for any car, if the value lb/bhp is known, it would be possible to use the equations of the two straight lines or the graphs to find the corresponding 0–60 mph and 0–¼ mi times. However, as the scatter of the data shows, we don't live in an ideal world and there are a number of reasons why the acceleration times of a given car might not fit the straight lines exactly. Normal variation between two seemingly identical cars is a possibility. Another consideration is whether the car is equipped with a manual gearbox or a less efficient automatic, and if a manual gearbox, whether it's a 4- or a 5-speed. Final-drive ratio is a factor because a low numerical ratio coupled with a tall 1st gear might cause the engine to bog when moving from rest. Conversely, numerically high overall gearing might result in clutch slip or too much wheel spin off the line. How well the overall gearing is matched to the horsepower and torque curves in the speed range of interest must be considered. Flywheel inertia (a light flywheel revs up more quickly) enters the picture. Even aerodynamics is a factor. And it must be remembered that SAE net horsepower ratings don't tell you how much engine power is lost during transmission to the drive wheels. Generally, a front-wheel-drive design absorbs less power than a rear-drive car.

In analyzing the data for the 10 cars tested it was found that using the new equipment resulted in 0–60 mph times that ranged from 1.0–2.5 sec quicker and 0–¼ mi times ranging from 0.4–0.9 sec quicker. As expected, the largest time differences occurred in those cars having the greatest change in lb/bhp. You can use these time differences as a guide in determining how a car tested with the new equipment would fare using the old test method and vice versa. It's also possible to use either the graphs or the straight-line equations to approximate the differences in times between the old and new equipment. Suppose, for example, that a car R&T tested in 1975 had a test weight of 2690 lb and a horsepower rating of 100 bhp giving a weight-to-power ratio (lb/bhp) equal to 26.9, a 0–60 mph time of 12.0 sec and a 0–¼ mi time of 18.1 sec. A good approximation of the test weight with the new equipment is to take the old test weight and subtract 250 lb. This gives a new test weight of 2440 lb and a lb/bhp figure of 24.4. This corresponds to a 0–60 mph time of 11.1 sec and a 0–¼ mi time of 17.7 sec. In the case of a car whose performance doesn't fit the straight lines very well (the Mazda GLC is a good example of a car whose acceleration times are quicker than its weight-to-power ratio would indicate), plotting the known point and then drawing a straight line through this point parallel to the given straight line will give a good approximation of the new 0–60 mph or 0–¼ mi time.

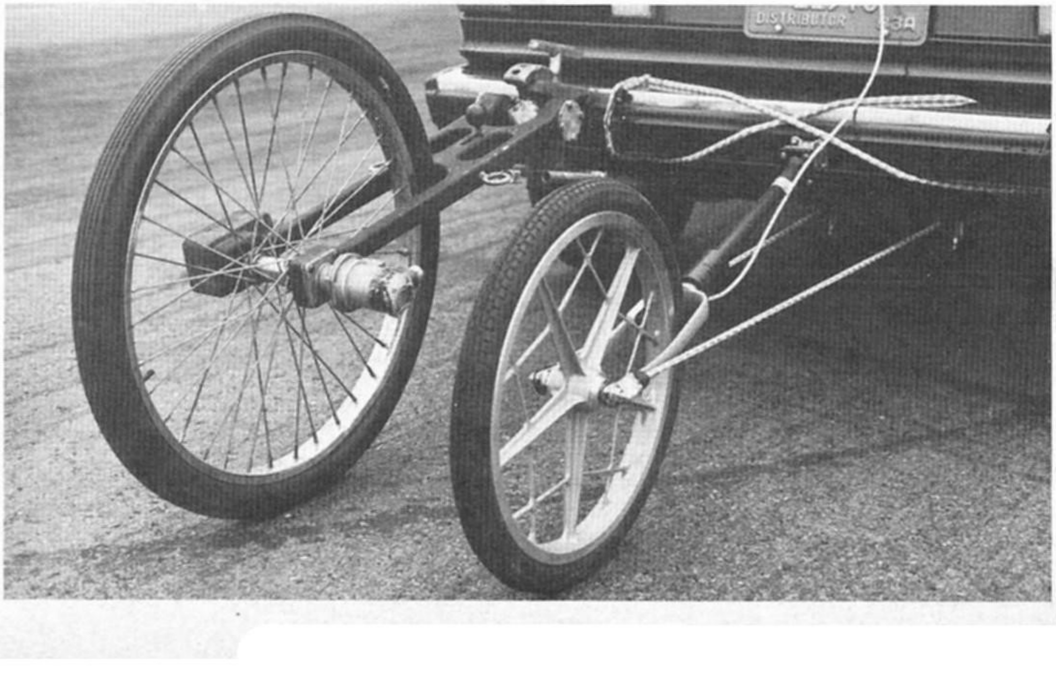
As in the past, the acceleration curves that accompany the data panel will be the average of the best four out of five or six runs in alternating directions to cancel out wind effect and to compensate for possible elevation changes on the straightaway. However, we no longer have to make separate acceleration runs to obtain both curves because the microprocessor gives times to speed, times to distance and the ¼-mi speed and time for each run.

The procedure for obtaining the simulated panic-stop braking distances from 60 and 80 mph is virtually identical to the one we have been using. The electric switch attached to the brake pedal plugs into the computer instead of the electronic distance counter. When the driver hits the switch the computer starts counting and the printed readout not only gives the stopping distance in feet but also a record of the speed at which braking was initiated and the time it takes to stop. For the 10 cars tested, the old and new test equipment gave average braking distances that were within ±5–10 ft of each other, easily within the range of the run-to-run variation for a given car and a given type of equipment. Unlike the trends apparent in the acceleration times, the braking results, though consistent from stop to stop, are less predictable. The lighter test weight means the brakes have less mass to stop but sometimes the change in weight distribution can affect braking distances more than a reduction in weight. For example, some cars when loaded to capacity stop quicker because of improved brake bias or because wheels have less tendency to lock. To a lesser extent than the stopping distances, fade will also be affected. A lighter test weight should result in slightly less fade.

For the moment, only the acceleration figures and, to a much lesser extent, the braking distances in the data panel will be different than in the past. There will be no change in how we measure interior noise, fuel economy, or speeds in gears. However, speedometer error and speeds in gears will be more accurate and easier to measure because the LCD gives the driver a digital readout of car speed and engine rpm. No longer will an observer have to balance a speedometer and a separate tachometer on his lap and call out numbers indicated by two pointers while the driver holds the car at a steady speed. Instead, the driver brings the car to an indicated speed using the car's speedometer, then he hits a button connected to the computer which causes the adding machine to print the actual speed and rpm. Neat.

As I mentioned previously, the microcomputer is very flexible and right now Lamar is investigating ways for it to time a car on the skidpad and in the slalom without the aid of an outside observer. If the times change because of a different timing technique (though we don't expect they will) we'll tell you about it.

Who said computers aren't fun?



New "mag" 5th wheel versus previous wire type. New wheel is considerably smaller and lighter and can easily be disassembled for shipping. Old wheel has separate pickups for speed and distance data; one photoelectric pickup does both on the new wheel.

After this article was published in Road & Track I received a lot of inquires from other people interested in testing cars. A Phd by the name of Dave Lynn called me from the Los Alamos Atomic Energy laboratory in New Mexico. Dave was testing fuel cell powered golf carts and needed some real time test equipment. He proposed a deal with me. He found out I did not have a 6502 assembler but he had one running on a 10 million dollar Cray 1 Super computer back at LASL. He told me if I would let him study my code he would translate it to assemble language and let me have a copy. Dave moved into my house in Hermosa Beach overlooking the Pacific ocean for a couple of weeks and spent 12 hours a day on my kitchen table studying and translating the program and hardware it took me a year to develop and write in hex code. We later co wrote a technical article for the IEEE on the code and the hardware. I have that around here somewhere.

About that time the Apple II came out and I had started a company to sell Apple II accessories and programs. My first Apple II had no keyboard and no power supply let alone a box to put it in. Just a mother board. I scrounged up a surplus keyboard and power supply and got the Apple II working. A friend of mind by the name of Bob Bishop helped me port a 6502 assembler to the Apple II. We started selling those for about $39.95 and we sold thousands the first year. We went from zero to $100,000 gross in less than a year. We also became an Apple II dealer. As far as I know we were the second computer store in the world. Most of the early Apple II program where written using our assembler.

The road test equipment biz was going well so I redesigned the KIM 1 and called it the SuperKIM. Chuck Peddle was the designer of the 6502 and the KIM 1... I think. I flew up to Northern California where he was working for MOS Technology and asked him personally if it was OK to use the name SuperKIM. Fortunately he said yes.
The SuperKIM was designed for the needs of the road test system so it had more I/O and more memory. It also had the 8 hardware interrupts on board. We sold Road Test Systems to just about every vehicle manufacturer in the entire world. The SuperKIM was also widely used in Robots and industrial process control systems.

The road test system was also used by Road & Track to measure the take off acceleration of the Rutan around the world Voyager aircraft.

Microcomputers and Peripherals

LAMAR INSTRUMENTS

LAMAR INSTRUMENTS Part No. 1330

Apple II 6502 Development System

To develop a microprocessor application requires a computer with even greater capacity than the system under development.

Which Microcomputer Development System

. . . Is a development system for the world's most popular 8-bit Microprocessor?

. . . Costs about a half to a third of comparably equipped systems?

. . . Comes complete with prototype computer and system analyzer ready to plug in and start working on those tough hardware/software trade-offs?

. . . Comes with EPROM Programmer, printer and interface?

. . . Comes with a ROM Simulator for the fastest checkout of software changes directly in the prototype microcomputer?

. . . Has software with trace, single step, block-move, single location modify, and a powerful disassembler that generates text files for the **microproducts** Editor/Assembler, which is also included?

. . . Can also do payroll, general ledger and customer mailing lists after you have developed the product?

. . . Plays chess with you in high resolution graphics during your lunch hour?

Answer

The **LAMAR INSTRUMENTS**/Apple II 6502 Development System.

This system consists of an Apple II microcomputer with 48K of RAM and 10K of user ROM, a 12-inch monitor, a floppy disk and interface, a printer and interface, an EPROM Programmer, a direct hard-wire interface to the 6502 based **SUPERKIM** using a ROM simulator.

The prototype microcomputer (SUPERKIM) has 2K monitor (KIM-1), hex keypad and address and data display LED's, for quick checkout of minor hardware or software problems.

Also included with this system is a symbolic, coresident Editor/Assembler, a symbolic Disasembler/Text File Generator and Enhanced Monitor/Debugger.

In addition, the SUPERKIM with power supply on-board, can be expanded to incorporate additional off-the-shelf memory, video, A to D, D to A, 8" floppy disk, music, AC controller, clock and other LSI chips in proto area.

A complete system can be obtained for less than $4,000.

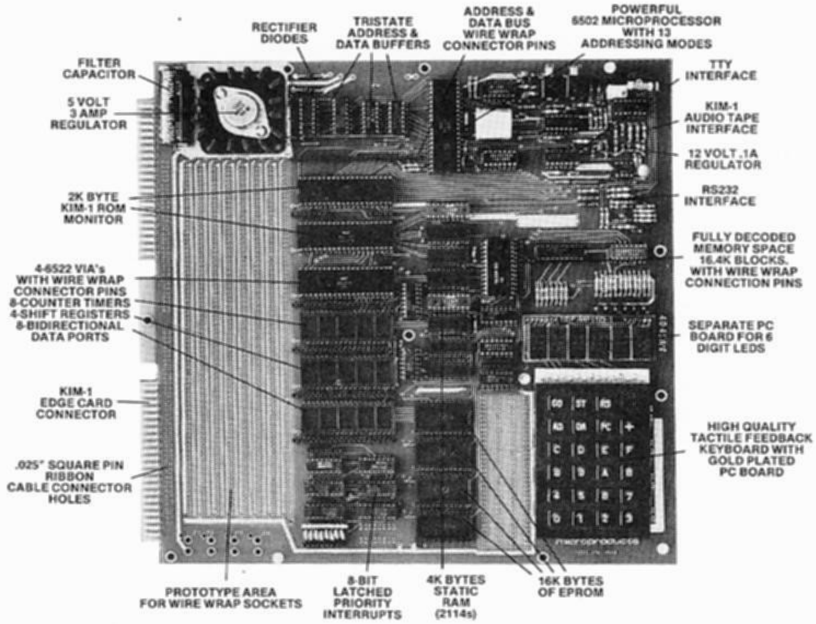
Call or write today for further information on how this powerful microcomputer development system can get you started on the road to the computer age with your process or equipment being rapidly and efficiently controlled by a powerful microprocessor.

LAMAR INSTRUMENTS 2107 ARTESIA BLVD. • REDONDO BEACH • CA 90278 • (213) 374-1673

SUPERKIM

Part No. 1017

Here is a powerful microprocessor control system development tool and a complete real-time multitasking microcomputer in one package. There is no need to buy a power supply, motherboard, memory boards and separate I/O boards when your requirements may be satisfied by a **SUPERKIM.** You may only need a couple of wire-wrap sockets and a few LSI chips installed in the big 3" x 10" onboard prototype area to accomplish the required memory expansion and interface with the real world.



Some single chip interface devices available are: UARTS, 16 channel-8 bit analog to digital data acquisition systems, floppy disk controllers and dot matrix printer controllers. Furthermore, you will shortly be able to buy single 5 volt supply pseudo static 8K byte (that's right, you read it right, 8K x 8 bits) memory chips in a single 28 pin package. These chips use the same technology developed for the 64K bit dynamic RAMs now being manufactured by TI, MOTOROLA and others. Just five of these chips and four 2732 EPROMs in the sockets already supplied in the **SUPERKIM** will yield a fully populated **SUPERKIM** with 44K bytes of RAM, 16K bytes of EPROM with serial and parallel I/O ports, and enough room left-over in the prototype area for a LSI floppy disk controller chip. ZILOG already has, on the market, a 4K byte version of this memory chip that is pin compatible with the 8K byte version; no need to rewire your sockets when the larger memories become available. Put in 24K now and upgrade later to 44K.

If you started with a KIM-1, SYM-1 or AIM-65 and tried to expand it to the basic capabilities of the **SUPERKIM**, you would need a power supply ($60), a motherboard ($120), a prototype board ($30), a memory board ($120), and an I/O board ($120) for a total cost of from $620 in the case of the KIM-1 to $825 in the case of the AIM-65. You still would not have real time multitasking capabilities.

Multitasking is a situation where the microcomputer appears to be doing more than one job simultaneously. For example, the microcomputer could be sending data to a printer, accepting analog data from a 16-channel data acquisition system and presenting data to an operator monitoring a LCD or LED display, all the while keeping track of time.

Multitasking is accomplished on the **SUPERKIM** by use of vectored priority interrupts and a real time clock. This real time clock is implemented using one of the four on-board 6522 programmable tone generators.

The **SUPERKIM**, with its keyboard, display and ROM monitor, can be used as a system analyzer for troubleshooting hardware and software in-the-field or during system development as an in circuit emulator. The monitor can stop the CPU at any point in the program, step through the program, change the contents of the systems' memory and CPU registers, and record the CPU's registers during a selected portion of the program. It offers one of the most powerful combinations of development and diagnostic tools available on the market today.

All of the above is unavailable on any other singleboard computer at any price.

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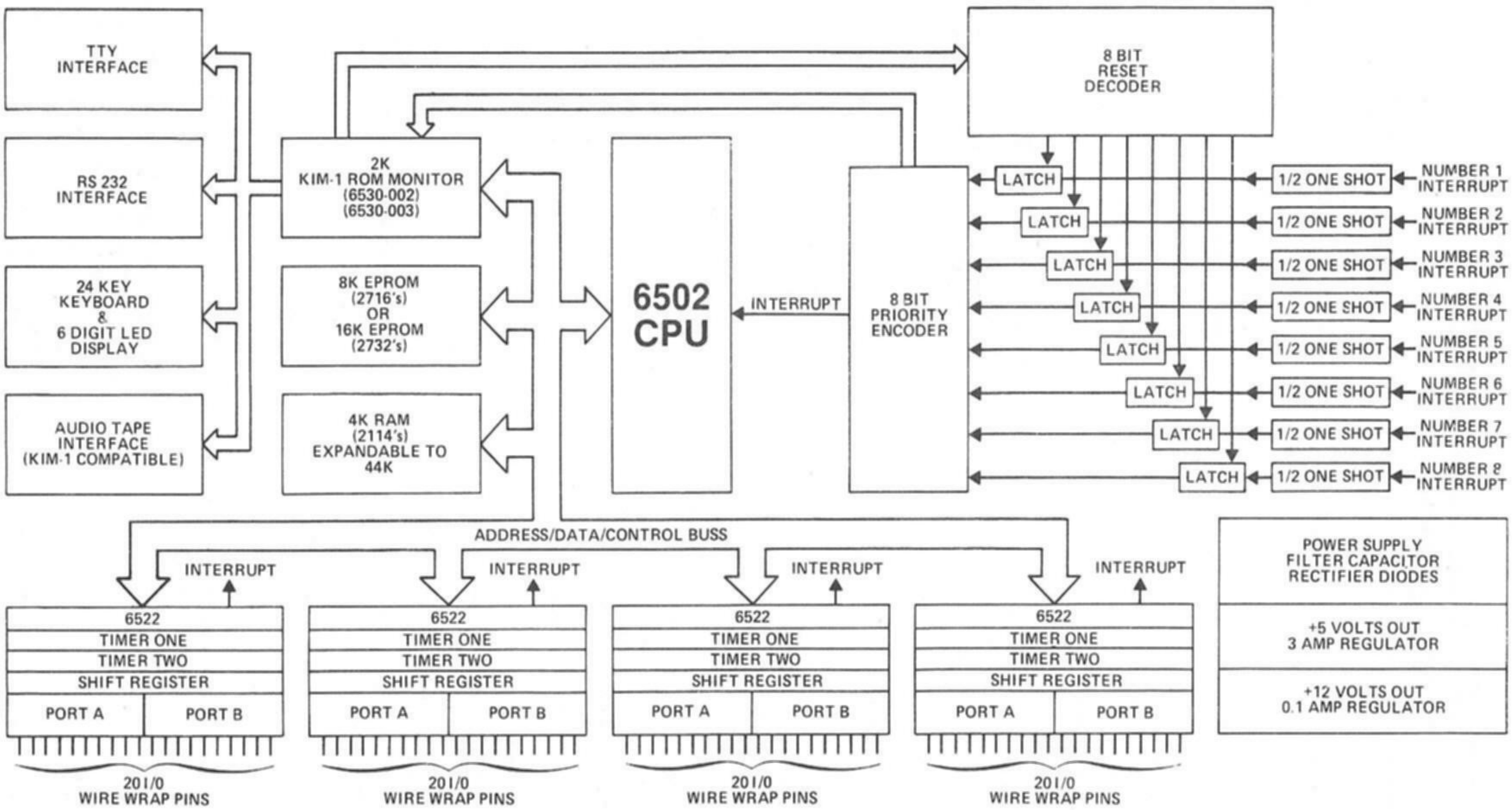
Block Diagram of Superkim



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Description of Superkim and 6502 Microprocessor

The uses of the Superkim are many and varied but mainly intended for use as a development tool in adapting microprocessor control to useful commercial and industrial applications.

This super controller can be applied to any situation where intelligent control is desirable, such as any manufacturing or production line process where automation is possible or to automatic machine tool operation or to real time data collection. The board has a large prototype area suitable for mounting Analog to Digital, Digital to Analog converters, relays and other interface devices.

The 6500 family of microprocessors and interfaces has established itself as the most popular third generation microprocessor family.

True Pipeline Architecture

Unusual in a low cost microprocessor, but even as the 6502 microprocessor is interpreting one instruction, it is accessing the next memory location. By doing its tasks in parallel, the 6502 attains tremendous system throughput. At 2MHz, the 6502 has a potential throughput equal to a 6800 or 8080 running at 4MHz — if they could.

Thirteen Addressing Modes

The thirteen different addressing modes include zero page and indirect indexed. The flexibility of these addressing modes allows you to write your program using an average of 20-40% less code. This means a savings in the amount of ROM required. The 6502 operates from a single 5 Volt power supply: it has true indexing capability, two interrupt modes and addressing memory range up to 65K bytes. It offers both decimal and binary arithmetic.

Outstanding Interface Chips

6500 interface chips combine functions which require several packages in first generation microprocessor systems; all feature an 8-bit bidirectional data bus for interface to the microprocessor. The 6530 has a 1K byte ROM, 64 byte RAM, interval timer and I/O.

The 6522 (VIA) Versatile Interface Adapter has two 8-bit bidirectional data ports, four peripheral control/interrupt lines plus latching inputs, two fully programmable interval timers an 8-bit shift register for serial interface.

Because of the multiple sources, you are assured of the continued availability of the 6500 microprocessor family with high performance and competitive prices. MOS Technology, Rockwell and Synertek are shipping identical parts on all members of the 6500 microprocessor family and interface chips.

Advantages of Superkim

- Total hardware and software compatibility with KIM-1* and most APPLE II** hardware interfaces.
- Fully socketed for maximum replacement flexibility and simple expanison to 4K RAM and 16K EPROM.
- Expansion capability to 65,536 bytes total RAM, ROM and I/O with fully decoded address space.
- User EPROM physically addressable anywhere in the memory space of 2000 hex to FFFF hex. No need to relocate existing Rom-able software.
- TTY serial interface onboard automatically adjusts for a variety of baud rates.
- Programs can be saved on audio tape or read into computer via the built-in audio tape interface (tapes are KIM-1 compatible.)

Interfacing Features

- Eight latched priority interrupts. Latches are individually resetable under software control. Absolutely essential for implementing highly useful real time systems.
- All hardware necessary to implement real time clock onboard using one of the interrupts.
- Four 6522 versatile interface adapter sockets available; one 6522 supplied. A full complement of 6522's can provide:
  - Nine complete bidirectional 8-bit ports with hand shaking.
  - 95 individual I/O connections onboard which can be used with inexpensive single in-line ribbon cable connectors. No need to use expensive edge card connectors.
  - 8 counter/timers or frequency generators (musical notes, etc.).
  - Four 8-bit, bidirectional serial to parallel shift registers.
  - Onboard but remotely mountable terminal comprised of an improved hexidecimal keyboard with separate injection molded, positive feedback ("click") keys and six digit LED display. The keyboard is one of the most critical elements of a computer as it is the normal point of man-machine interface. The keyboard has double-sided, gold plated pc board and is dust proof and drip proof.

Power Supply

- The basic board with the 6-digit LED displays "off" only draws 750 ma because of the extensive use of low power Schottky chips. The onboard 3 amp 5-volt regulator therefore will accommodate a considerable number of chips in the prototype area.
- All you need is a center tap filament transformer with 2 amp capability; readily available everywhere.

Software Available

The 6502 microprocessor has more books and documentation available than any other and they are compatible with **LAMAR INSTRUMENTS** Superkim. For instance, • "KIM MANUAL" • MOS Technology "Hardware Manual for 6502" • "First Book of Kim" by Butterfield, Ockers & Rehnke • "How to Program Microcomputers" by Barden • "Programming a Microcomputer, 6502" by Foster • "MICRO, the 6502 Journal" • "Kim-1/6502 User Notes".

Specifications of Superkim

Hardware Features

- The 11-½" X 11-½" pc board is double-sided with plated-through holes and solder mask.
- 4K bytes of RAM sockets, 1K byte RAM supplied.
- Sockets to accommodate up to 16K bytes of EPROM using 2732's or 8K bytes of EPROM using 5 volt 2716's.
- Mini-jacks onboard to provide direct connection to audio tape recorder.
- RS 232/TTY serial interface onboard.
- Onboard 5 volt regulator, rectifier diodes and filter capacitor.
- Fully buffered data and address lines.
- Prototype areas onboard will take all dips with 0.3 inch or 0.6 inch pin spacing. Space for up to 46-16 pin dips; however, dips with up to 40 pins may be used.
- Provisions in prototype area for two 62 pin flat cable connectors or a combination of smaller connectors and a KIM-1 style edge card connector onboard which can be wired for compatibility with the many KIM-1 expansion buses.
- Provisions onboard for a four slot APPLE II bus which can be used to interface to APPLE II peripherals.
- 200 gold-plated wirewrap pins extending through the board for interconnections to prototype area onboard or offboard via ribbon cable and single in-line connectors.

SUPERKIM/APPLE II DEVELOPMENT SYSTEM

LAMAR INSTRUMENTS can supply a hardware interface and a software downloading routine for the APPLE II and a firmware receiver routine, located in a 2716 EPROM, for installation in the Superkim. This greatly facilitates software development for the Superkim because of the powerful microproducts/APPLE II assembler and the large memory available in the APPLE II. The software can be instanteously transmitted from your APPLE II software development system to your Superkim RAM for instant checkout and use.

This Superkim/APPLE II development team concept constitutes the fastest, lowest cost microcomputer application prototyping system presently available.

*KIM-1 is a product of MOS Technology **APPLE II is a trademark of APPLE COMPUTER INC