THE MICROPROCESSOR
A Biography

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For Tad Malone
who will live in the
microprocessor's world.

Preface

This book is not what it seems. It appears to be about technology, but it is really about people. It looks like a history book, but it is really an adventure story. Even its title is an oxymoron.

These ambiguities are intentional, the paradoxes planned. The microprocessor is not only a supremely important invention, but also a Rosetta Stone of our culture. To see how a microprocessor is made is to understand our current limits of technology; to understand how it works is to appreciate the present sophistication of engineering; and to know how it is used is to discern the underlying social forces that are transforming our world. Even the events surrounding the microprocessor industry—the new marketing techniques, the litigation, the business partnerships—regularly set precedents that are soon followed by other industries. Thus the microprocessor, more than any other product, decodes and defines modern life.

That's why understanding the microprocessor from every perspective is vitally important for all of us. And that is why *The Microprocessor: A Biography* was not written for a select audience, but for every audience—and especially for the general reader. If, as I believe, the microprocessor will define our lives for at least the next generation, if it has the potential for both great good and great evil, then for our own sake we need to know about the microprocessor in order to maintain control over it.

That's why this book is written and constructed the way it is. The general reader, with little or no understanding of electronics and computers, will find a complete overview of the microprocessor written in a style that is intentionally non-technical and that takes great pains to explain complicated topics. He or she will also find, I hope, an entertaining story about human ambition, greed, teamwork, feuds, and glory. For the scholar, from the high school senior to the college undergraduate to the vocational school student, *The Microprocessor:*

A Biography is designed to be both the first complete introduction to the subject—both technologically and historically—and a reference book for years to come.

For graduate business students, this book should prove a useful survey of what is the key technology of just about any business they may enter. Meanwhile, the history sections may be a revelation about how the business of high-tech entrepreneurship really works. And, for engineering students, while the technology sections may prove a bit simplistic, they are up-to-date, and the final chapter offers clues to where one's studies should lead in the future. But more important are the history chapters, which should serve as a perpetual reminder that the best designs, as often as not, don't triumph, and that a far more likely barometer of success can be found in the pride of the employees, the leadership skills of top management, the insightfulness of the marketing campaign, and most of all, the ability of the organization to cope with the unexpected.

The largest audience for whom this book was written are people newly hired into high tech or established in other industries that are now being transformed by electronics. For this group, to which I once belonged, *The Microprocessor: A Biography* is designed to be the long-needed guidebook, a Baedekker, to the tiny machine at the heart of the electronic revolution. I hope it sits on your office bookshelf and grows dog-eared with use.

*

Like the microprocessor itself, this book represents an alliance between logic and memory. The 'logic' component consists of the two chapters at the beginning of the book, Chapters 3 and 4, describing how the microprocessor is made and how it operates, and a final chapter, Chapter 8, that speculates where microprocessor technology goes from here. The 'memory' component includes the opening chapter and the middle chapters on the history of the microprocessor industry.

Just as the logic and memory regions on the surface of the microprocessor have distinctly different architectures, so too do the two sections of the book exhibit different structures and narrative styles.

As the name suggests, the 'logic' section is designed to be objective, practical and instructive. To my knowledge, no one has ever attempted to write, in-depth, a layman's description both of how a microprocessor is fabricated and then how the finished chip actually operates.

Now I know why: the experience is both daunting and a little embarrassing. Daunting, because nowhere out there is that sacred text or two that puts the story all together and provides a foundation for any subsequent narratives. On the contrary, books on microprocessor (actually semiconductor) fabrication come in one of two forms: 1) instructional brochures and books that simplify the process nearly to absurdity then rush off to stories about more interesting things like computers, or 2) hard-nosed engineering texts that offer four pages of overview, then dive right into 250 pages of equations. As a result, as the footnotes will attest, I cobbled together the "How it is Made" chapter from sources as diverse as children's books, academic textbooks, corporate brochures, trade show catalogs, and even books on electronics from the antediluvian 1970s. Thankfully, the "How it Works" chapter was made easier by a burst of explanatory articles in recent years in computer magazines such as *MacWorld*.

And that gets us to the embarrassing part. I've written about the electronics industry now for nearly twenty years. Through osmosis, if nothing else, I've gained a pretty good working understanding of how microprocessors are made and how they function. I could list product numbers and nod knowingly when touring a semiconductor clean room. Once, for the first investigative series on toxics in Silicon Valley, I even created a chart of the steps to fabricating an integrated circuit.

But the reality was that it was all a newspaperman's gloss on his beat when asked to explain the difference between vapor deposition and epitaxy, or draw the elements of a Boolean adder at the transistor level, I was completely at sea. I like to think that my ignorance was unique, that all my counterparts in the press are far more knowledgeable on the topic than me, but their articles suggest the opposite.

Still, I like to think that this ignorance of mine has worked to our mutual advantage. By necessity, I became the average reader's surrogate. Every explanation and definition had to be clear to me before it was committed to print. Since few things were self-evident to me, few complex notions slipped past me into print. Furthermore, because I had to develop them for my own understanding, I tried to fill the text with simple examples and real-life allusions . . . and these, I hope, will not only aid in understanding, but also make these chapters more fun.

Best of all, my self-acknowledged ignorance allowed me to climb onto the shoulders of giants. Every word I wrote was passed by people like microprocessor co-inventor Fredrico Faggin, IBM (now NEC Research) Fellow

Harold Stone, Intel veteran John Crawford, Motorola design guru R. Gary Daniels and textbook author and Cal-State Long Beach professor Stanley Wolf. These gentlemen spent long hours poring over the manuscripts. They caught my mistakes, cleared out passages of fuzzy thinking and brought me up-to-date on new technologies. Moreover, Wolf and fellow Long Beach State professor Christopher Druzgalski also helped create, redesign or correct the technical illustrations in the book. To each of them my gratitude is as deep as that of any person who has been saved from looking like a public fool.

The result, I think, is three chapters that offer a broad overview of the creation, operation and future of the microprocessor. I hope it will serve as a platform upon which other writers can build in the future.

I must say that writing these chapters also offered a second lesson in humility. As a 'print guy' I've always believed that *anything* can be described in words. And while that may be true, you may not want to read them all. No matter how dynamic the prose and how many metaphors an author comes up with, describing the fabrication of an integrated circuit inevitably has moments resembling a long march along an endless row of complicated boxes. That's where the computer-generated illustrations created by Dan Clark proved so helpful. By *showing* the steps of wafer fabrication or the operation of an transistor, Clark made the processes far more comprehendible than I ever could. By the same token, developmental editor Nick Baran, sitting on his porch in Idaho, helped my writing in two ways. First, he line-edited the text and saved me from my usual grammatical errors and solecisms. Second, he developed the glossary, and it is one of the best and most comprehensive I've seen in a technology book.

*

The 'memory' chapters about the history of the microprocessor also live up to their name. By design, their prose style is subjective, controversial and literary. Not that the text diverges from the facts—on the contrary—but it certainly doesn't fit with the received view as presented in corporate brochures and "official" histories. High technology rarely looks back; and when it does, it usually has a selective memory. The engineering mind would much rather see history as the stately advance of technology by brilliant minds.

But the world doesn't work that way. It is far more messy than any blueprint. Genius is often as much a handicap as an advantage. The meek rarely

inherit the Earth. Stripped of the false veneer of propriety in which the industry prefers to wrap itself, the story of the microprocessor is a ripping yarn, full of mighty deeds and unforgettable characters. Few of us in our lives will ever work for a company that grows to a billion dollars in less than ten years or spend time with individuals as extraordinary as Robert Noyce or Bob Galvin—but in the story of the microprocessor we can do so vicariously, without the 80 hour work weeks, the broken marriages or the ulcers. Of course, without the riches either.

The memory chapters also provide the opportunity to set things straight. Having lived through the microprocessor era in Silicon Valley, and having covered the story up close, it has been a particular pleasure to, among other things, give Dr. Federico Faggin his due in the invention of the first microprocessor (an oversight I perpetuated in my first book, *The Big Score*), recognize the preeminence of the Zilog Z80, and to applaud the continuing excellence of Motorola's designs. Freed to temporarily step back from the fray, I've been able for the first time to recognize larger trends and characteristics and to see individual skirmishes as part of a larger continuing struggle. For example, it was only in writing this book that I came to appreciate the real reason for Intel's greatness, which is not that it never stumbles—in fact, it does so more often than many of its competitors—but that through superhuman effort and an unappreciated genius for marketing it has never allowed itself to fall.

Not every industry veteran will agree with the events I chose to emphasize in the history chapters, much less the conclusions I draw from them. But it is my hope they will at least appreciate the attempt to break away from the bowdlerized fairy tale to present a story of real men and women struggling to build one of the great miracles of our time. With this book, I've made my own humble contribution to that effort.

*

Finally, why the title? The easiest answer is that we thought it was clever. Rob Wolff, the brilliant Apple Advanced Technology Group scientist who helped begin this project but tragically had to leave because of illness, thought of the title first. He came up with it over an Italian dinner and Allan Wylde, my publisher, and I quickly agreed.

But that only begs the question. Why did a term like 'biography' ring true? We anthropomorphize a lot of non-human entities in our world—the sun, pets, our favorite cars—but a *silicon chip?!*

Yes, as a matter of fact. In the electronics industry, thanks to different operating systems and cloning, people have long referred to their personal computers by their central processors—"I've got an old Z80 machine", "Yeah? I bought a 286 clone from South Korea"—rather than their brands. The only exception was Apple computers, though nowadays its not unusual to hear:

— "Finally bought me a Macintosh."

— "No kidding? 68000 or PowerPC?"

By the early 1990s, thanks to the apparent ubiquity of personal computers, the rise of Microsoft Windows and the *Intel Inside* marketing campaign, the microprocessor came to the fore even in the mind of consumers. The introduction of the latest chip generation, once covered only by *Electronic News*, jumped first to the business pages of local newspapers and then, with Pentium and the PowerPC, to the front page. Now, new microprocessor generations were treated like royal births, with the press conference serving as the public christening for millions of thrilled on-lookers.

These days, schoolchildren judge each other on whether they own 386 or 486 computers and the local pharmacist is saving his money for a Macintosh PowerPC. As I type this, the baseball game on the radio is touting the first video game machine with '64-bit processing power.' Who can still deny that this tiny component has begun to take on a life of its own? Or that it is time for the story of this life to be told?

Michael S. Malone
Sunnyvale, California
June 1995

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