Early Si Bipolars, YIG, SRD, and Thin Film Enable 86290A

The 86290A was a blockbuster product introduction in 1975. Previous products largely covered octave bands but the 86290A covered 2-18 GHz in a single sweeper plug-in. The 86290A was highly successful and launched multiple successor source projects which dominated their markets for years. Key enabling technologies included the TC-21 discrete bipolar transistors, YIG resonators for both the oscillator (YTO) and the frequency multiplier (YTM), the step-recovery diode used for x1, x2, x3 frequency multiplication, Thin Film, and some clever but challenging assembly and mechanical design choices.

Early silicon bipolar development was done in Palo Alto, and there was a period of overlap between production at the Stanford Park site and at the Valley site in Santa Rosa; all this was later consolidated into the 1L fab in Fountaingrove in 1975. Key people involved included Pat Wang, Sandy Kakihana, Daryl Cernusak, Jerry Gladstone, Phil Chen. The first YIG oscillator development at HP was an S-Band (1.8-4.2 GHz) YTO designed by Jack Dupre circa 1968. The S-Band YTO and other early YIG oscillators all used purchased YIG spheres from Airtron. Ganesh convinced management that YIGs were important enough to justify internal development and sourcing and Dick Puttbach was recruited from Airtron. His work at HP was later supported by John Mendenhall and Scott Hewett.

The 86290A RF Block diagram (from the March 1975 HP Journal article) is shown here:

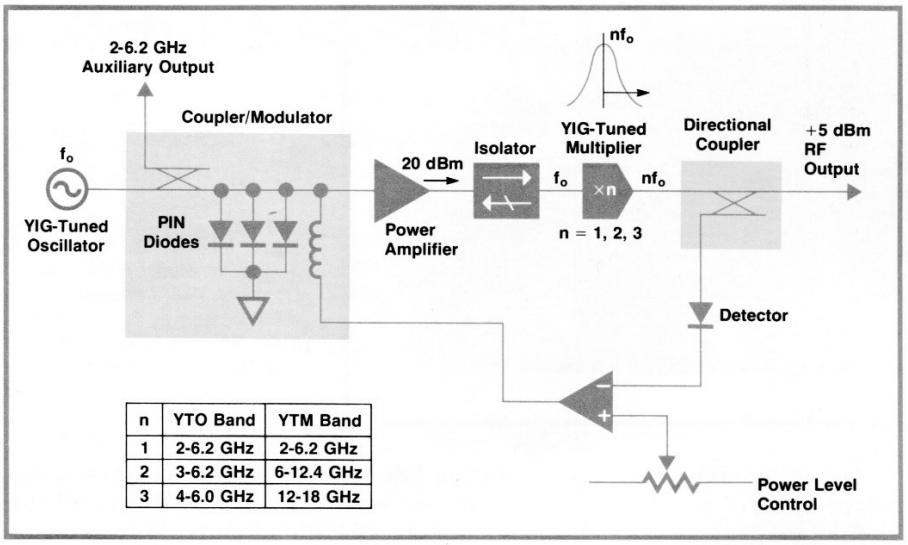

Fig. 3. *RF block diagram of the 2-18 GHz plug-in. The YIG-tuned oscillator and YIG-tuned harmonic multiplier track each other in frequency.*

The 2-6.2 GHz amplifier took full advantage of the newer discrete Si bipolar from the Tech Center, known internally as the HP-21. The major design requirement was to deliver +20 dBm (100 mW) of output power to drive the step recovery diode in the YTM. The HP-21 was also the active device used for the 2-6.2 GHz YTO.

The basic RF design of the 86290A was later updated using newer technology from the Tech Center. First, Derry Hornbuckle designed a 2-6.2 GHz power amp replacement using new discrete FETs; this significantly increased power levels and shipped in the 86290B. Secondly, the multiplier was extended to include a fourth harmonic output, thus extending the frequency coverage through 26.5 GHz. Key contributors for this work were Bob Jewett, Ganesh Basawapatna and Jacque Collard. In hindsight, the rapid advance from octave-band sources to a 2-26.5 GHz source is quite amazing!

Key contributors to the 86290A development, as written by Paul Hernday, Project Manager, from the March 1975 HP Journal article:

Acknowledgments

The authors gratefully acknowledge the contributions of the many talented people who cooperated very effectively to make the 86290A a reality. The detailed YTM concept was provided by Rit Keiter, and Robert Joly did the early design and optimization. Earl Heldt did much of the early magnet and circuit package designs for the YIG tuned devices. Alejandro Chu made several important improvements in YTM performance, did the original ALC design, and gave valuable help in many other areas, including FET switching and delay compensation in the YIG drivers. Ganesh Basawapatna designed the 2-6.2 GHz power amplifier and contributed greatly to several other RF designs. Roger Stancliff made valuable improvements in the ALC design and did final design of the YTO. Gary Holmlund did the exacting YTO and YTM driver designs and helped to coordinate the many changes that took place during the prototype phase. Bill Misson did the excellent product design and Bill

Knorpp designed the RF section heat sink casting. Dick Bingham designed the FM driver board. Jack Kuhlman provided the coupler/modulator design. Phil Chen did the early YTO design. Industrial design support came from Dave Eng and Roy Church. We also wish to thank Callum Logan, Jeff Gomer and Jim Yarnell for fabricated part process development.

The lab team had important assistance in microelectronic technology from Weldon Jackson, Yeng Wong, Jim Smith and Pete Planting. Phil Froess and Harry Portwood of the transistor fabrication group helped ensure a good supply of high-performance devices.

Production Engineering support for the 86290A is provided by John Turner at the instrument level and Alejandro Chu and Val Peterson for the components. Additional help has been given by Jeff Ho and Alan Kafton, and by Bud Edgar for the 8620A modification.

The 86290A operation and service manual was written by Doug Andrus and Don Jackson. Jim Arnold set up the fine instrument support program.

We are indebted to Cyril Yansouni and Jack Dupre for their leadership and encouragement over the several years of developmental work.

Memories of Some Highlights - by Ganesh Basawapatna:

- Development of the Step Recovery Diode 1970 - 1980
  - Multiplier Development Steven Hamilton and Robert Hall (HP Associates)
  - Refinement to 20 picosecond switching time enabling >20 GHz, 1975
  - Products enabled: 2 – 18.6 GHz YIG Tuned multiplier, later extended to 2-26.5 GHz and (later) Switched YIG Tuned Multiplier (Bob Jewett, Ganesh Basawapatna and Jacque Collard)
  - Instruments Enabled: HP 86290, HP 8672, and HP8340 family – BIG SELLERS with virtually no competition until 1980

- HP 21 Transistor – By any measure a Landmark Device – The first real micron-level transistor
  - Refinement for low $r_e + r_b$' for low noise and high frequency – Ken Richter, Darryl Cernusak, Byron Anderson and Ganesh Basawapatna (some bruising meetings)
  - Instruments enabled: 2 – 6.2 GHz amplifiers up to 100 mW, 2.4 GHz S-Band low noise YIG oscillator for the HP 8555 family (Phil Lavelle, Ganesh Basawapatna), 2 – 6.2 GHz Low Phase Noise oscillators for the 8672 and 8340 Broadband Synthesizers (Ganesh Basawapatna), the 8505 and other Vector Network Analyzers – Big Sellers with no competition
  - Widely copied – The HP 21 from HP Associates, and later copied by NEC which called it the NEC 21 to make sure of name association were some of the biggest sellers for these companies, purchased by HP competitors and later LNB converter manufacturers.

There is a huge amount to be proud of. Tech center products helped HP dominate the world of Instrumentation by being years ahead of the competition. The close work between the Instrument R & D labs and Tech Center engineers made this possible. HP management in those days encouraged risk taking with no clear end product in sight. The 2 – 18 GHz amplifier was totally a G-Job.

In those days, innovation was treated as equal to product definition.

A 2.0-6.2-GHz Power Amplifier

The power amplifier used in the 86290A had to meet one major requirement: it had to provide 20 dBm (100 mW) of power output to the YIG-tuned multiplier, given an input power of approximately 10 dBm. The term "power amplifier" might be surprising, because much higher powers have been achieved at these frequencies. However, to obtain the power and the bandwidth at the same time is a real design challenge.

The amplifier design is based on the HP 35820 transistor. The amplifier has two stages of preamplification that account for 4.5 dB gain, and three stages of power amplification that account for an additional 5.5 dB. The preamplifier has been described in detail elsewhere.[1]

Power amplifier design could have followed any of three avenues. A large number of preamplifier stages could have been paralleled, using power dividers and combiners, or two-stage power amplifiers with 18 dBm power output could have been built and paralleled to get the desired output. A third method was to parallel two transistors within a stage and obtain the 20 dBm output with three stages. Although it required more circuit optimization, this option had the advantages of lower manufacturing cost, smaller size, and lower power dissipation, and was therefore used in the amplifier. The HP 35820 transistor pair was modeled as a single device to obtain its small-signal S-parameters. The large-signal parameters were obtained experimentally using external tuners at high RF power levels. The input, interstage and output matching networks were then designed and the designs verified using a computer.

All amplifier stages are built on sapphire substrates. Fig. 1 shows the amplifier with its lid removed.

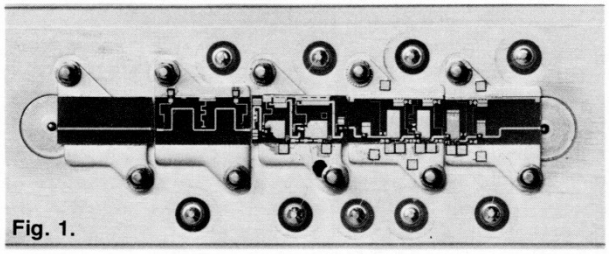

Fig. 1.

The amplifier has a rather large small-signal gain between 2 and 3 GHz. Since the amplifier follows the PIN modulator, amplifier gain compression detracts from system on/off ratio, an important parameter when the 86290A is being modulated by the 8755A Network Analyzer (see text, page 13). To shape the gain and saturating characteristics, a frequency selective attenuator consisting of three PIN diodes imbedded in a microstrip filter is used at the input of the amplifier. Its attenuation is set with an external bias voltage and ranges from 2 to 8 dB at 2 GHz. Loss drops to 1 dB above 4 GHz, where compression is slight.

Ganesh Basawapatna

References

1. P. Chen, "Design & Applications of 2-6.5 GHz Transistor Amplifiers", IEEE Journal of Solid-State Circuits, August 1974, Vol. SC-9, No. 4.