HRP Training Aid

Amplifiers

Amplifiers	ECCN
Crossed-field amplifier tubes	3A001.b.1.b
Microwave monolithic integrated circuits (MMIC) power amplifiers	3A001.b.2, 3A611.c
Microwave power amplifiers	3A001.b.8
MMIC amplifiers with integrated phase shifter	3A001.b.12
Pulse amplifiers	3A999.d
Solid state microwave amplifiers	3A001.b.4

Key Words and Terminology for Export Controlled Amplifiers

- Gyrotron
- Klystron
- Crossed-field amplifier (CFA), also known as an *amplitron* or *platinotron*
- Microwave monolithic integrated circuits (MMIC) amplifiers
- Pulse amplifiers
- Solid state amplifiers

Definitions

Amplifier: A device for enhancing the output power signal of a microwave device, usually by increasing the amplitude or height of the wave that directly relates to its power level. Amplifiers are available in many sizes, ranging from small integrated circuits (ICs) to large high-power transmitter amplifiers.

Gain: The amplified difference between the input and output signals (e.g., voltage, current, power). Gain is a measure of how much an amplifier "amplifies" the input signal.

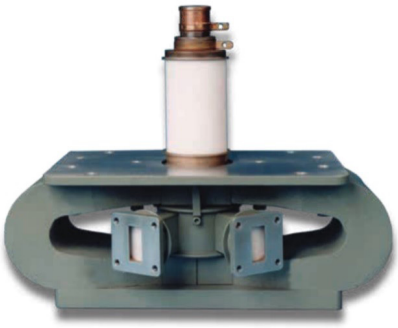
Applications

- Telecommunication systems
- Particle accelerator research
- Broadband communications
- Satellite ground stations
- Radar systems
- Electronic warfare by the military

ECCN 3A001.b.1.b
Crossed-Field Amplifiers (CFA)

Key Points and Features

- CFA is a specialized vacuum tube frequently used as a microwave amplifier in very-high-power transmitters (i.e., peak output power of tens of kilowatts to megawatts)
- The electric and magnetic fields in a CFA are perpendicular to each other ("crossed fields")
- Other names used by manufacturers include *amplitron*, *platinotron*, or *stabilotron*
- Key manufacturers include Raytheon and Communications and Power Industries (CPI)
- Current use is in satellite ground stations and deep space communications networks
- Export controlled only if a CFA with a gain of more than 17 dB
  - o Look for the following on paperwork or nameplate to determine gain if not explicitly listed: Voltage gain (A_v), current gain (A_i), or power gain (A_p)



SFD 233G CFA

CPI, Beverly, Massachusetts

Description:
X-band, 1 MW CFA ideal for high-power radars

Features:
- Frequency: 9.0–9.5 GHz
- Peak power output: 900 kW
- Anode voltage: 38 kV
- Anode current: 60 A
- Liquid-cooled anode

VKS 1925 CFA

CPI, Beverly, Massachusetts

Description:
S-band cathode-pulsed 250 kW CFA ideal for high-power search radars

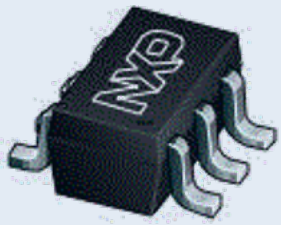
Features:
- Frequency: 3.1–3.5 GHz
- Peak power output: 250 kW
- Anode voltage: 35 kV
- Anode current: 16 A
- Liquid cooled

Water-cooled CFA in its transport case

ECCN 3A001.b.2; 3A611.c
Monolithic Microwave Integrated Circuit (MMIC) Amplifiers

Key Points and Features

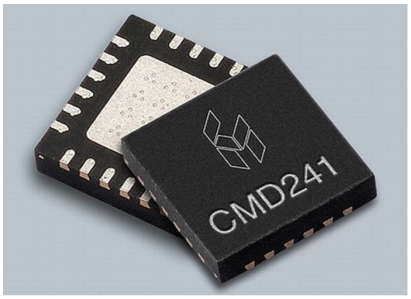
- Monolithic microwave integrated circuit, or MMIC (pronounced "mimic")
- A type of IC device that operates at microwave frequencies (300 MHz to 300 GHz)
- MMICs are dimensionally very small (from around 1 to 10 mm^2). For reference, a square inch is equal to 645 mm^2
- These devices typically perform functions such as microwave mixing, power amplification, and low-noise amplification
- MMIC power amplifiers controlled under ECCN 3A001.b.2 include the following:
  - o Frequency (GHz)—must exceed 2.7 GHz
  - o Fractional bandwidth (%)—must exceed 10%
  - o Peak saturated power output (W) may also be listed on product data sheets as output power, saturated power output, maximum power output, peak power output, or peak envelope power output and must be >5 W
  - o Refer to ECCN 3A001.b.4 for detailed breakdown of controls as a function of frequency range, fractional bandwidth, and peak power output of the amplifier



Silicon MMIC wideband amplifier

Notes:

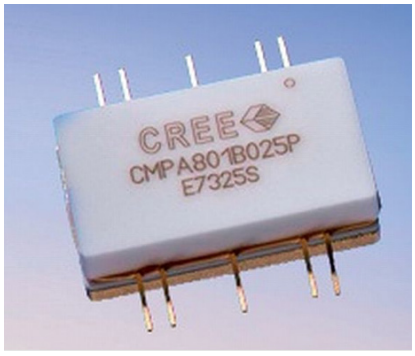
- *Export control of MMIC amplifiers with more than one operating frequency range is determined by the lowest peak saturated power output (W) control threshold.*
- *MMIC power amplifiers specially designed for military applications are controlled under ECCN 3A611.c*



CMD241 ultra-wideband gallium arsenide monolithic microwave integrated circuit (GaAs MMIC) distributed low-noise amplifier

Manufacturer: Custom MMIC (Chelmsford, Massachusetts)
Applications:

- L-, S-, C-, X-, Ku-, and K-band wideband radar
- Broadband microwave/millimeter wave communications
- Communications satellite (SATCOM)
- Test and measurement instrumentation radiofrequency and microwave applications



CMPA801B025 X-Band GaN MMIC power amplifier

Manufacturer: Custom MMIC (Chelmsford, Massachusetts)
Applications:

- Aerospace and defense

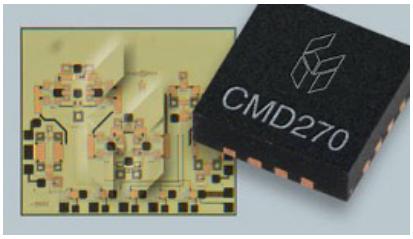
Features:

- 8.5–11.0 GHz operation
- 37 W typical POUT
- 16 dB power gain

ECCN 3A001.b.12
MMIC Amplifiers (with integrated phase shifter)

Key Points and Features

- Phase shifters are passive microwave devices that change the phase angle of a radiofrequency signal. Microwave phase shifters are important elements for use in oscillators and phased array antenna systems
- Look for the following keywords on paperwork to identify the presence of a phase shifter: "phased array," "transmit/receive module," "transmit/receive MMIC"
- Export controlled only if having all of the following:
  - o Rated for operation at frequencies >2.7 GHz
  - o A peak saturated power output (W) greater than 505.62 divided by the maximum operating frequency (GHz) squared, for any channel
  - o A fractional bandwidth of ≥5% for any channel



MMIC amplifier with integrated phase shifter

Manufacturer: Custom MMIC
Applications:
- Communication receivers
- Phased array radar

ECCN 3A001.b.4
Solid State Microwave Amplifiers

Key Points and Features

- Items controlled under ECCN 3A001.b.4 include microwave assemblies/modules containing microwave solid state amplifiers
- Amplifier Research is the industry leader of solid state radiofrequency power amplifiers
- Solid state microwave amplifiers controlled under ECCN 3A001.b.2 include the following:
  - o Frequency (GHz)—must exceed 2.7 GHz
  - o Fractional bandwidth (%)—must exceed 5%
- Peak saturated power output (W) may be listed on product data sheets as output power, saturated power output, maximum power output, peak power output, or peak envelope power output

Key Points and Features (cont'd)

- Export control status of microwave solid state amplifiers with more than one operating frequency range is determined by the lowest peak saturated power output (W) control threshold
- Refer to ECCN 3A001.b.4 for a detailed breakout of controls as a function of frequency range, fractional bandwidth, and peak power output of the amplifier

Microwave Solid State Amplifier

Manufacturer: Amplifier Research
Model 500S1G6A is a portable, self-contained, air-cooled, broadband, completely solid state amplifier.
Features:

- Rated output power: 500 W minimum
- Input for rated output: 1.0 mW maximum
- Weight: 300 lb
- Size (W × H × D): 19.8 × 50 × 24 in.
- ECCN 3A001.b.4

ECCN 3A001.b.8
Microwave Power Amplifiers

Controlled Items

Must contain vacuum electronic devices controlled by 3A001.b.1 (i.e., a CFA tube or CFA) and have all of the following:

- Operating frequencies >3 GHz
- Average output power to mass ratio >80 W/kg
- Volume of <400 cm^3 (24.4 $in.^3$)

ECCN 3A999.d Pulse Amplifiers

Key Points and Features

This ECCN controls exports to North Korea for antiterrorism (AT) reasons specific to processing equipment (including item d. Pulse amplifiers) not elsewhere specified in the Commerce Control List.

Traveling Wave Tube Pulse Amplifier

Manufacturer: Amplifier Research
Model 6900TP2G4 is a self-contained, forced air–cooled, broadband traveling wave tube microwave amplifier system designed for pulse applications.

Applications:

- Test and measurement
- Industrial and university research and development

Features:

- 6,900 W
- 2–4 GHz
- ECCN 3A999.d

DOE/NNSA High Risk Property

https://hrp.doe.gov

https://ecap.doe.gov

Krystee Ervin
ervinkp@ornl.gov

Dave Snider
sniderjd@ornl.gov

Shane Duffle
dufflesc@ornl.gov