Multilayer coil design is made easy with a programmable calculator. Not only are AWG numbers provided, but also wire material and tempco can be changed.

Multilayer coil design is laborious when done with tables, charts and complicated formulas. [1,2,3] But now a programmable calculator like the TI-59 can handle the large number of steps needed to provide comprehensive calculations for rectangular and circular multilayer coils. Although the equations (Fig. 1) relating inductance to number of turns, dimensions, wire size, resistance and temperature are complicated, the program makes them easy to implement.

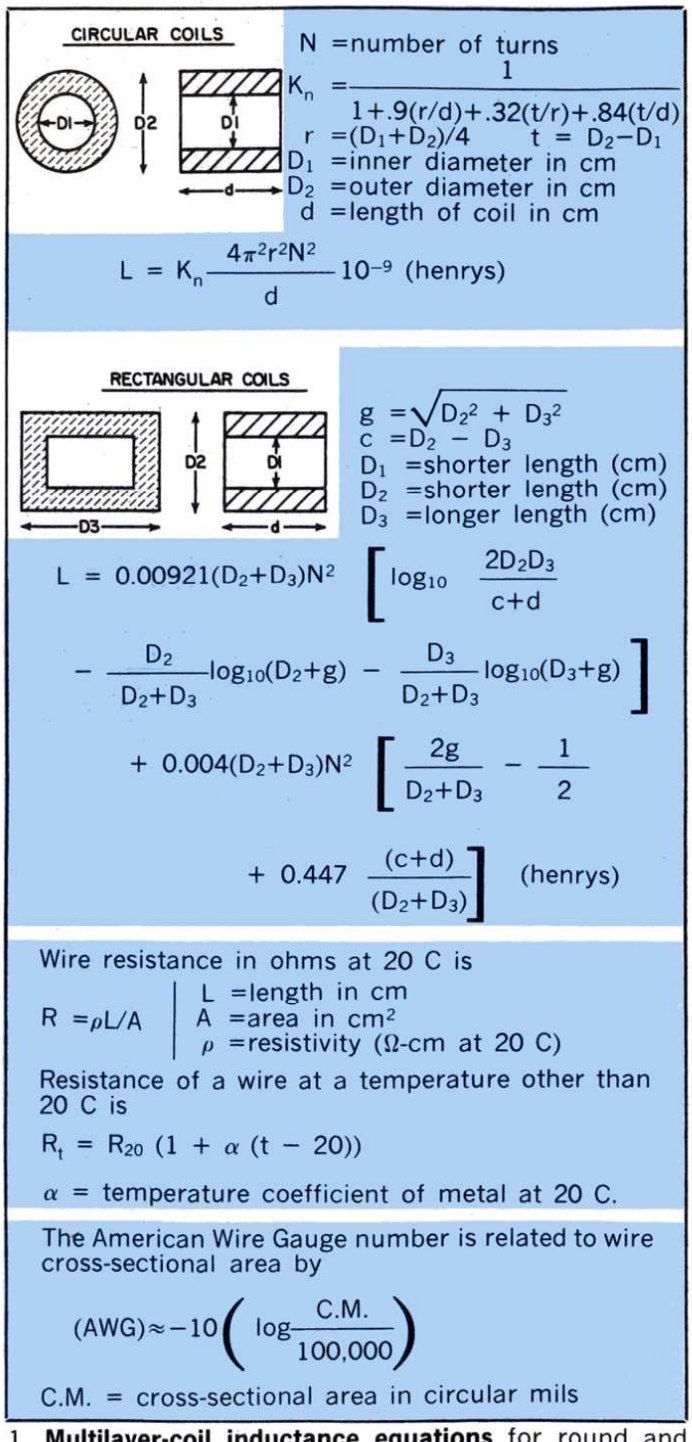
With its 795 steps, the TI-59 program can design a coil of a desired inductance, resistance or number of turns, given its dimensions. Also, the program selects the American Wire Gauge (AWG) number for the wire that will fill the coil's window and yield the maximum inductance possible for a given resistance, or the minimum resistance for a given inductance. In addition, the program can compute temperature effects on resistance and the effect of using wire materials other than copper.

The program's easy to use

To run the program, just enter the dimensions of the bobbin as in step 3 of the sequence (see table). Enter the known item—the inductance, the number of turns or the resistance—into labels A, B or C, respectively. After a few seconds the calculator displays the first of the three unknowns. The remaining answers are obtained, thereafter, by pressing R/S (steps 4a, 4b or 4c) until you have solved all the unknown parameters, including the AWG number.

Note that circular and rectangular coils have the same sequence, but rectangular calculations are performed with labels *A′, *B′, and *C′. And when the calculator is connected to a PC-100A printer, all values are printed and identified by name.

Furthermore, you don't have to press R/S to obtain the next answer; R/S is activated automatically as answers are printed. The program "knows" when the calculator is attached to the printer, and consequently doesn't halt after each intermediate answer. This programming sequence, which incidentally can be helpful in other TI-59 programs, is contained in steps



1. **Multilayer-coil inductance equations** for round and rectangular coils are too complicated and time-consuming to solve manually. The work becomes even more difficult if you also calculate coil resistance for any metal at any temperature, and then get answers in AWG numbers. But a calculator makes it all easy.

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Sequence of operations

1. **Partition calculator**
   Enter 2 Press 2nd *Op 17 Display 799.19
2. **Load both cards:** all four sides
3. **Enter bobbin dimensions** in cm:
   Enter D_1 Press D Display D_1
   Enter D_2 Press 2nd *D' Display D_2
   Enter d Press E Display d
   (and for rectangular coils:)
   Enter D_3 Press 2nd *E' Display D_3

4a. **Enter inductance** (L) in henrys:
   For circular coils Press A
   For rectangular coils Press 2nd *A'
   Display (N)
   **Press R/S Display (AWG)
   **Press R/S Display (OHMS)

4b. **Enter number of turns** (N):
   For circular coils Press B
   For rectangular coils Press 2nd *B'
   Display (L) henrys
   **Press R/S Display (AWG)
   **Press R/S Display (OHMS)

4c. **Enter resistance** in ohms:
   For circular coils Press C
   For rectangular coils Press 2nd *C'
   Display (AWG)
   **Press R/S Display (N)
   **Press R/S Display (L) henrys

**Performed automatically when used with PC-100A printer

Program constants and codes

Registers	Contents	Comments
00	0.4	space factor
01	D_1	
02	D_2	
03	D_3	
04	d	
05	(used)	
06	(used)	
07	1.	relative resistivity of copper
08	1.724137931	resistivity of copper at 20 C ($\mu\Omega$-cm)
09	0.00393	temperature coefficient of copper
10	20.	temperature °C.
11	16021530.	"D1CM"
12	16031530.	"D2CM"
13	16041530.	"D3CM"
14	27001530.	"L CM"
15	32233036.	"OHMS"
16	55275623.	"(L)H"
17	134322.	"AWG"
18	(used)	
19	(used)	

280 through 289 of the program.

To enter the program into the calculator, you first partition the calculator. In the calculator's notation, 20 registers for data (00 to 19) and 800 registers for the program (000 to 799) appear as 799.19 on the calculator's display. You obtain this partitioning by pressing keys 2, 2nd, *Op 17, in that order. A space factor is put into data register 00, and the other constants and alphanumeric codes used in the program are put into registers 07 to 17 (see table of

000	98	ADV	055	12	B	110	01	01	165	91	R/S	220	71	SBR
001	98	ADV	056	71	SBR	111	13	13	166	71	SBR	221	06	06
002	98	ADV	057	03	03	112	91	R/S	167	07	07	222	31	31
003	91	R/S	058	07	07	113	71	SBR	168	62	62	223	81	RST
004	76	LBL	059	65	×	114	05	05	169	81	RST	224	76	LBL
005	13	C	060	71	SBR	115	77	77	170	76	LBL	225	14	D
006	71	SBR	061	04	04	116	81	RST	171	18	C'	226	42	STO
007	03	03	062	17	17	117	76	LBL	172	71	SBR	227	01	01
008	65	65	063	87	IFF	118	17	B'	173	03	03	228	25	CLR
009	53	(	064	07	07	119	71	SBR	174	65	65	229	43	RCL
010	43	RCL	065	00	00	120	06	06	175	43	RCL	230	11	11
011	02	02	066	68	68	121	31	31	176	03	03	231	69	OP
012	33	X^2	067	91	R/S	122	87	IFF	177	65	×	232	04	04
013	75	-	068	71	SBR	123	07	07	178	43	RCL	233	43	RCL
014	43	RCL	069	05	05	124	01	01	179	02	02	234	01	01
015	01	01	070	54	54	125	27	27	180	65	×	235	69	OP
016	33	X^2	071	87	IFF	126	91	R/S	181	43	RCL	236	06	06
017	54	)	072	07	07	127	71	SBR	182	04	04	237	91	R/S
018	65	×	073	00	00	128	07	07	183	75	-	238	76	LBL
019	89	π	074	76	76	129	62	62	184	43	RCL	239	19	D'
020	65	×	075	91	R/S	130	81	RST	185	01	01	240	42	STO
021	43	RCL	076	71	SBR	131	76	LBL	186	65	×	241	02	02
022	04	04	077	05	05	132	16	A'	187	43	RCL	242	25	CLR
023	55	÷	078	77	77	133	71	SBR	188	04	04	243	43	RCL
024	04	4	079	81	RST	134	03	03	189	65	×	244	12	12
025	65	×	080	76	LBL	135	93	93	190	53	(	245	69	OP
026	71	SBR	081	11	A	136	55	÷	191	43	RCL	246	04	04
027	04	04	082	71	SBR	137	53	(	192	03	03	247	43	RCL
028	28	28	083	03	03	138	71	SBR	193	75	-	248	02	02
029	87	IFF	084	93	93	139	06	06	194	71	SBR	249	69	OP
030	07	07	085	55	÷	140	59	59	195	03	03	250	06	06
031	00	00	086	71	SBR	141	85	+	196	31	31	251	91	R/S
032	34	34	087	04	04	142	71	SBR	197	54	)	252	76	LBL
033	91	R/S	088	85	85	143	07	07	198	95	=	253	15	E
034	71	SBR	089	95	=	144	32	32	199	65	×	254	42	STO
035	03	03	090	34	FX	145	54	)	200	71	SBR	255	04	04
036	39	39	091	95	=	146	65	×	201	04	04	256	25	CLR
037	55	÷	092	22	INV	147	01	1	202	28	28	257	43	RCL
038	71	SBR	093	52	EE	148	52	EE	203	87	IFF	258	14	14
039	03	03	094	58	FIX	149	09	9	204	07	07	259	69	OP
040	56	56	095	00	00	150	95	=	205	02	02	260	04	04
041	87	IFF	096	42	STO	151	34	FX	206	08	08	261	43	RCL
042	07	07	097	05	05	152	95	=	207	91	R/S	262	04	04
043	00	00	098	69	OP	153	58	FIX	208	71	SBR	263	69	OP
044	46	46	099	06	06	154	00	00	209	03	03	264	06	06
045	91	R/S	100	87	IFF	155	22	INV	210	39	39	265	91	R/S
046	71	SBR	101	07	07	156	52	EE	211	55	÷	266	76	LBL
047	03	03	102	01	01	157	69	OP	212	71	SBR	267	10	E'
048	07	07	103	05	05	158	06	06	213	03	03	268	42	STO
049	65	×	104	91	R/S	159	42	STO	214	56	56	269	03	03
050	71	SBR	105	71	SBR	160	05	05	215	87	IFF	270	25	CLR
051	04	04	106	05	05	161	87	IFF	216	07	07	271	43	RCL
052	17	17	107	54	54	162	07	07	217	02	02	272	13	13
053	81	RST	108	87	IFF	163	01	01	218	20	20	273	69	OP
054	76	LBL	109	07	07	164	66	66	219	91	R/S	274	04	04

Program Constants and Codes). They are permanently recorded, along with program steps 000 to 794, in banks 1 to 4 of two magnetic cards.

Unless instructed otherwise, the program assumes that the coil is wound with annealed copper having double-film insulation. Also, the program assumes that the resistance entered is the value at 20 C. But you can easily adjust the program from the keyboard for other types of metal and change the space factor or temperature simply by storing new values in the

```
275  43 RCL
276  03  03
277  69 OP
278  06  06
279  91 R/S
280  53  (
281  02  2
282  00  0
283  69 OP
284  07  07
285  69 OP
286  19  19
287  25 CLR
288  54  )
289  92 RTN
290  53  (
291  53  (
292  01  1
293  85  +
294  43 RCL
295  09  09
296  65  ×
297  53  (
298  43 RCL
299  10  10
300  75  -
301  02  2
302  00  0
303  54  )
304  54  )
305  54  )
306  92 RTN
307  53  (
308  42 STO
309  05  05
310  71 SBR
311  02  02
312  80  80
313  03  3
314  01  1
315  69 OP
316  04  04
317  43 RCL
318  05  05
319  69 OP
320  06  06
321  25 CLR
322  43 RCL
323  16  16
324  69 OP
325  04  04
326  43 RCL
327  05  05
328  33 X²
329  54  )
330  92 RTN
331  53  (
332  43 RCL
333  02  02
334  75  -
335  43 RCL
336  01  01
337  54  )
338  92 RTN
339  53  (
340  71 SBR
341  03  03
342  31  31
343  65  ×
344  05  5
345  00  0
346  65  ×
347  43 RCL
348  04  04
349  65  ×
350  43 RCL
351  00  00
352  55  ÷
353  89  π
354  54  )
355  92 RTN
356  53  (
357  43 RCL
358  06  06
359  33 X²
360  55  ÷
361  04  4
362  95  =
363  54  )
364  92 RTN
365  53  (
366  42 STO
367  05  05
368  71 SBR
369  02  02
370  80  80
371  43 RCL
372  15  15
373  69 OP
374  04  04
375  43 RCL
376  05  05
377  55  ÷
378  71 SBR
379  02  02
380  90  90
381  95  =
382  48 EXC
383  05  05
384  69 OP
385  06  06
386  25 CLR
387  43 RCL
388  17  17
389  69 OP
390  04  04
391  54  )
392  92 RTN
393  53  (
394  42 STO
395  05  05
396  71 SBR
397  02  02
398  80  80
399  43 RCL
400  16  16
401  69 OP
402  04  04
403  43 RCL
404  05  05
405  52 EE
406  69 OP
407  06  06
408  25 CLR
409  03  3
410  01  1
411  69 OP
412  04  04
413  43 RCL
414  05  05
415  54  )
416  92 RTN
417  53  (
418  71 SBR
419  04  04
420  85  85
421  95  =
422  22 INV
423  58 FIX
424  69 OP
425  06  06
426  54  )
427  92 RTN
428  53  (
429  43 RCL
430  08  08
431  65  ×
432  43 RCL
433  00  00
434  55  ÷
435  43 RCL
436  05  05
437  65  ×
438  43 RCL
439  07  07
440  55  ÷
441  01  1
442  00  0
443  00  0
444  95  =
445  34 ΓX
446  65  ×
447  04  4
448  55  ÷
449  89  π
450  95  =
451  34 ΓX
452  54  )
453  53  (
454  53  (
455  53  (
456  42 STO
457  06  06
458  55  ÷
459  93  .
460  00  0
461  02  2
462  05  5
463  04  4
464  54  )
465  33 X²
466  55  ÷
467  01  1
468  52 EE
469  05  5
470  54  )
471  28 LOG
472  65  ×
473  01  1
474  00  0
475  94 +/-
476  95  =
477  22 INV
478  52 EE
479  58 FIX
480  00  00
481  69 OP
482  06  06
483  54  )
484  92 RTN
485  53  (
486  04  4
487  65  ×
488  89  π
489  33 X²
490  65  ×
491  53  (
492  53  (
493  43 RCL
494  02  02
495  85  +
496  43 RCL
497  01  01
498  54  )
499  55  ÷
500  04  4
501  54  )
502  42 STO
503  18  18
504  33 X²
505  55  ÷
506  43 RCL
507  04  04
508  55  ÷
509  01  1
510  52 EE
511  09  9
512  55  ÷
513  53  (
514  01  1
515  85  +
516  93  .
517  09  9
518  65  ×
519  43 RCL
520  18  18
521  55  ÷
522  43 RCL
523  04  04
524  85  +
525  93  .
526  03  3
527  02  2
528  65  ×
529  53  (
530  71 SBR
531  03  03
532  31  31
533  55  ÷
534  02  2
535  54  )
536  42 STO
537  19  19
538  55  ÷
539  43 RCL
540  18  18
541  85  +
542  93  .
543  08  8
544  04  4
545  65  ×
546  43 RCL
547  19  19
548  55  ÷
549  43 RCL
```

appropriate data registers.

For example, to design a coil wound with aluminum wire, change either the relative resistance in register 07 to 1.64, or the resistivity to 2.62 $\mu\Omega$-cm in register 08, but not both. And you can change the temperature in register 10 to investigate the effects of temperature changes.■■

References

1. Welsby, V. G., *The Theory and Design of Inductance Coils*, Macdonald & Co., London, 1960, pp. 42-44.

2. *Circular of the National Bureau of Standards C74*, Washington, 1937, p. 265.

3. "Copper Wire Tables," *National Bureau of Standards Handbook 100*, 1966, pp. 7 and 14.


```
550  04  04      605  54  )       660  09  9       715  54  )       770  91  R/S
551  54  )       606  33  X²      661  93  .       716  28  LOG     771  43  RCL
552  54  )       607  55  ÷       662  02  2       717  75  -       772  15  15
553  92  RTN     608  89  π       663  01  1       718  43  RCL     773  69  OP
554  53  (       609  65  ×       664  65  ×       719  03  03      774  04  04
555  25  CLR     610  43  RCL     665  53  (       720  65  ×       775  22  INV
556  43  RCL     611  07  07      666  53  (       721  53  (       776  58  FIX
557  17  17      612  65  ×       667  43  RCL     722  43  RCL     777  53  (
558  69  OP      613  43  RCL     668  02  02      723  03  03      778  43  RCL
559  04  04      614  08  08      669  85  +       724  85  +       779  03  03
560  53  (       615  55  ÷       670  43  RCL     725  43  RCL     780  85  +
561  71  SBR     616  01  1       671  03  03      726  19  19      781  43  RCL
562  03  03      617  52  EE      672  54  )       727  54  )       782  01  01
563  39  39      618  04  4       673  42  STO     728  28  LOG     783  54  )
564  55  ÷       619  95  =       674  18  18      729  54  )       784  65  ×
565  43  RCL     620  65  ×       675  65  ×       730  54  )       785  02  2
566  05  05      621  71  SBR     676  53  (       731  92  RTN     786  65  ×
567  54  )       622  02  02      677  02  2       732  53  (       787  43  RCL
568  34  FX      623  90  90      678  65  ×       733  04  4       788  05  05
569  65  ×       624  95  =       679  43  RCL     734  65  ×       789  55  ÷
570  02  2       625  22  INV     680  02  02      735  53  (       790  71  SBR
571  95  =       626  52  EE      681  65  ×       736  02  2       791  06  06
572  71  SBR     627  69  OP      682  43  RCL     737  65  ×       792  00  00
573  04  04      628  06  06      683  03  03      738  43  RCL     793  54  )
574  53  53      629  54  )       684  55  ÷       739  19  19      794  92  RTN
575  54  )       630  92  RTN     685  53  (       740  75  -       795  00  0
576  92  RTN     631  53  (       686  43  RCL     741  43  RCL     796  00  0
577  53  (       632  71  SBR     687  04  04      742  18  18      797  00  0
578  25  CLR     633  03  03      688  85  +       743  55  ÷       798  00  0
579  22  INV     634  07  07      689  71  SBR     744  02  2       799  00  0
580  58  FIX     635  65  ×       690  03  03      745  85  +
581  43  RCL     636  71  SBR     691  31  31      746  93  .
582  15  15      637  06  06      692  54  )       747  04  4
583  69  OP      638  59  59      693  54  )       748  04  4
584  04  04      639  85  +       694  28  LOG     749  07  7
585  89  π       640  43  RCL     695  75  -       750  65  ×
586  65  ×       641  05  05      696  43  RCL     751  53  (
587  53  (       642  33  X²      697  02  02      752  43  RCL
588  43  RCL     643  65  ×       698  65  ×       753  04  04
589  01  01      644  71  SBR     699  53  (       754  85  +
590  85  +       645  07  07      700  43  RCL     755  71  SBR
591  43  RCL     646  32  32      701  02  02      756  03  03
592  02  02      647  95  =       702  85  +       757  31  31
593  54  )       648  55  ÷       703  53  (       758  54  )
594  55  ÷       649  01  1       704  43  RCL     759  54  )
595  02  2       650  52  EE      705  02  02      760  54  )
596  65  ×       651  09  9       706  33  X²      761  92  RTN
597  43  RCL     652  95  =       707  85  +       762  53  (
598  05  05      653  22  INV     708  43  RCL     763  71  SBR
599  55  ÷       654  58  FIX     709  03  03      764  05  05
600  53  (       655  69  OP      710  33  X²      765  54  54
601  43  RCL     656  06  06      711  54  )       766  87  IFF
602  06  06      657  54  )       712  34  FX      767  07  07
603  55  ÷       658  92  RTN     713  42  STO     768  07  07
604  02  2       659  53  (       714  19  19      769  71  71
```